THE RELATIONSHIP BETWEEN SUSTAINABILITY AND WALKABILITY

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Abstract

Over the past decades, mobility system has become one of the main concerns and urban designers and planners have paid more attention to highways rather than citizens and pedestrian areas. The present study aims at analyzing the relationship between the walkability and sustainability in urban planning. It also aims at explaining the possible advantage for both urban environment and people. For residences of cities, it can be highly effective on economic and health of people and for talking about the urban part, it leads to a sustainable community for having secure, comfortable and useful environment. In addition, another focus of this thesis is using mixed-use methodology, not only analyzing quantitative but also qualitative indicators for walkability analysis. This thesis explores these topics through finding indicators for sufficiently analyzing walkability with comprehensively and systematic literature review methodology such as studying and comparing different protocols, assessment tools and articles and then applying them on case study "San Salvario district in Turin city, Italy". Then, all of the indicators have been assessed and analyzed by ArcGIS software. The result highlights how it can be improved walkability in this neighborhood towards promoting sustainable urban planning.

Key words: Walkability, Neighborhood, mix use methodology, Indicators, ArcGIS

1. Introduction

Walking can be mentioned as the most used form of transportation in the city and one of the sustainable means. Accessibility by walking and high quality of pedestrian areas between home, work, and urban amenities have many advantageous and facilitate their lives. Nowadays, due to the various problems that the city has faced in terms of air pollution, referring to walkable areas and improving them are the most important solution, which help city change in a sustainable way. If different neighborhood levels can increase walkability in own scale, it is an essential point that a city can promote its own walkability. Furthermore, Walkability as a node between public transportation and other sustainable transportation, has an important role to connect them in the neighborhood level. So that, analyzing walkability in neighborhood level is an initial point to know the weakness and strength of neighborhood areas to increase walkability in the whole city. Whether the walkability as a means of transport or a type for recreational activities can bring many advantageous for citizens not only moving but also connecting with surrounding. Although, recently, cars have essential roles to shape the city and connect different points, urban planners and architects must not neglect the role of walkability.

1-1. Problem Statements and Research Backgrounds

Walking was widely considered as the significant and oldest type of transportation since the first small towns were constructed and before the revolution in transport technology in nineteenth century [1]. By the time private car became highly common during the twentieth century [2] noticing to urban walkability gradually became less important [3] compared with other types of transportation in urban design.

After studying literature review, the major two problems associated to walkability area can be divided in two parts: one problem related to the city and citizens in sustainable approaches when there is not walkable environment in neighborhood level and generally in the city. The other related to the way and methodology that walkability has been analyzed and evaluated.

1- In these modern days, by increasing rates of vehicles, many cities can be interpreted as automobile-dependent [4]. Therefore, One of the today main problems of urbanization is the increasing dependence on automobiles and the major type of transportation even in the small scale such as neighborhood area are the individual cars because it is the norm of urbanism to use the motorized vehicles rather than walking [5]. There are many drawbacks due to the fact that the city has not the walkable environment and people are not enthusiastic for walking. It can be divided in two major parts: the disadvantageous for the city and the problems for the citizens.

It is harmful for people to do not have a walkable city in terms of health aspects such as obesity and heart disease and as well as different accidents that are happened by vehicles. Moreover, well-being and social aspects of community have been affected by walkability.

In the last decades, obesity has been greatly considered as a worldwide public health crisis due to the profound changes in behavioral patterns and insufficient physical activities, especially in developed countries [6]. Thus, various studies have illustrated the relationship between walkability and health benefits which are necessarily important to have regular physical activity [7]. In addition, Unsustainable mobility systems have also negative impacts on death rate and physical injuries due to accidents [8]. Subsequently, urban designers rethought about the street and traffic safety [9-10]. It shall not be forgot to talk about the effects on social aspects. Not having walkable area and just using private car have made people more isolated. Many express that every day walking is alleviating depressive symptoms [11] and strongly enhance resident's sense of community [12-13].

In addition, unsustainable transportations not only cause many problems for citizens, but also it exacerbate the air quality due to air pollution, CO_2 emissions, energy consumption and infrastructure cost [3-14].

In 2015, the total CO_2 emissions in the European Union (EU) were 22 % lower than 1990 levels [15]. Whereas, transport-related emissions have increased at the same time. Road transportation have effect on 24 % of total CO_2 emissions in the EU [15]. Hence, concerns about this aspect have been increasing and without any actions and policies, these rates will be immensely growing in the following years [16]. Furthermore, by having urban sprawl for settlements, people become more dependent on their own motilities to travel to the surrounding areas and thus it must be invested on public infrastructures for improving transportation systems' conditions [17].

Because of these reasons, discussing about walkability and the beneficial of it have been proposed in many research realm to promote the life style of residents. Much of the renewed attention on urban walkability is associated with concerns that car dependent cities will not be sustainable in the future [14] and walking area can potentially combat with these mentioned disadvantageous [18-19].

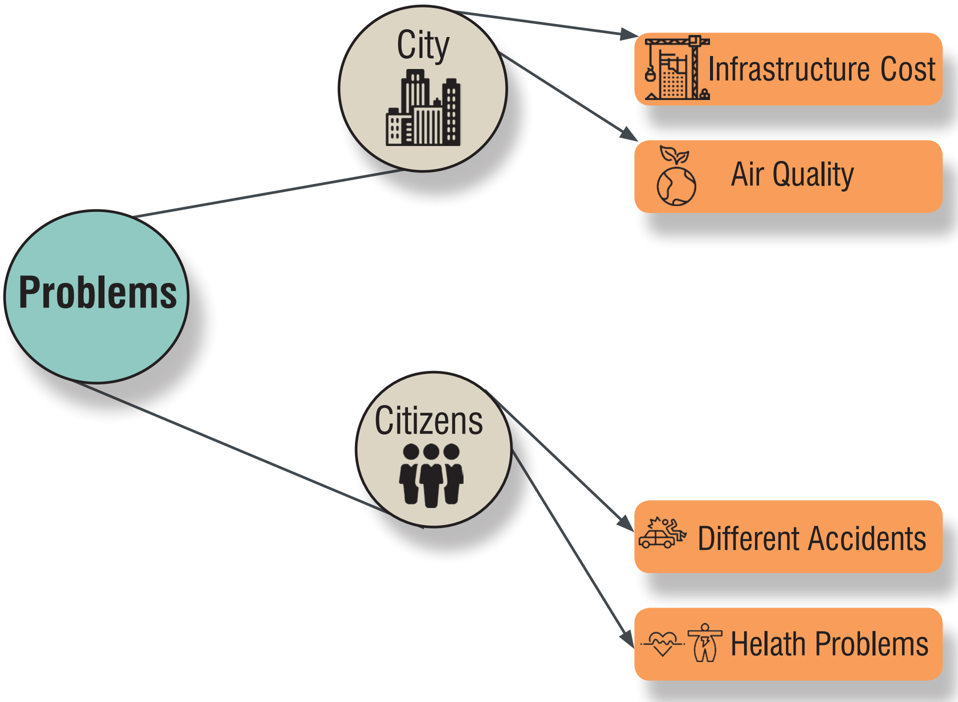


Figure 1: Problems of unsustainable transportation,
Source: Author elaboration

2- The methodological problems related to the walkability researchers have been categorized in three aspects. Firstly, most of them just consider some aspects of sustainability in their analysis and not all of the parts, for example just social part of walkability. Moreover, the other research are mainly focusing on quantitative analysis and not considering qualitative indicators, such as the original walkability index, which consisted of three categories: street connectivity, net residential density, and land use mix. Then, the retail floor area ratio has been joined to these there indexes. Afterwards, these four factors have been applied in different researches [44] which all of them are quantitative aspects of walkability. Finally, some of walkability evaluations have surveyed just one protocol or only few assessment tools. For instance just Walkscore analysis or Audit protocols [54]. Therefore, after analysis these problems, it is noticeable to say that there is a lack of mix-used methodology for analyzing walkability, which will be considered in this thesis.

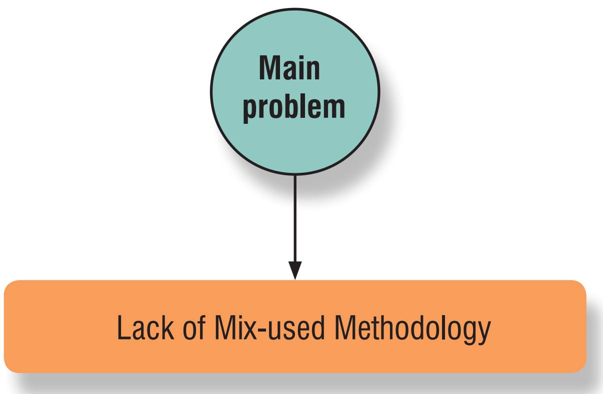


Figure 2: Main problmes of walkability researching
Source: Author elaboration

Definition of Walkability

What is particularly important here to define the terminology of walkability used in various researches. The three common terms used in urban planning researches and health related literature are walking, walkable, and walkability. Although these three words may imply similar meanings, there are differences between the terms walking and walkable/walkability [20]. Walking refers to a physical activity done either for leisure or as a mode of transportation and the terms walkable and walkability are used to describe the degree to which the physical environment allows walking to take place. The portion of the physical environment often referred to when studying walkability is the space that is created by the streets, streetscapes, and building, presented in a specific location[20].

Among these three terms, Walkability has been become an important term in the transportation engineering and urban planning. Nevertheless, various researchers and urban designers have been using and defining walkability in various aspects as well [21].

The first concept of walkability that identified in scientific paper back to the early in nineties which introduced by urban designers and spatial planners [22-23]. Afterwards, many different authors and researchers have talked about walkability definitions:

P.T. Seilo defines walkability as "… a measure of the urban form and the quality and availability of pedestrian infrastructure contained within a defined area. Pedestrian infrastructure includes amenities developed to promote pedestrian efficiency and safety such as sidewalks, trails and pedestrian bridges…" [24].

Abley defined walkability as "the extent to which the built environment is friendly to the presence of people living, shopping, visiting, enjoying or spending time in an area", which reflects the modern definition of walkable space [25].

Jan Gehl: "Walkability is a quantitative and qualitative measurement of how inviting or uninviting an area is to pedestrians. Built environments that promote and facilitate walking – to stores, work, school and amenities – are better places to live, have higher real estate values, promote healthier lifestyles and have higher levels of social cohesion" [26].
Additionally, walkability have been considered for various purposes in researchers' views. For example Leslie 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 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 [27].

As a result, the idea of walkability is more than accessibility of places and reaches to different destinations by walking. What is remarkably important here is the quality of the accessibility and how the urban environment (built environment, social practices, etc.) is conducive to walking [28]. If the pedestrian way is amiable and spatially integrated with the surroundings by good urban design, if it is full of urban activities, if it is well maintained and (perceived as) safe, if it is not crowded by car traffic [28].

The General Theory of Walkability illustrated how a walk has to satisfy four main categories: it must be useful, safe, comfortable, and interesting. Each of these qualities is essential, they must be together and none alone is sufficient. Useful means that most aspects of daily life are located close at hand and organized in a way that walking serves them well. Safe means that the street has been designed to give pedestrians a fighting chance against being hit by automobiles; they must not only be safe but also feel safe, which is even tougher to satisfy. Comfortable means that buildings and landscape shape urban streets into “outdoor living rooms,” in contrast to wide-open spaces, which usually fail to attract pedestrians. Interesting means that sidewalks are lined by unique buildings with friendly faces and that signs of humanity abound [29].

According to Jeff Speck in his book is telling that there are many advantageous of Economics, Health, Climate, Equity and Community that the urban designers must inevitably notice to walkability [30].

1-1-1. The Adaptable References

Literature Review

Walking as above mentioned is a greatly unmeasured and extremely under appreciated element of the urban transportation system [31]. Urban designers often notice exclusively about vehicles and transit trips, ignoring pedestrian travel, even when it is an important component like walking to a public transportation stop or from a parking area to reach destinations [32]. Consequently, walkability has been under emphasized or ignored as a vital form of urban transportation [31]. So, there is no doubt that, it must be necessary to again talk and refer to walkability as a key factor in urban designing and finding a good references for appraising it.
Neighborhood with walkable places has many positive points, residents easily walk to reach destinations or take some other mobility systems. These places are also denser and have more of a mix of different land uses [33]. As Jane Jacobs has observed, walkability is at the heart of urban vibrancy, short blocks, population density and diversity and a mix of uses, building types and ages that all play out in a “sidewalk ballet” [34]

Systematic Literature Review Methodology

This part is explaining how systematic literature reviews methodology was applied in this thesis for literature review. This methodology has been used for the reviewing of journal articles and scientific papers [35] and it has five stages of analysis [36] as it is explained below.

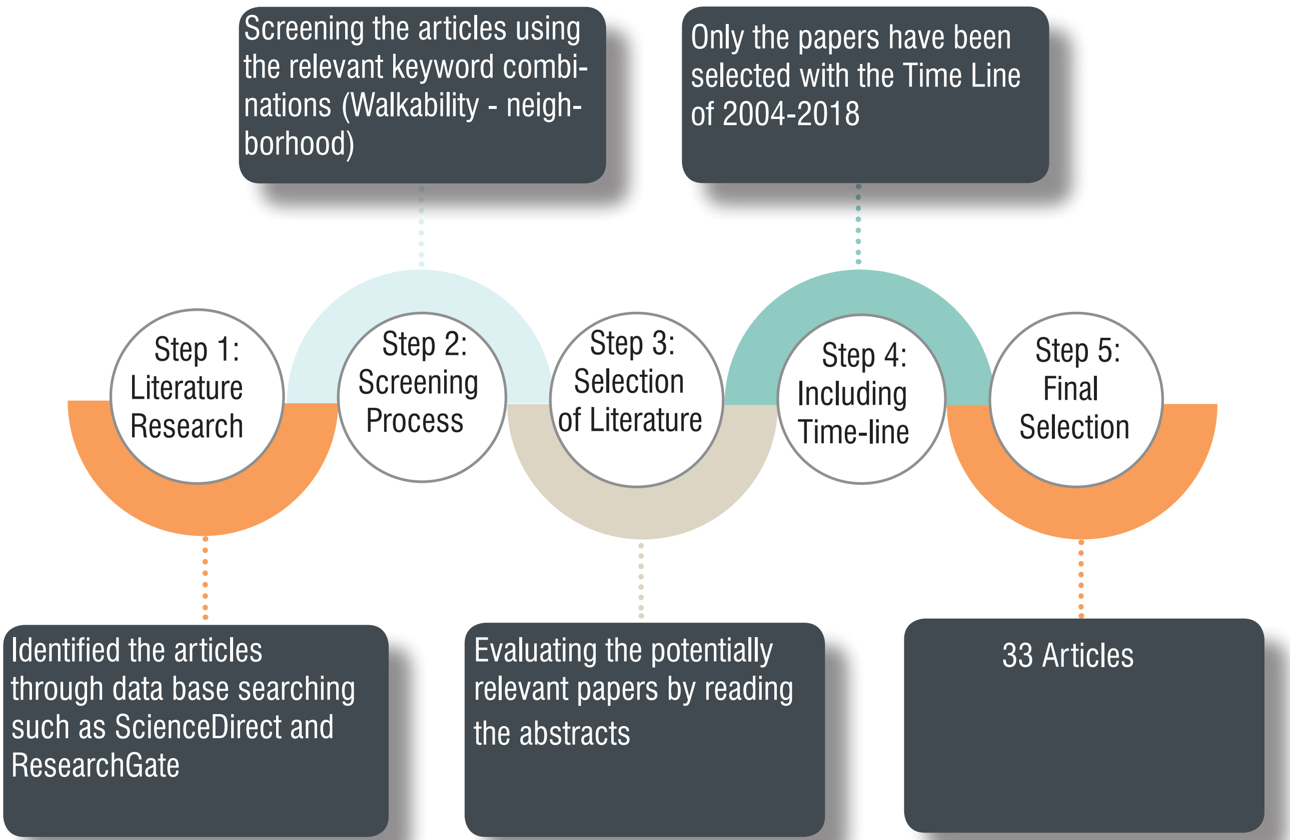


Figure 3: Systematic Literature Review Methodology
Source: Author elaboration

This thesis explores evaluating walkable area through finding qualitative and quantitative indicators for sufficiently analyzing walkability with comprehensive studying literature review such as articles, protocols and assessment tools. First of all, among the existing articles, those of 2004-2018 (14 years) were selected as the most up-dated references. This is achieved by comparing and studying different articles in order to find which articles are suitable for analyzing specially in neighborhood level.
After studying the articles and understanding which indicators were used to analyze in neighborhood, the result shows that:
It can be totally divided the walkability index in different categories and indicators have been extracted subsequently.

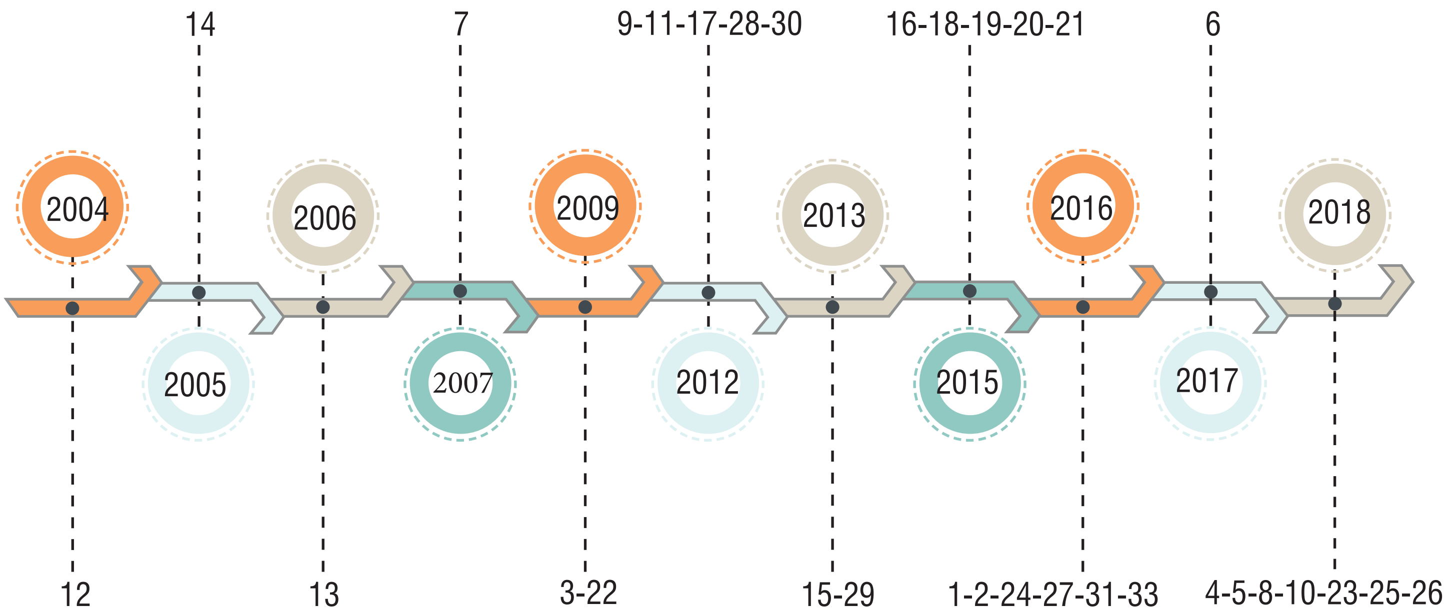


Figure 4: Timeline boundary and trend
Source: Author elaboration

The name of 33 articles are:

1-Adriana A.Zuniga-Terann, B. J. (2016). Designing healthy communities: A walkability analysis of LEED-ND.
2-Alexandros Bartzokas Tsiomprasa, Y. N. (2016). What matters when it comes to “Walk and the city”? Defining a weighted GIS-based walkability index.
3-Al-Hagla, K. S. (2009). Evaluating new urbanism’s walkability performance: A comprehensive approach to assessment in Saifi Village, Beirut, Lebanon.
4-Ali Keyvanfar, M. S. (2018). A Path Walkability Assessment Index Model for Evaluating and Facilitating RetailWalking Using Decision-Tree-Making (DTM) Method.
5-Ali Soltani, M. S. (2018). The development of a walkability audit. Based on Iranian cities pedestrian environment.
6-Ana Paula Barrosa, L. M. (2017). How urban form promotes walkability?
7-Ann Forsyth, J. M. (2007). Does Residential Density Increase Walking and Other Physical Activity?
8-Austin Dunn, B. H. (n.d.).2018. Evaluating Walkability in the Age of Open Data: OpenStreetMap and Community-level Transportation Analysis.
9-Cambra, P. (2012). Pedestrian Accessibility and Attractiveness Indicators for Walkability Assessment.
10-Ceylan, R. (2018). A GIS-Based Walkable Service Area Analysis from a Smart Growth Perspective in the City of Edirne.
11-Diyanah Inani Azmi, H. A. (2012). Implications of Walkability towards Promoting Sustainable.
12-Eva Leslie, B. S. (2004). Residents’ perceptions of walkability attributes in objectively different neighbourhoods: a pilot study.
13-Eva Leslie, I. B. (2006). Measuring the walkability of local communities using Geographic Information Systems data.
14-Eva Lesliea, N. C. (2005). Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes.
15-Farzaneh Moayedib, R. Z. (2013). Conceptualising the Indicators of Walkability for Sustainable Transportation.
16-Hee-Jung Jun, M. H. (2015). The relationship between walkability and neighborhood social environment: The importance of physical and perceived walkability. Applied Geography.
17-Hossein Bahrainy, H. K. (2012). The impact of urban design features and qualities on walkability and health in under-construction environments: The case of Hashtgerd New Town in Iran.
18-Ivan Blečić, A. C. (2015). An Evaluation and Design Support System for Urban Walkability.
19-Ivan Blečić, A. C. (2015). Evaluating walkability: a capability-wise planning and design support system.
20-Ivan Blečić, A. C. (n.d.) (2015). Walkability and urban capabilities: evaluation and planning decision support.
21-Ledraa, T. A. (2015). Evaluating Walkability at the Neighborhood and Street Levels in Riyadh Using GIS and Environment Audit Tools.

Table 1: 33 articles selected for finding sufficient indicators
Source: Author elaboration

22- Marc A. Adams, S. R. (2009). Validation of the Neighborhood Environment Walkability Scale (NEWS) Items Using Geographic Information Systems.
23- Melissa Bartshe, C. C. (2018). Perceived Walkability, Social Capital, and Self-Reported Physical Activity in Las Vegas College Students.
24-Miguel Zuza Aranoa, C. R.-I. (2016). Walkability City Tool (WCT): measuring walkability.
25-Patricia A. Collins, J. T. (2018). Residential moves, neighbourhood walkability, and physical activity: a longitudinal pilot study in Ontario Canada.
26-Lawrence D. Frank, J. M. (2019). Unmet Demand for Walkable Transit-Oriented Neighborhoods in a Midsized Canadian Community: Market and Planning Implications. Planning Education and Research.
27-Reihaneh Rafiemanzelata, M. I. (2016). City sustainability: the influence of walkability on built environments.
28-Said, R. S. (2012). Constructing Indices Representing Physical Attributes for Walking in Urban Neighborhood Area.
29-Sapura Mohamad, A. S. (2013). The Path Walkability Index (PAWDEX) Model: To Measure Built Environment Variables Influencing Residents' Walking Behavior.
30-Shuhana Shamsuddin, N. R. (2012). Walkable Environment in Increasing the Liveability of a City.
31-Singha, R. (2015). Factors affecting walkability of neighborhoods. Urban Planning and Architecture Design for Sustainable Development.
32-Yehua Dennis Wei, W. X. (2016). Walkability, Land Use and Physical Activity.
33-Sourav Bhadra, A. K.-U.-Z. (2016). A GIS Based Walkability Measurement within the Built Environment of Khulna City, Bangladesh.

Table 1: 33 articles selected for finding sufficient indicators
Source: Author elaboration

Protocols

After analyzing completely literature review, in this section three protocols have been chosen for finding what indicators are particularly important in these protocols. How these three were selected, it is notable to say that, each of them is analyzing walkability with different point of view. LEED-ND has a rating system, PEDS is evaluating by questionnaire by people and finally NEAT-GIS is investigating by GIS and applying on a real case study. Therefore, each of these three protocols will be explaining subsequently.

1- LEED-ND (Leadership in Energy and Environmental Design-Neighborhood Development)

Writer: the U.S. Green Building Council, a private, non-profit organization **Date:** July 2018
Country: U.S.
Indicator: Three basic sections:
Smart Location and Linkage (SLL)—where to build
Neighborhood Pattern and Design (NPD)—what to build
Green Infrastructure and Buildings (GIB)—how to manage environmental impacts

Nowadays, the most influential sustainable urban planning certification systems are BREEAM, LEED and CASBEE.

BREEAM (Building Research Establishment Environmental Assessment Methodology) was developed in the United Kingdom in 1990. There are different kind of BREEAM certification; BREEAM Communities is the one applied in urban planning. BREEAM assesses factors like accessibility, the distance to green areas, the design of safe spaces (in terms of the characteristics of the building facades, lighting, the existence of furniture, etc.), whether facade design encourages street activity (number of shops, number of gaps, blind zones, etc.) [37].

LEED (Leadership in Energy & Environmental Design) is a certification system developed by the U.S. Green Building Council in 1998, in which projects earn points for meeting specific criteria. There are different kinds of LEED certification; LEED for Neighborhood Development is the one applied in urban planning. LEED assesses factors that directly affect walkability, such as sidewalk width, building facades (number of entrances, glassed-in areas, etc.), the accessibility of parks, recreational facilities, etc. [37].

CASBEE (Comprehensive Assessment System for Built Environment Efficiency) is a Japanese certification system that started being developed in 2001. A variety of different tools have been developed; CASBEE for Cities and CASBEE for Urban Development are the ones applied in urban planning. CASBEE assesses what it calls social aspects such as traffic safety and crime safety, environmental quality aspects like shade and universal accessibility, and other factors [37].

As, it is shown, for reaching a high LEED-ND ranking ,Connectivity, together with smart location and walkability, have substantial role in receiving LEED-ND certification.

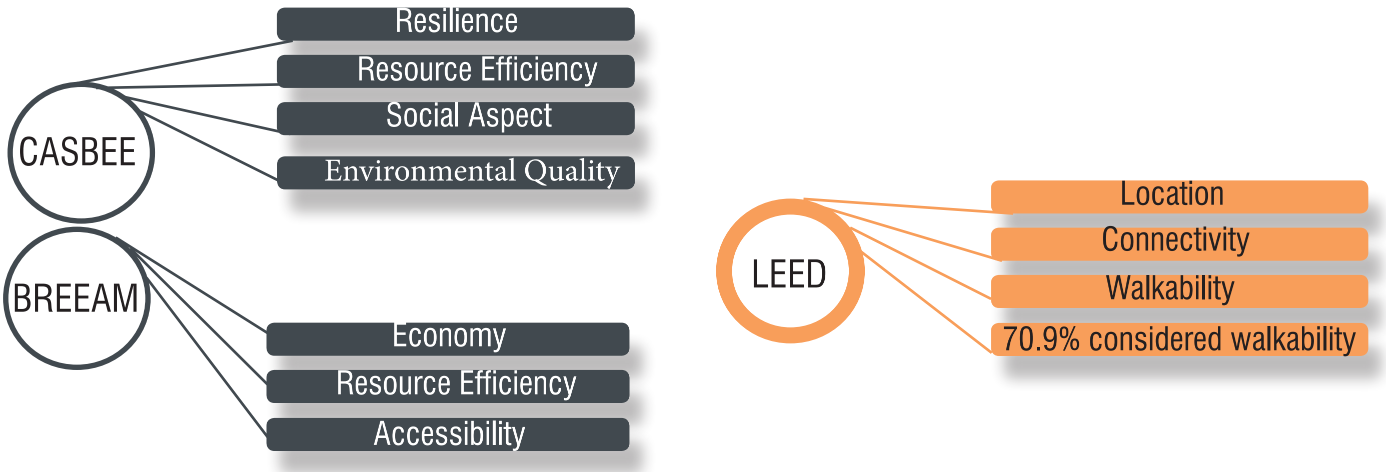


Figure 5: Comparison between urban certification systems
Source: Ayoob Sharifi, A. M. (2014).

As above mentioned the LEED-ND certification is analyzing much more walkability than other certification systems. In addition, it is argued that analyzing all categories showed that the LEED-ND in its current form considered walkability in 78 of the available 110 points (70.9%) [38]. As a result, among the sustainable urban planning certifications, LEED-ND has been selected for evaluating and explaining more.

For explaining more about LEED, it has included building design and construction, interior design and construction, building operations and maintenance, neighborhood development, and homes. The certification system for neighborhood development was implemented in 2009, and many neighborhoods have been certificated around the world [39]. LEED-ND is a rating system used by urban designers and architects who are noticing to build sustainable and walkable neighborhoods [38]. By achieving points that provide situation for pedestrian activity and then creating walkable neighborhood, the LEED-ND indirectly encourages physical activity [40]. Moreover, it is integrating sustainable mobility, effectively reducing the transportation by automobile travel [41].

LEED v4 for Neighborhood Development Plan
Project Checklist

Project Name:
Date:

Yes	?	No			
0	0	0	**Smart Location & Linkage**		28
Y			Prereq	Smart Location	Required
Y			Prereq	Imperiled Species and Ecological Communities	Required
Y			Prereq	Wetland and Water Body Conservation	Required
Y			Prereq	Agricultural Land Conservation	Required
Y			Prereq	Floodplain Avoidance	Required
			Credit	Preferred Locations	10
			Credit	Brownfield Remediation	2
			Credit	Access to Quality Transit	7
			Credit	Bicycle Facilities	2
			Credit	Housing and Jobs Proximity	3
			Credit	Steep Slope Protection	1
			Credit	Site Design for Habitat or Wetland and Water Body Conservation	1
			Credit	Restoration of Habitat or Wetlands and Water Bodies	1
			Credit	Long-Term Conservation Management of Habitat or Wetlands and Water Bodies	1
0	0	0	**Neighborhood Pattern & Design**		41
Y			Prereq	Walkable Streets	Required
Y			Prereq	Compact Development	Required
Y			Prereq	Connected and Open Community	Required
			Credit	Walkable Streets	9
			Credit	Compact Development	6
			Credit	Mixed-Use Neighborhoods	4
			Credit	Housing Types and Affordability	7
			Credit	Reduced Parking Footprint	1
			Credit	Connected and Open Community	2
			Credit	Transit Facilities	1
			Credit	Transportation Demand Management	2
			Credit	Access to Civic & Public Space	1
			Credit	Access to Recreation Facilities	1
			Credit	Visitability and Universal Design	1
			Credit	Community Outreach and Involvement	2
			Credit	Local Food Production	1
			Credit	Tree-Lined and Shaded Streetscapes	2
			Credit	Neighborhood Schools	1

Yes	?	No			
0	0	0	**Green Infrastructure & Buildings**		31
Y			Prereq	Certified Green Building	Required
Y			Prereq	Minimum Building Energy Performance	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Certified Green Buildings	5
			Credit	Optimize Building Energy Performance	2
			Credit	Indoor Water Use Reduction	1
			Credit	Outdoor Water Use Reduction	2
			Credit	Building Reuse	1
			Credit	Historic Resource Preservation and Adaptive Reuse	2
			Credit	Minimized Site Disturbance	1
			Credit	Rainwater Management	4
			Credit	Heat Island Reduction	1
			Credit	Solar Orientation	1
			Credit	Renewable Energy Production	3
			Credit	District Heating and Cooling	2
			Credit	Infrastructure Energy Efficiency	1
			Credit	Wastewater Management	2
			Credit	Recycled and Reused Infrastructure	1
			Credit	Solid Waste Management	1
			Credit	Light Pollution Reduction	1
0	0	0	**Innovation & Design Process**		6
			Credit	Innovation	5
			Credit	LEED® Accredited Professional	1
0	0	0	**Regional Priority Credits**		4
			Credit	Regional Priority Credit: Region Defined	1
			Credit	Regional Priority Credit: Region Defined	1
			Credit	Regional Priority Credit: Region Defined	1
			Credit	Regional Priority Credit: Region Defined	1
0	0	0	**PROJECT TOTALS (Certification estimates)**		110

Certified: 40-49 points, **Silver:** 50-59 points, **Gold:** 60-79 points, **Platinum:** 80+ points

Table 2: LEED check list
Source: https://www.usgbc.org/resources/leed-v4-neighborhood-development-current-version

All LEED certifications can be achieved by simple point-based rating. The rating system contains mandatory prerequisites that projects must approve them. The total number of points earned by a project determines its LEED certification level: Certification (40–49 points), silver (50–59 points), gold (60–69 points), and platinum (80 points and above). The overall point is 110 [38].
The LEED-ND indicators are divided into five sections: (1) smart location and linkage (SLL), (2) neighborhood pattern and design (NPD), (3) green infrastructure and building (GIB), and (4) innovation and design process, with additional points that maybe earned for extra significance in the local area under the optional section, (5) Regional Priority [42].

Figure 6: LEED rating systems
Source: https://new.usgbc.org/leed-v41

2- PEDS (Pedestrian Environment Data Scan Audit Protocol)

Writer: written by Andrea D. Livi, Clifton -Spring 2004; modified by Tracy E. McMillan – summer 2006. Modified for Mexico, June 2012 **Date:** 2004, 2006, June, 2012 **Country:** U.S.
Indicator: Four sections: 35
A: Environment, B: Pedestrian Facility, C: Road Attributes, D: Walking/Cycling Environment

The PEDS protocol was initially used to assess environmental characteristics that relate to walking in varied environments in the United States [43]. This audit protocol provides a comprehensive method to evaluate the effect of urban form on pedestrian behavior and their travel choices [44]. Thus, it is evaluating by questionnaire that will be filled by people who are primary training which is a significant feature to ensure reliability of the audit. The audit training will be completed from 4-8 hours in anywhere. The instructor should express which questions are "check all that apply" and make sure administrators perceive terms they probably have not heard before [45]. By this protocol, both walking and cycling modes are rated in terms of safety and security of street segments. As it is focused on micro level factors, it is going beyond the mere 'objective' analysis of census–block indicators and evaluate the one's perception of the space [46].
It is analyzing four sections with 35 indicators: Environment, Pedestrian Facility, Road Attributes and Walking/Cycling Environment and each section will be scored between 1 to 8 depending on section. Besides, there is fifth section that is associated to Subjective Assessment and the question here is that whether the street is attractive and safe for cycling or walking. The answer's range is between strongly agree to strongly disagree. The indicators, which are related to walkability are shown with orange frame:

Name: ____________ Date: ____________ Study Area: ____________ PEDS
Segment Number: ____________ Time: ____________ Weather: ____________

0. Segment type
Low volume road 1
High volume road 2
Bike or Ped path - skip section C 3

A. Environment
1. Uses in Segment *(all that apply)*
Housing - Single Family Detached 1
Housing - Multi-Family 2
Housing - Mobile Homes 3
Office/Institutional 4
Restaurant/Café/Commercial 5
Industrial 6
Vacant/Undeveloped 7
Recreation 8

2. Slope
Flat 1
Slight hill 2
Steep hill 3

3. Segment Intersections
Segment has 3 way intersection 1
Segment has 4 way intersection 2
Segment has other intersection 3
Segment deadends but path continues 4
Segment deadends 5
Segment has no intersections 6

B. Pedestrian Facility *(skip if none present)*
4. Type(s) of pedestrian facility *(all that apply)*
Footpath (worn dirt path) 1
Paved Trail 2
Sidewalk 3
Pedestrian Street (closed to cars) 4

The rest of the questions in section B refer to the best pedestrian facility selected above.
5. Path material *(all that apply)*
Asphalt 1
Concrete 2
Paving Bricks or Flat Stone 3
Gravel 4
Dirt or Sand 5

6. Path condition/maintenance
Poor (many bumps/cracks/holes) 1
Fair (some bumps/cracks/holes) 2
Good (very few bumps/cracks/holes) 3
Under Repair 4

7. Path obstructions *(all that apply)*
Poles or Signs 1
Parked Cars 2
Greenery 3
Garbage Cans 4
Other 5
None 6

8. Buffers between road and path *(all that apply)*
Fence 1
Tress 2
Hedges 3
Landscape 4
Grass 5
None 6

9. Path Distance from Curb
At edge 1
< 5 feet 2
> 5 feel 3

10. Sidewalk Width
< 4 feet 1
Between 4 and 8 feet 2
> 8 feet 3

If no sidewalk,skip now to section C.
11. Curb cuts
None 1
1 to 4 2
> 4 3

12. Sidewalk completeness/continuity
Sidewalk is complete 1
Sidewalk is incomplete 2

13. Sidewalk connectivity to other sidewalks/crosswalks
number of connections ____ 1

C. Road Attributes *(skip if path only)*
14. Condition of road
Poor (many bumps/cracks/holes) 1
Fair (some bumps/cracks/holes) 2
Good (very few bumps/cracks/holes) 3
Under Repair 4

15. Number of lanes
Minimum # of lanes to cross ____ 1
Maximum # of lanes to cross ____ 1

16. Posted speed limit
None posted 1
(mph): ____ 1

17. On-Street parking *(if pavement is unmarked, check only if cars parked)*
Parallel or Diagonal 1
None 2

18. Off-street parking lot spaces

0-5	6-25	26+
1	2	3

19. Must you walk through a parking lot to get to most buildings?
Yes 1
No 2

20. Presence of med-hi volume driveways
< 2 1
2 to 4 2
> 4 3

21. Traffic control devices *(all that apply)*
Traffic light 1
Stop sign 2
Traffic circle 3
Speed bumps 4
Chicanes or chokers 5
None 6

22. Crosswalks
None 1
1 to 2 2
3 to 4 3
> 4 4

23. Crossing Aids *(all that apply)*
Yield to Ped Paddles 1
Pedestrian Signal 2
Median/Traffic Island 3
Curb Extension 4
Overpass/Underpass 5
Pedestrian Crossing Warning Sign 6
Flashing Warning Light 7
Share the Road Warnign Sign 8
None 9

24. Bicycle facilities *(all that apply)*
Bicycle route signs 1
Striped bicycle lane designation 2
Visible bicycle parking facilities 3
Bicycle crossing warning 4
No bicycle facilities 5

D. Walking/Cycling Environment
25. Roadway/path lighting
Road-oriented lighting 1
Pedestrian-scale lighting 2
Other lighting 3
No lighting 4

26. Amenities *(all that apply)*
Public garbage cans 1
Benches 2
Water fountain 3
Street vendors/vending machines 4
No amenities 5

27. Are there wayfinding aids?
No 1
Yes 2

28. Number of trees shading walking area
None or Very Few 1
Some 2
Many/Dense 3

29. Degree of enclosure
Little or no enclosure 1
Some enclosure 2
Highly enclosed 3

30. Powerlines along segment?
Low Voltage/Distribution Line 1
High Voltage/Transmission Line 2
None 3

31. Overall cleanliness and building maintenance
Poor (much litter/graffiti/broken facilities) 1
Fair (some litter/graffiti/broken facilities) 2
Good (no litter/graffiti/broken facilities) 3

32. Articulation in building designs
Little or no articulation 1
Some articulation 2
Highly articulated 3

33. Building setbacks from sidewalk
At edge of sidewalk 1
Within 20 feet of sidewalk 2
More than 20 feet from sidewalk 3

34. Building height
Short 1
Medium 2
Tall 3

35. Bus stops
Bus stop with shelter 1
Bus stop with bench 2
Bus stop with signage only 3
No bus stop 4

Subjective Assessment: Segment…
Enter 1,2,3, or 4 for 1=Strongly Agree 2= Agree, 3=Disagree, 4=Strongly Disagree
……is attractive for walking. ____ 1
……is attractive for cycling. ____ 1
……feels safe for walking. ____ 1
……feels safe for cycling. ____ 1

Table 3: Audit protocol questions
Source: Kelly J. Clifton, PhD - National Center for Smart Growth - University of Maryland, College Park

3- NEAT-GIS Protocol (Neighborhood Environment for Active Transport Geographic Information Systems)
Writer: Edited by Ann Forsyth, Contributors (alphabetically): Ed D'Sousa, Ann Forsyth, Joel Koepp, Nicole Larson, Leslie Lytle, Nishi Mishra, Dianne Neumark-Sztainer, J. Michael Oakes, Kathryn H. Schmitz, David Van Riper, Jason Zimmerman
Date: 2006, June 2007, November 2010 and January 2012 **Country:** U.S.
Indicator: Seven Chapters
1- Conceptual Issues, 2- Fundamental Protocols and Procedures, 3- Density, 4- Pedestrain Infrastructure, 5- Land-Use Mix, 6- Street Pattern, 7- Other Built Environment related/ Spatial Variables

Why these protocols have been written is firstly because transportation planning, which is a large number of quantified measurements, has widely consider motorized transportation, leaving the topic relating to walking in the hands of urban designers. With few exceptions (such as environmental aspects) urban designers have been less interested in quantification than in developing a great sensitivity to the qualitative aspects of place. Even if they were interested in quantification, however, little funding has been available for such work [47]. Additionally, the results of this study will be reported elsewhere and can be replicated. To perform the study, the team realized that it is necessary to develop protocols to define and operationalize objective (GIS-based) measures of the environment [47].

There are two types of protocols related to GIS. The first one is LEAN-GIS protocol (Local Environment for Activity and Nutrition-Geographic Information Systems) and the second one is NEAT-GIS Protocol (Neighborhood Environment for Active Transport-Geographic Information Systems).

The recent version of LEAN-GIS (Version 2.1) has been made in January 2012.

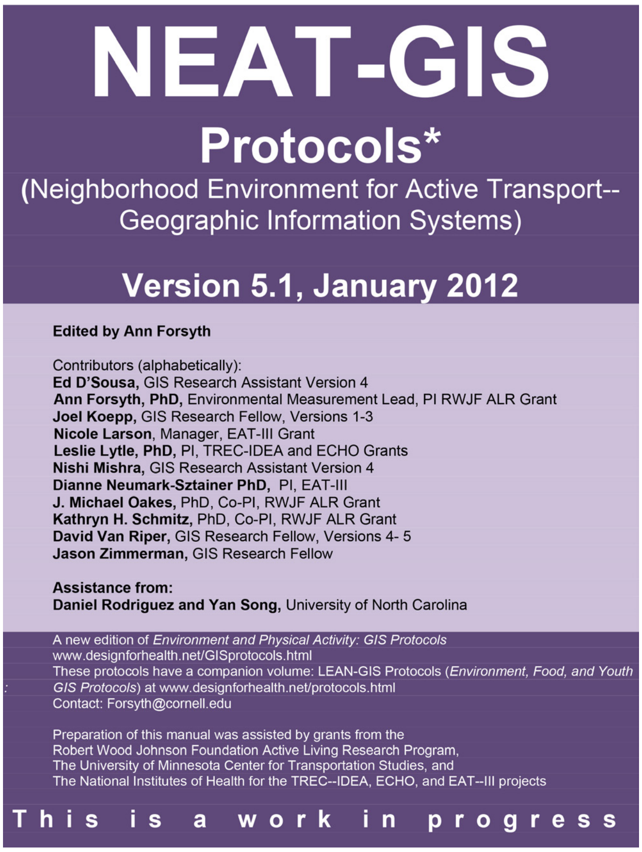
Up until now, NEAT-GIS protocols have been provided in five versions and the most up-dated of this is version 5.1, which has written in 2012, after version 4.0 refer to the companion protocols manual (LEAN-GIS).

NEAT-GIS manual is a protocol for assessing environmental variables associated with walking. So that the research team can replicate its own findings later and it will be highly useful for other research groups doing this kind of environmental measurement. Moreover, researchers, not particularly familiar with GIS, but interested in understanding the strengths and limitations of GIS-based measures of environmental features potentially related with physical activity, can access to this protocol [46]. It has been used in the case study of Twin Cities Walking Study (2003-2006). It was firstly written in the context of a research project measuring the walkability of residential zone in the environmentally diverse northern sector of the Minneapolis-St. Paul metropolitan area. It was deciding to focus on residential environment rather than work environment [48].

For analyzing this case study, a grid was chosen in order to demarcate neighborhoods rather than using "natural" neighborhoods and it was individually defined neighborhoods, census geographies, etc. The research focused on 36 districts focus areas, 0.5*0.5 miles (805*805 meters) in size, selected for variation along two dimensions hypothesized to be important for physical activity: (A) gross population density and (B) street pattern (measured as median block size) were noticed to selecting the districts for evaluating walkability. The 0.25-mile (402-meter) and 0.5-mile (405-meter) radius from a nodal point is frequently used as a baseline for walkability.

 It was also involved 718 participants, who wrote an accelerometer for 7 days, completed a 7 days travel diary, had their height and weight measured, and answered a survey dealing with demographic, environmental perception, attitudinal, and socioeconomic issues [47].

A central focus was that the amount of walking suggested for health benefits is 30 minutes on most days [49], which translates to about two miles (or approximately 3200 meters) per day. The four categories, based on a review of earlier research, were selected that might be associated with how much people walk: population density, pedestrian infrastructure and amenities, mixed use or destinations, and street pattern or connectivity. Moreover, having an excellent and high quality GIS data, this area was selected as a case study [47-48]. The manual is organized into eight sections. This protocol takes a particular format and each variable contains six main parts. In each part, the basic concept and formula are being completely explained and after that, GIS approach and steps are being defined to detail the GIS instructions [48], beginning with a reasonably precise definition of each variable and followed by how to operationalize in GIS software with precise explanation [47].


NEAT-GIS
Protocols*
(Neighborhood Environment for Active Transport--
Geographic Information Systems)

Version 5.1, January 2012

Edited by Ann Forsyth

Contributors (alphabetically):
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David Van Riper, GIS Research Fellow, Versions 4- 5
Jason Zimmerman, GIS Research Fellow

Assistance from:
Daniel Rodriguez and Yan Song, University of North Carolina

A new edition of *Environment and Physical Activity: GIS Protocols*
www.designforhealth.net/GISprotocols.html
These protocols have a companion volume: LEAN-GIS Protocols (*Environment, Food, and Youth GIS Protocols*) at www.designforhealth.net/protocols.html
Contact: Forsyth@cornell.edu

Preparation of this manual was assisted by grants from the
Robert Wood Johnson Foundation Active Living Research Program,
The University of Minnesota Center for Transportation Studies, and
The National Institutes of Health for the TREC--IDEA, ECHO, and EAT--III projects

This is a work in progress

Figure 7: NEAT-GIS latest version
Source: Ann Forsyth, 2012

Assessment Tools

Recently, many different assessment tools have been used to analyze walkability with several indexes and variables due to the fact that the growing demand for walkable neighborhoods (especially from younger generations) assessment tools have been made to calculate walkability (e.g., walkonomics.com, Walkscore.com) well-known among real estate agents, health-care agencies, environmentalists and urban designers [50].
Among them, in this thesis three assessment tools have been chosen to know about the used indicators, which are Walkscore, Walkonomics and PEDshed. Why these three were selected is because each of them is evaluating walkability in a specific way. For instance, walkscore is a website, walkonomics is an application for mobile phone and PEDshed is a vision for developing countries.

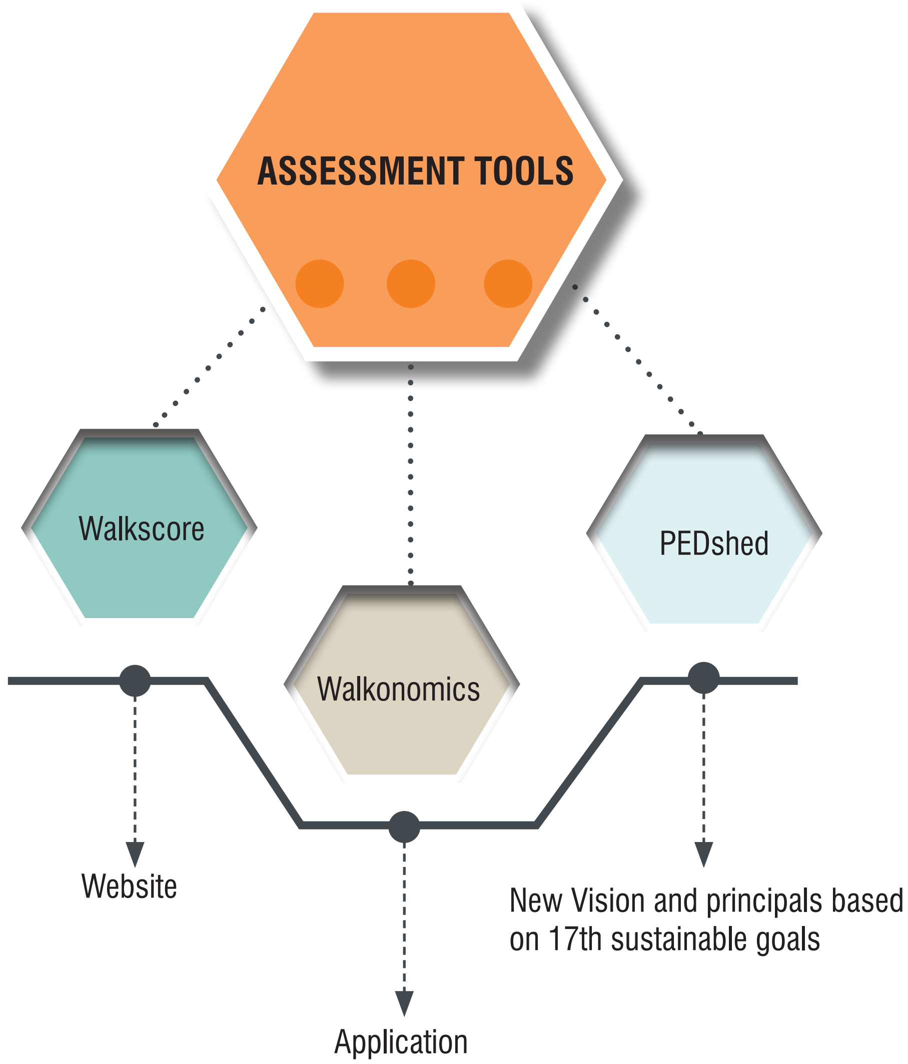


Figure 8: Different assessment tools approaches
Source: Author elaboration

1-Walkscore
Founder: Frontlane in partnership with academics such as Larry Frank and Reid Ewing
Date: 2007 **Countries:** U.S. cities, several Canadian cities and U.K.
Indicators:

Housing variable	Neighborhood Characteristics
House Size	Centrality
Bedrooms	Job Access
Bathrooms	Neighborhood
House Type	Income
House Age	**Walk Score**

One well-known too to measure neighborhood's walkability is through Walkscore [51], which was developed in 2007 by Frontlane in partnership with academics such as Larry Frank and Reid Ewing [52]. Some recent studies have found that overall neighborhood walkability like Walkscore is the most predictive of physical activity results [53] and has been validated as a reliable tool and an adequate measurement of walkability [54].
The web-based real estate assessment tool Walkscore allows users to observe and assess the not only walk, but also bike and transit-friendliness of addresses and neighborhoods in mainly for U.S. cities, several Canadian cities and U.K. [55]. This popular and comprehensive assessment tool, which is free of charge, allows a user to enter any location into the online Walkscore publicly available website (www.Walkscore.com) and obtain the Walkscore assigned to that place [56].
There are some positive points related to this website. Most importantly, Users can recognize walking, biking, and transit conditions in different neighborhoods. Secondly, it has undoubtedly useful for comparisons between different locations. Furthermore, being helpful for development planning decisions to think about land use and transportations and finally it is quantifying walkability, transit access, and bikeability by considering real estate aspects [55].
However, Walkscore does not account the width of streets, traffic, or other obstacles to walking [53] and most notably, it does not take into consideration a variety of micro-scale elements such as the condition of the sidewalk, presence of street trees that might affect walkability [57].

Walk Score®	Description
90–100	Walker's Paradise Daily errands do not require a car.
70–89	Very Walkable Most errands can be accomplished on foot.
50–69	Somewhat Walkable Some errands can be accomplished on foot.
25–49	Car-Dependent Most errands require a car.
0–24	Car-Dependent Almost all errands require a car.

Table 4: Walk Score
Source: https://www.Walkscore.com/

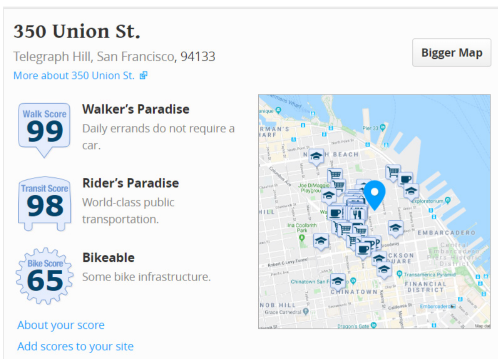


Figure 9: Screen shot of a Walk Score Website
Source: https://www.Walkscore.com/

Walkscore methodology

The Walkscore algorithm measures the walkability on the fixed route distance from one's home to nearby amenities. The number of amenities found nearby is the leading predictor of whether people will walk rather than taking other mobility systems [58] and lastly produces a score of 0 (car dependent) to 100 (most walkable) [56]. The method contains a summary measure of walkability based on the distance to amenities within a 1-mile radius from a specified location (generally between one- quarter mile and one mile of a home) [46].

The nine different amenities, which are explaining below, are weighted based on importance [59].

Amenity weights = {
"Grocery": [3],
"Restaurants": [.75, .45, .25, .25, .225, .225, .225, .225, .2, .2],
"Shopping": [.5, .45, .4, .35, .3],
"Coffee": [1.25, .75],
"Banks": [1],
"Parks": [1],
"Schools": [1],
"Books": [1],
"Entertainment": [1],
}

The distance to each specific location counts and weights. Then, it will be a base score of an address, which is afterward normalized to a score from 0 to 100 [59].

The distance decay function determines what percentage of a full score a category will receive based on the distance between the address being examined, which refer to as the origin, and an amenity's location [59].

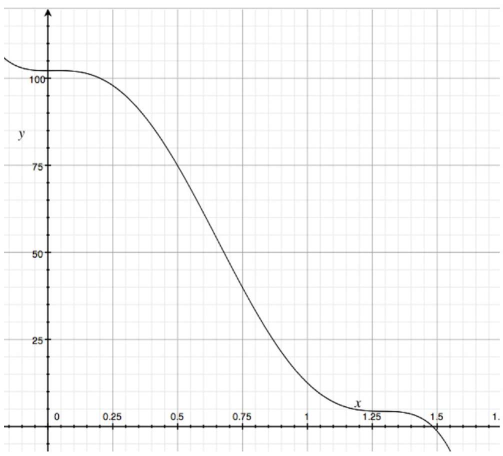


Figure 10: Distance decay function
Source: Walk Score Methodology, 2011

Next, an address may receive a penalty for having poor pedestrian friendliness metrics, such as having long blocks or low intersection density that are examined in the algorithm [59].

After multiplying each category score by 6.67, the category scores are added to each other to calculate the overall walk score, which will range from 0 to 100. It is this score that can be penalized by the pedestrian friendliness measures, losing 0 to 10% of this score. After the penalties are taken into account, the final walk score has been computed [59].

In addition to changes to the algorithm, WalkScore allows people to the WalkScore website to add amenities that may be missing or delete amenities that are mistakenly existed [59].

Walkability and home values

WalkScore has been used on over 3,000 websites, displayed in over 500 print publications and 50 TV and radio segments, mentioned as one of the seven ideas changing real estate by Inman News, and featured in discussions by the Wall Street Journal on the increasing importance of walkability in the real estate market [60].

Researchers in several fields (urban planning, real estate economics, geography, social science and public health) have examined the relationship between walkability and housing prices by different empirical studies [61]. Leinberger and Alfonzo [62] studied a walkability in Washington, D.C.; the results indicate that home values in highly walkable neighborhoods in the D.C. area were more expensive and valuable on average than housing that had less walkable neighborhoods. It also means that walkable neighborhood is a valuable feature for buyers that they can access to various amenities by walking. Cortright [63] conducted a study in 15 large metropolitan areas and reported 12 cities with a positive relationship between walkability and housing values at the neighborhood level.

In the Walkscore algorithm, the connection between home values and walkability has been measured by using an economic technique called hedonic regression. More than 90,000 recent home sales in 15 different markets around the nation were analyzed. The statistical approach were conducted for two main key characteristics which are housing variables (their size, number of bedrooms and bathrooms, house age and type) and neighborhood characteristics (including the neighborhood's income level, proximity to the urban center, relative accessibility to employment opportunities and finally the Walkscore).

After controlling these factors that are known to influence housing value, it showed a positive correlation between walkability and housing prices in 13 of the 15 housing markets that were studied. These results show that consumers and housing markets attach a positive value to living within easy walking distance of shopping, services, schools and parks [33].

It is significant to say that generally, the measure of walkability is not just the benefits associated with walking but with greater accessibility to near amenities and places with higher walk scores tend to have more mixed uses, some of the value measured here may be attributable to those assets. In addition, places with higher Walkscores are not only convenient for walking than places with lower Walk Scores, but they are also similarly more conducive to cycling and are more likely to be well-served by transit [33].

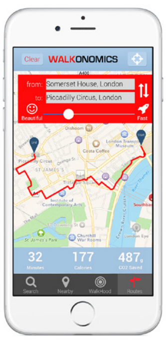
This research makes it clear that walkability is immensely related with higher housing values in nearly all metropolitan areas. The choice, convenience and variety of walkable neighborhoods are reflected in housing markets and are the product of buyer demand for these features. The nation's urban designers and developers should pay greatly attention to walkability as a key factor of urban vitality and as a motivation for public policy that will increase overall property values. Walking and cities go hand in hand. Sidewalks, streetscapes and destinations all effectively define urban space. The rebirth interest in downtowns and in promoting mixed-use developments throughout metropolitan areas is, in part, driven by a completely knowing of the value of walkability in neighborhood [33].

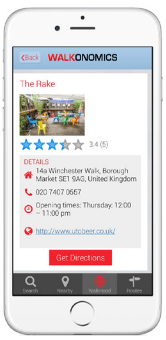
2-Walkonomics

Founder: Adam Davies (Website and APP), Carsten Moeller **Date:** May 1, 2011
Cities: Washington DC, Central London, Paris, New York, San Francisco, Toronto, Buenos Aires, Glasgow, Hamburg
Indicators: Road safety; Easy to cross, Pavement/Sidewalk, Hilliness, Navigation, Fear of crime, Smart & beautiful, Fun & relaxing.

In 2011, Adam Davies and Carsten Moeller developed Walkonomics, a web platform and mobile app that maps and rates the pedestrian-friendliness of over 700,000 streets in nine countries such as England, San Francisco, Toronto and Manhattan. This mobile app has been installed in more than 8,000 devices and the website has been visted by thousands of monthly people [50]. Each street has five-level ratings in eight different categories. Those categories are the most important factors associated with walkability by public agencies [70] and existing research [71]: Road safety, Easy to cross, Sidewalks, Hilliness, Navigation, Safety from crime, Smart and beautiful, Fun and relaxing [50].

What is particular fascinating is that in order to correct any inaccuracies or errors in analyzing streets, Walkonomics allows its web and mobile phone users to upload their own street reviews and stimulate people to comment their own ideas. To incentivize, the mobile app allows them to:
check the walkability of nearby streets and areas on a map; search by location, place name or post code; view search results on a map with color-coded markers. Read detailed reviews with star ratings for each category and user-generated photos, add their own ratings, reviews, photos and ideas for improvement. Then, The street's overall walkability score is the average of the eight categories, equally weighted [50].





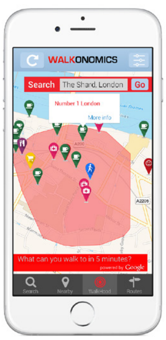


Figure 11: The walking route will take, how many calories you will burn and how much CO_2 you will save
Figure 12: Rate the pedestrian-friendliness
Figure 13: Places you can walk to in 5 minutes
Source: https://angel.co/company/walkonomics-1

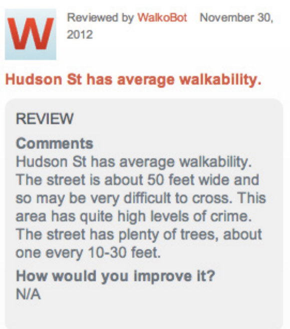


Figure 14: Putting comments
Source: Sarah Laskow, 2012

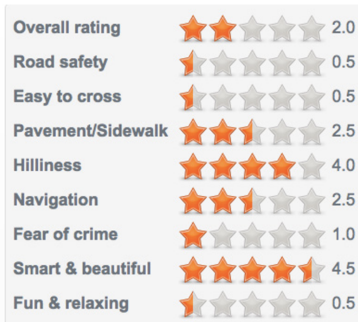


Figure 15: Walkconomic's indicators
Source: Sarah Laskow, 2012

This analysis has illustrated that the relationship between behavioral features and walkability does not only assess in the offline world but also holds in the online world. This demonstrates evidence that users' offline communities have a strongly effect on their online interactions. This insight will be important if the relationship between, the streets (that people experience in their cities) and the social media content (they create as long as being on those streets) are considered [50].

3- PEDshed
Book: Connected Cities **Writer:** Oliver Christopherson, Brian Q Love, Ruth Reed, Nichola
Country: U.K. **Date:** August 21, 2017

In the book Connected Cities, it is investigating on the setting up principles of the English planning system and conducts them forward to show how much a city can be developed whilst maintaining local centers, green space and effective infrastructure. Essentially focused on southeast England, the principles could be replicated to other parts of the world, where the urban planning is going to grow by considering sustainable transportation routes that could provide many more benefits for development. The Connected Cities principles havw been applied not only to Hertfordshire to the North of London, but also been tested in an expanding city in the South of India, so the ideas are undoubtedly universal [64].

Connected Cities is working on a global sustainable development strategy which is highly relevant to the UK. The UN predicts that the world population will grow by 2.4 billion by 2050, and to deal with the challenge, it has proposed seventeen sustainable development goals [65].
Connected Cities is a tool of ensuring growth reduces energy usage and carbon emissions by merging brownfield and green field development into a unified system concentrated on public transportation. The vision is for compact, high-quality, walkable developments around existing and new railway stations. By existing rail corridors, groups of settlements - some existing, some new - are linked and clustered around 'hub towns' and then together, they create a Connected City. All undeveloped land is protected as a green belt [64].
New infrastructure is taking a lot of cost and time to construct, so it is obviously necessary to make full use of the existing networks to provide the spines to serve the essential growth, and to concentrate large-scale development within walking distance of rail stations - either existing or new. With denser development around existing stations, together with new stations surrounded by compact new settlements, create a self-contained Connected City in which most people by short walking and brief train can reach to all the destinations of commerce, entertainment, healthcare, education, etc. [64].
Mostly, all development and growth in the Connected Cities has been within 1km of a station, in walkable areas called pedsheds. People use weather-protected pathways to get to their local station. Vehicles essentially used to travel to places not accessible by public transport. The core of the pedshed is a high-density mixed-use development around the station. It is certainly not possible to build everywhere. Only in the 1km radius circles around stations in order to protect the countryside and prevent sprawl by considering sustainable development [64].

As long as Pedsheds are designed, walking is the first choice of transport because it is simple and comfortable. Walkers and cyclists do not have to face with traffic and they are always in safe 'defensible space' which is overlooked by residents. These glazed canopies incorporate photo voltaic cells which pay for their installation and also provide street lighting. Many collect and harvest rainwater, and some incorporate wind turbines which reduce air turbulence. The walkways are pedestrian priority, but are shared by walkers, bicycles and 'small traffic' – buggies and compact smart town cars. Nowhere in a pedshed is ever more than 10-12 mines walk from station or 5 mines from shops and services, and the longer stretches of journey are made quicker and easier by moving walkways [64].

Pedsheds are made by nine pedshed principles which apply to all pedsheds. In new green towns created from green field sites, the influences are much more obvious. However, where the pedshed was already developed they are retrofitted into the existing urban fabric. Any vehicles or main road passing through the pedshed is separated from the development by noise-screening earth barriers which are part of the green infrastructure network [64].

Existing features

As well as a railway line, there will always be pre-existing buildings, rivers, woods, etc. The important ones are protected and enhanced.

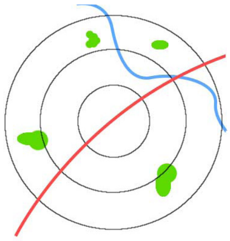


Figure 16: Existing features
Source: Oliver Christopherson, B. Q. (2017)

Protected walkways

All areas have covered or protected routes for pedestrians and small traffic (bicycles, electric scooters, etc.) which are the easiest and quickest routes to the center.

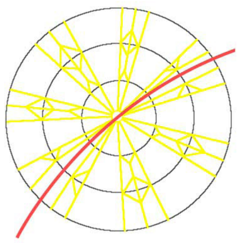


Figure 17: Protected walkways
Source: Oliver Christopherson, B. Q. (2017)

Employment

The areas either side of the rail line are employment uses. Warehousing and manufacturing may have sidings with direct rail access.

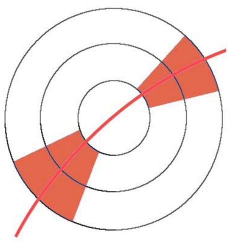


Figure 18: Employment
Source: Oliver Christopherson, B. Q. (2017)

Pedshed center

The core is a pedestrian area which is the focus of public transport, retail, educational, health, community and commercial facilities. In a new green town this is the town center; in a hub or sister town it is a district center.

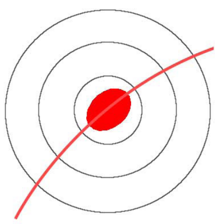


Figure 19: Pedshed center
Source: Oliver Christopherson, B. Q. (2017)

Green areas

Greenery and water are integral with the built environment. A green infrastructure network permeates the pedshed, with green corridors between the villages converging on a central park and meeting place.

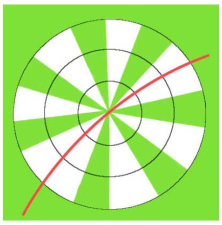


Figure 20: Green areas
Source: Oliver Christopherson, B. Q. (2017)

High density mixed use

The inner area is mixed use, high density and pedestrian priority, with limited vehicle access, as in the traditional center of York or Canterbury.

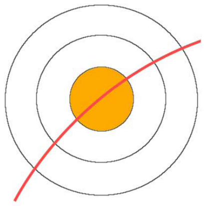


Figure 21: High density mixed use
Source: Oliver Christopherson, B. Q. (2017)

Vehicle routes

Traffic does not pass through the center, but uses other bridges over or under the railway on a circular route on which a PRT/bus service links the villages to each other and the pedshed center. In family housing areas, vehicles use pedestrian-friendly roads without extraneous traffic.

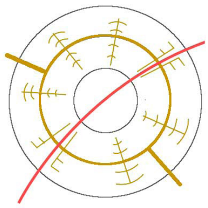


Figure 22: Vehicle routes
Source: Oliver Christopherson, B. Q. (2017)

Family housing - Villages

Family housing is medium density, low rise in pedestrian priority villages with protected walkways, greens and play areas.

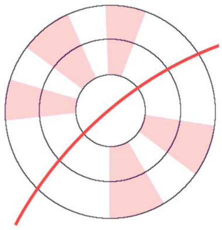


Figure 23: Family housing - Villages
Source: Oliver Christopherson, B. Q. (2017)

High streets and community

There are higher density developments on the bus/PRT route with flats, mixed-use houses and community uses. Spiritual nourishment, meeting-places and community cohesion are integral to the life of the community and embrace both green and urban areas.

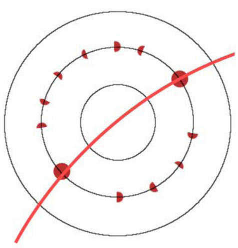


Figure 24: High streets and community
Source: Oliver Christopherson, B. Q. (2017)

Literature review analysis

	Protocols			Assessment Tools			Articles
	LEED-ND	**PEDS**	**NEAT-GIS**	**Walkscore**	**Walkonomics**	**PEDshed**	**33**
Approach	Urban Certification	Questionnaire	Case Study with ArcGIS	Website	Application	New Vision and principals based on 17th sustainable goals	Walkability in neighborhood
Year	2018	2012	2012	2007	2011	2017	2004-2018
Country	U.S.	U.S.	U.S.	U.S. cities, several Canadian cities and U.K.	Washington DC, Central London, Paris, New York, San Francisco, Toronto, Buenos Aires, Glasgow, Hamburg	U.K.	

Table 5: Comparative table of literature review
Source: Author elaboration

As above mentioned, after comparing protocols and assessment tools, three of each category with different approaches have been selected in order to also analyze with thirty-three papers. Three protocols, three assessment tools and thirty-three articles have been studied and major indexes and indicators have been extracted. Subsequently, the relevant indexes are divided into ten sections and each section contains sub category indicators, which are totally eighty indicators. After analyzing which index have been more relevant, the next step has been related to indicators calculations. Finally, each percentage shows that the using of and indexes and indicators in the whole literature review.

Number	Different Factors that affect on city's walkability		ARTICLES																						
Number	Category Index	Sub-Category Indicator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	A- Demographic Characteristics	Population density	X	✓	X	X	X	X	✓	X	✓	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2		Employment density		X					✓		X							X	X						X
3		Residential population in residential parcels		X					✓		X							X	X						X
4		Population plus employment per unit land area		X					✓		X							X	X						X
5		Residence density		X					✓		X							X	X						X
6		Age		X					X		X							✓	X						✓
7		Education		X					X		X							✓	X						X
8		Gender		X					X		X							✓	✓						✓
9		Income		X					X		X							✓	X						X
10		Own vehicle		X					X		X							X	X						✓
11		Poverty rate		X					X		X							✓	X						X
12		Race/Ethnicity		X					X		X							X	X						✓
13	B- Denisity	Residential density	✓	X	X	X	X	X	X	X	X	X	X	✓	✓	✓	X	✓	X	X	X	X	✓	X	X
14		Net floor area density												X	X	X		X			X				
15		Retail density												X	✓	✓		✓			X		X		
16		Building density												X	X	X		X			✓		X		
17		Commercial density												X	X	X		X			X		✓		
18		Block density												X	X	X		X			X		✓		
19		Net educational institutional floor area density												X	X	X		X			X		X		
20		Net footpath area density												X	X	X		X			X		X		
21		Net roadside vegetation area density												X	X	X		X			X		X		
22	C- Secuirity	Traffic safety	✓	X	X	X	✓	X	X	X	✓	X	X	✓	X	X	X	X	X	X	X	X	X	X	✓
23		Safe for walking	X		✓	X	X				X			X					X	X	X				
24		Traffic volume	X		✓	X	✓				X			X					X	X	X				
25		Traffic control devices	X		✓	X	X				X			X					X	X	X				
26		Vacant building, Abandon building, Undesirable land use	X		X	X	X				✓			X					X	X	X				
27		Safety facilities at sidewalks	X		X	✓	X				X			X					X	X	X				
28		Riding speed	X		✓	X	✓				X			X					✓	✓	✓				
29		Safety from Crime	X		X	X	✓				X			✓					X	X	X				
30		Presence of different social classes in space	X		X	X	✓				X			X					X	X	X				
31		Variety of activities	X		X	X	✓				X			X					✓	X	X				
32	D- Comfort	Easy access without obstacles	X	X	X	✓	X	✓	X	X	✓	X	✓	X	X	X	X	X	X	X	X	X	X	X	X
33		Sidewalk length	X			✓	X	X			X		X						X			X			X
34		Sidewalk width	X				X	X			✓		✓						✓	✓	✓	✓			X
35		Windows and facade transparency	X				✓	X			✓		X						X	X	X	X			X
36		Covered spaces (sun, rain)	X				X	X			X		✓						X	✓	X	✓			X
37		Street cleanliness	X				X	X			X		X						X	X	X	X			X
38		Direction signs	X				X	X			X		X						X	X	X	X			X
39		Traffic noise mitigation	X				X	X			X		X						X	X	X	X			X
40		Clear route	X				X	X			✓		X						X	X	X	X			X
41		Good smell	X				X	X			X		X						X	X	X	X			X
42		Place for casual contacts	X				X	X			X		X						X	X	X	X			X
43		Noise levels	X				X	X			X		X						X	X	X	X			X
44		Parking lots	✓				X	X			X		X						X	X	X	X			✓
45	E- Accessibility	Sidewalk condition	X	X	✓	✓	✓	X	X	✓	✓	X	✓	X	✓	✓	X	X	✓	✓	X	✓	X	X	X
46		Public transport condition			X		X	X		X	X								X	X		X			X
47		Viewable start and end node			X		X	X		X	X								X	X		X			X
48		Number of foot paths			X		X	X		X	X								X	X		X			X
49		Network integration in the urban fabric			X		X	X		X	✓								X	X		X			X
50		Proximity to 13 categories (1- grocery store, 2-coffee shop, 3-movie theater, 4-park, 5-bookstore, 6- drug store, 7-clothing and music store, 8-restaurant, 9-bar, 10- school, 11- library, 12-fitness, 13-hardware store)			X		X	X		X	X								X	X		X			X
51		Proximity to public transport (buses, metro)			X		X	✓		X	X								X	X		X			X
52		Separation of pedestrian route from car roadway			X		X	X		X	X								X	X		✓			X
53		Land use accessibility			X		X	X		X	X								X	X		X			✓
54	F- Attractiveness & Aesthetics	Number of street trees	✓	X	✓	✓	X	X	X	X	X	X	X	✓	X	X	X	X	X	✓	X	✓	X	X	✓
55		Rows of trees			X		✓	✓		X	X						X		X		X			✓	
56		Skyline of building			X		✓	X		X	X						X		X		X			X	
57		Historical buildings			X		✓	X		X	X						X		X		X			X	
58		Building height			X		✓	X		X	X						X		X		X			X	
59		Landmarks			X		✓	X		X	X						✓		X		X			X	
60		Public open spaces (Plaza)			X		✓	X		X	X						X		X		X			X	
61	G- Pedestrian Infrastructure	Pedestrian slope (Disability)	✓	X	X	X	✓	✓	X	✓	X	X	X	✓	X	X	✓	X	X	X	X	✓	X	X	✓
62		Bicycle lanes	X		X	X	X	X		X	✓								X	✓	✓	✓		X	
63		Lighting	X		✓	X	✓	X		X	✓								X	X	X	✓		✓	
64		Furniture	X		X	X	X	X		X	✓								✓	✓	X	✓		X	
65		On street parking	X		✓	X	X	X		X	X								X	✓	✓	✓		X	
66		Pedestrian crossings along Street	X		X	X	X	X		X	✓								X	X	X	X		X	
67	H- Climatic and Environmental Factors	Windy climate, Rainy climate (Climate comfort for the path)	X	X	X	✓	✓	X	X	X	X	X	X	X	X	X	X	X	✓	X	X	X	X	X	X
68		Thermal comfort	✓				X																		
69	I-Land Use Mix	Mixed land use	✓	✓	✓	X	✓	X	X	X	✓	✓	X	✓	✓	✓	X	✓	✓	X	X	X	X	✓	✓
70		parks								X	✓	X										X		✓	
71		Open-air markets								X	✓	X										X		X	
72	J- Street Connectivity	Continuity of walking path	✓	✓	✓	✓	X	✓	X	✓	✓	X	✓	✓	✓	✓	X	X	X	X	X	X	X	X	✓
73		Intersection		✓	X						X	X						✓	X			X	X		
74		Block length		X	X						X	X						X	X			X	✓		
75		Block width		X	X						X	X						X	X			X	✓		
76		Public transportation		X	X						X	✓						X	X			X	X		
77		Modal distribution		✓	X						X	X						X	X			X	X		
78		Connectivity between uses		X	X						X	X						X	X			X	X		
79	K- Economy	Housing variable (House Size, Bedrooms, Bathrooms, House Type, House Age)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
80		Neighborhood characteristics (Centrality, Job Access, Neighborhood Income, walkability Analysis)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 6: Indicators availability in literature reviews
Source: Author elaboration

										PROTOCOLS			ASSESSMENT TOOLS			Conclusion		RESULTS
24	25	26	27	28	29	30	31	32	33	1p	2p	3p	1a	2a	3a	Percentage	Percentage	Selected Indicators
X	X	✓	X	X	X	X	X	X	X	X	X	✓	X	X	✓	15%	26%	A1-Population density
		✓						✓				✓			X	10%		A2-Employment density
		X						X				✓			X	5%		
		X						X				✓			X	5%		
		X						X				✓			X	5%		
		X						✓				X			X	8%		A3-Age
		X						✓				X			X	5%		A4-Education
		X						X				X			X	8%		A5-Gender
		X						✓				X			X	5%		
		X						✓				X			X	5%		
		X						X				X			X	3%		
		X						X				X			X	3%		
X	X	X	✓	X	X	X	X	✓	X	✓	X	✓	X	X	✓	28.21%	31%	B1- Residential density
								X	✓	✓		✓			X	12.82%		B2- Net floor area density
								✓	✓	X		✓			X	20.51%		B3- Retail density
								X	X	X		X			X	7.69%		
								X	X	X		✓			X	10.26%		
								X	X	X		✓			X	10.26%		B4- Block density
								X	✓	X		X			X	7.69%		
								X	✓	X		X			X	7.69%		
								X	✓	X		X			X	7.69%		
✓	X	X	✓	X	✓	✓	X	X	X	X	X	✓	X	X	X	25.64%	35.90%	C1-Traffic safety
	X			X							X	X		✓		17.95%		
	X			✓							X	X		X		20.51%		
	X			X							✓	X		X		17.95%		
	X			✓							X	X		X		17.95%		C2-Vacant building, Abandon building, Undesirable land use
	X			X							✓	X		✓		20.51%		
	X			✓							✓	X		X		30.77%		C3- Riding speed
	✓			✓							X	✓		✓		28.21%		C4-Safety from Crime
	X			X							X	X		X		15.38%		
	X			X							X	X		X		17.95%		
✓	X	X	X	✓	X	X	X	X	X	X	✓	X	X	X	X	17.95%	35.90%	
X				X	✓		✓			X	X	✓		X	X	10.26%		D1-Sidewalk length
X				X	✓		X			X	✓	X		X	X	23.08%		D2-Sidewalk width
X				X	X					X	X	X		X	X	7.69%		
X				✓	✓					✓	X	X		X	✓	20.51%		D3-Covered spaces (sun, rain)
X				X	X					X	X	X		X	X	2.56%		
✓				X	X					X	X	X		X	X	5.13%		
X				✓	X					X	X	X		X	X	5.13%		
X				✓	X					X	X	X		X	X	7.69%		
X				X	✓					X	X	X		X	X	5.13%		
X				✓	X					X	X	X		✓	X	7.69%		
✓				✓	X					X	X	X		X	X	7.69%		
✓				X	X					✓	✓	✓		X	X	17.95%		D4-Parking lots
X	✓	X	X	✓	X	X	X	✓	X	X	✓	X	X	✓	X	41.03%	43.59%	E1-Sidewalk condition
X	X	X					X			✓	X	X	X	✓	X	20.51%		
X	X	X					X			X	X	X	X		X	17.95%		
X	X	X					X			X	X	X	X		X	17.95%		E2-Number of foot paths
X	X	X					X			X	X	X	X		✓	23.08%		E3- Network integration in the urban fabric
X	X	X					X			X	X	✓	✓		✓	25.64%		E4-Proximity to 13 categories (1- grocery store, 2-coffee shop, 3-movie theater, 4- park, 5-bookstore, 6- drug store, 7-clothing and music store, 8-restaurant, 9-bar, 10- school, 11- library, 12-fitness, 13-hardware store)
✓	X	X					✓			✓	X	✓	X		✓	33.33%		
X	X	X					X			X	X	X	X		X	20.51%		
X	X	X					X			X	X	X	X		X	20.51%		
X	X	X	✓	X	X	X	X	X	X	X	✓	✓	X	✓	X	28.21%	38.46%	
✓		X		✓	X					✓	X	X			✓	38.46%		F1-Rows of trees
X		X		X	✓					X	X	X			X	25.64%		
X		X		X	X					✓	X	X			X	25.64%		
X		X		X	✓					X	✓	X			X	28.21%		
X		X		X	X					X	X	X			X	25.64%		
X		X		X	X					✓	X	X			X	25.64%		F2-Public open spaces (Plaza)
✓	X	X	X	X	X	✓	X	X	X	✓	✓	X	X	✓	X	33.33%	46.15%	G1- Pedestrain slope (Disability)
✓	✓	X		X	X					✓	✓	✓		X	✓	35.90%		G2- Bicycle lanes
✓	X	X		✓	✓					✓	✓	✓			X	38.46%		G3-Lighting
✓	X	X		X	X					X	X	X			X	23.08%		G4-Furniture
X	X	X		X	✓					✓	✓	X			X	28.21%		
X	X	X		X	✓					X	✓	✓			X	20.51%		
✓	x	X	X	X	✓	X	X	X	X	X	X	✓	X	X	X	15.38%	10.26%	H1-Windy climate, Rainy climate (Climate comfort for the path)
					X					X	X	X				10.26%		
X	x	✓	✓	✓	X	X	X	✓	✓	✓	X	✓	X	X	✓	53.85%	38.46%	I1-Mixed land use
											X				✓	51.28%		I2- parks
											X				X	46.15%		
X	X	X	✓	X	X	X	X	X	x	X	✓	X	X	X	✓	38.46%	38.46%	J1-Continuity of walking path
X	X			X					✓	✓	✓	✓				43.59%		J2-Intersection
X	✓			X					x	X	X	✓				35.90%		J3- Block Length
X	X			X					x	X	X	✓				33.33%		J4-Block Width
✓	X			X					x	✓	X	✓				38.46%		J5-Public transportation
✓	X			X					x	✓	✓	✓				41.03%		J6-Modal distribution
X	X			✓					x	X	X	X				30.77%		
X	X	X	X	X	X	X	X	X	X	X	X	X	✓	X	X			K1-Housing variable (House Size, Bedrooms, Bathrooms, House Type, House Age)
X	X	X	X	X	X	X	X	X	X	X	X	X	✓	X	X			k2-Neighborhood characteristics (Centrality, Job Access, Neighborhood Income, walkability Analysis)

Table 6: Indicators availability in literature reviews

Source: Author elaboration

A Demographic Characteristic: 26%

• Population density	15%
• Employment density	10%
• Residential population in residential parcels	5%
• Population plus employment per unit land area	5%
• Residence density	5%
• Age	8%
• Education	5%
• Gender	8%
• Income	5%
• Own vehicle	5%
• Poverty rate	3%
• Race/Ethnicity	3%

D Comfort: 35.9%

• Sidewalk condition	17.95%
• Public transport condition	10.26%
• Viewable start and end node	23.08%
• Number of footpaths	7.69%
• Network integration in the urban	20.51%
fabric	2.56%
• Proximity to 13 categories	5.13%
• Proximity to public transport	5.13%
(buses, metro)	7.69%
• Separation of pedestrian route	5.13%
from car roadway	7.69%
• Land use accessibility	7.69%
	17.95%

B Density: 31%

• Residential density	28.21%
• Net floor area density	12.82%
• Retail density	20.51%
• Building density	7.69%
• Commercial density	10.26%
• Block density	10.26%
• Net educational institutional floor area density	7.69%
• Net footpath area density	7.69%
• Net roadside vegetation area density	7.69%

E Accessibility: 43.59%

• Sidewalk condition	41.03%
• Public transport condition	20.51%
• Viewable start and end node	17.95%
• Number of footpaths	17.95%
• Network integration in the urban fabric	23.08%
• Proximity to 13 categories	25.64%
• Proximity to public transport (buses, metro)	33.33%
• Separation of pedestrian route from car roadway	20.51%
• Land use accessibility	20.51%

C Security: 35.9%

• Traffic safety	25.64%
• Safe for walking	17.95%
• Traffic volume	20.51%
• Traffic control devices	17.95%
• Vacant building, Abandon building, Undesirable land use	17.95%
• Safety facilities at sidewalks	20.51%
• Riding speed	30.77%
• Safety from Crime	28.21%
• Presence of different social classes	15.38%
• Variety of activities	17.95%

F Attractiveness & Aesthetics: 38.46%

• Number of street trees	28.21%
• Rows of trees	38.46%
• Skyline of building	25.64%
• Historical buildings	25.64%
• Building height	28.21%
• Landmarks	25.64%
• Public open spaces (Plaza)	25.64%

Table 7: Indexes and Indicators availability in literature reviews
Source: Author elaboration

G Pedestrian Infrastructure: 46.15%

• Pedestrian slope (Disability)	33.33%
• Bicycle lanes	35.90%
• Lighting	38.46%
• Furniture	23.08%
• On street parking	28.21%
• Pedestrian crossings along Street	20.51%

J Street Connectivity: 38.46%

• Continuity of walking path	38.46%
• Intersection	43.59%
• Block length	35.90%
• Block width	33.33%
• Public transportation	38.46%
• Modal distribution	41.03%
• Connectivity between uses	30.77%

H Climatic and Environmental Factors: 10.26%

• Windy climate, Rainy climate (Climate comfort for the path)	15.38%
• Thermal comfort	10.26%

K Economy: Walkscore

• Home values

I Land Use Mix: 38.46%

• Mixed land use	53.85%
• parks	51.28%
• Open-air markets	46.15%

Table 7: Indexes and Indicators availability in literature reviews
Source: Author elaboration

Final Result

The highest percentage of indicators have been selected which are thirty three. In addition to these ten indexes, one section has been added to them. After walkscore analysis and understanding that the relationship between home values and walkability, the index economy and sub category home values have been joined to other selected sections.

A
A1-Population density
A2-Employment density
A3-Age
A4-Education A5-Gender

F
F1-Rows of trees
F2-Public open spaces (Plaza)

B
B1-Residential density
B2-Net floor area density
B3-Block density
B4-Retail density

G
G1-Pedestrian slope (Disability)
G2-Bicycle lanes
G3-Lighting
G4-Furniture

C
C1-Traffic safety
C2-Vacant building, Abandon building, Undesirable land use
C3-Riding speed C4-Safety from Crime

H
H1- Windy climate, Rainy climate (Climate comfort for the path)

D
D1-Sidewalk length
D2-Sidewalk width
D3-Covered spaces (sun, rain)
D4-Parking lots

I
I1-Mixed land use
I2-parks

E
E1-Sidewalk condition
E2-Number of footpaths
E3-Network integration in the urban fabric
E4-Proximity to 13 categories

J
J1-Continuity of walking path
J2-Intersection
J3-Block length J4-Block width
J5-Public transportation J6-Modal distribution

K
K1-Home Values

Table 8: The highest relevant indicators
Source: Author elaboration

1-2: Questions

Much of the renewed consideration on urban walkability is related with concerns that motorized dependent cities will not be sustainable in the future. By achieving walkable city, numerous advantageous have been granted to the citizens such as economic, environmental and social benefits [66] which are three pillars of sustainability [67].

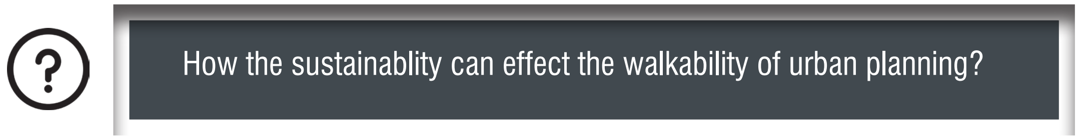


Figure 25: Research question
Source: Author elaboration

How walkability can effect on these three pillars are firstly, in social aspect, with walking area provides for people to interact and socialize more by direct communication. Secondly, with substitution by cars, the pollution and emission will be reduced and finally, it is much more cost saving and reduce commuting cost as an economical aspects.

Urban transportation is one of the most effective sectors for creating more sustainable and livable cities. A sustainable urban form is defined by prioritizing walking and non-motorized forms of transportation, mass transit, and compact and mixed use urban forms [68]. The same as bicycling, walking can be known as ‘green’ type of transportation, which has low-level impact on environmental, energy conserving with neither air nor noise pollution [69].

Hence, Walkability is the basis of sustainable city. The more walkability is increasing in the neighborhood, the more sustainable and livable area the city has. So, one of the important purposes to create a walkable environment is to achieve livablility in a city [69]. EIU [70] defines liveability as one of the aspects that could contribute to a high quality of living. This is because high quality of living will affects citizens’ lifestyle, health condition and shows stability of the built environment.

Generally, Liveability is a part of the sustainability concept [67], which consists of different elements and components. In the transportation part by enhancing walkability, giving more accessibility and more transportation choice, the livability will be partly achieved [71]. Liveable city put emphasis on sustainability of transportation system, which is to minimize noise and air pollution as well as encouraging residents to walk [72]. Therefore, liveable city needs the particular condition to reach the district and neighborhood.

In addition, to describing sustainable communities, Egan explained seven important factors and two of them are transport and services. In his point of view, a good connectivity to access private and public spaces lead to sustainable communities.

For these reasons, sometimes, walkable city considers equally to sustainable city [73]. Particularly as an accessible and affordable mobility service and safe infrastructure for non-motorized transport such as cycling and walking that are not existing in most developing country cities [74]. Through research backgrounds and empirical study, the research question of this paper is to understand the relationship between urban planning and walking [69-75-76]: How can the walkability affect the sustainable urban planning?

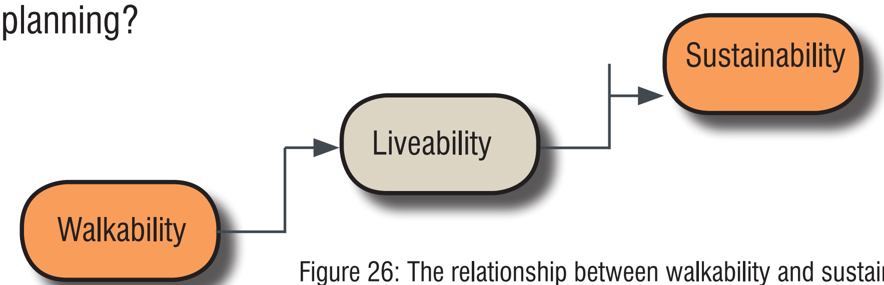


Figure 26: The relationship between walkability and sustainability
Source: University of Winconsin Transportation Analysis Team (2011)

1-3: Objectives

The initial concept of a sustainable transport has been started by The Brundtland Report about sustainable development ‘‘meets the needs of the present without compromising the ability of future generations to meet theirs’’ [77] and sustainable mobility is defined by accessible, safe, environmentally-friendly and affordable systems [74].
Through a comprehensive study of literature review, the main objective of research proposal is to investigate the relationship between sustainable cities and walking. This is achieved by comparing and applying different strategies: How can walkability lead to sustainable cities? [30]
The sustainable development goals have addressed to seventeen principals, where four principals of these goals are related to low carbon transport systems. These goals are good health and well-being (goal three), affordable and clean energy (goal seven), sustainable cities, communities (goal eleven) and climate action (goal thirteen) [78]. This consideration shows that how the mobility systems in the city is greatly important [79].

- **Main objective:** Analyzing the Relationship Between Walkability and Sustainability
- **Sub-Objective:** Finding Relevant Indicators for Evaluating Walkability

Figure 27: Research objectives
Source: Author elaboration

Recently, for a sustainable development in a city and the neighborhood, many tools have been experimented and applied. Indeed, walkability is one of the tools that has been emerging and can be helpful in shaping sustainable cities [26].
The OECD and the Canadian “Center for Sustainable Transport” (CST) define sustainable transport system is the one that [80]:
-Responds the wants of accessibility and mobility in individual and society level with esteem on human and environment, aiming to balance the wants of presence and future needs;
-Is sufficient and effective, gives alternative options of modes of transport, and underpins a competitive economy and a balanced territorial development.
-Reduces the emissions, uses alternative power resources and minimizes the used space.
As a result, there is a strong relationship between walkability, sustainable transportation and the environment. In addition to that, walkability is a concept that is consistent with sustainable development and transportation system [80]. The objective of this thesis, therefore, is to quantify the efficient walking environment indexes that have been selected by comprehensive study of literature review. Some of the data can be obtained from GIS databases of local planning agencies.This study also attempts to explore the relationship between walking behavior and physical environment and its impacts on city sustainability and finally, provide some suggestions for future developments in order to increase the walkability in neighborhood.

The relationship between walkable areas and cities are associated in three sections, which are three pillars of sustainability (environment, social and environment).

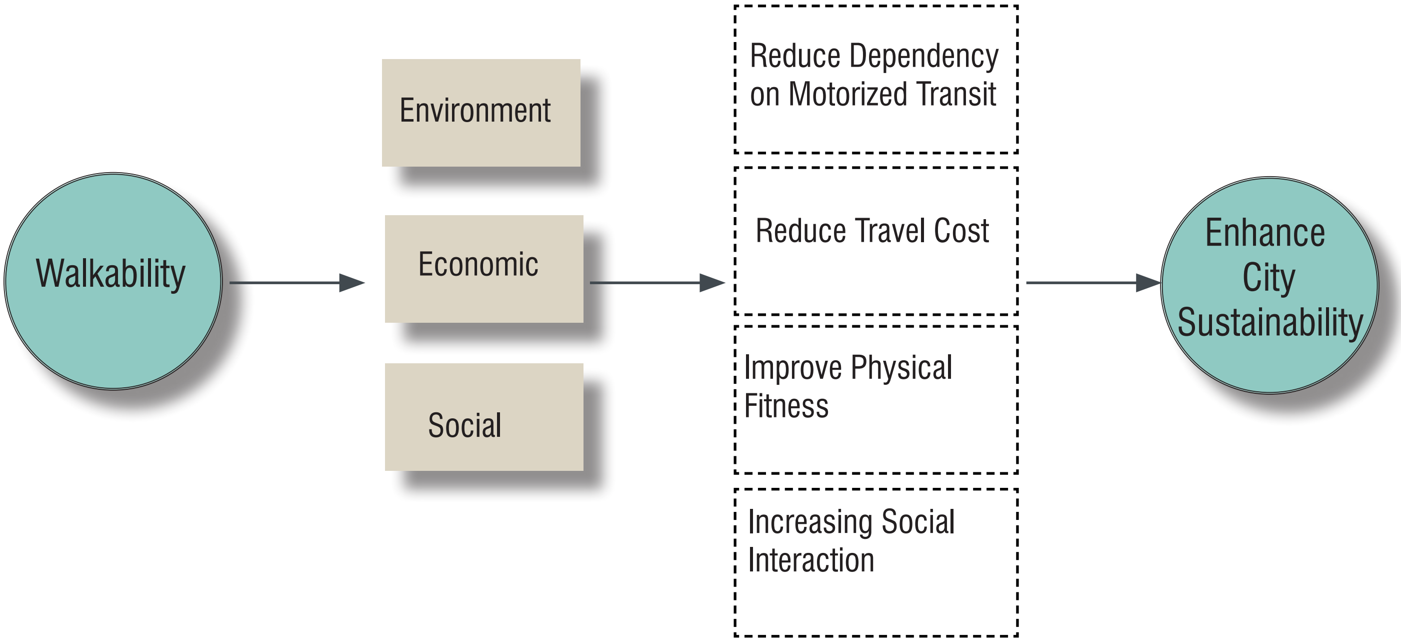


Figure 28: Conceptual integration between walkable pedestrian and city sustainability
Source: Md Mustiafiz Al Mamun, A. a. (2018).

So that, the Selection of indicators for analyzing walkability are being considered with sustainable approaches by these three visons to promote sustainability in neighborhood level and all the three aspects have been analysed. The example of this vison are in the table.

Environment	**Economic**	**Social**
-Proximity to Important Location in Urban Planning -Rows of Trees -Parks	-Home Values -Modal Distribution -Public Transportation	-Public Open Space -Mix land use -Intersection of Streets Furniture -Safety from Crime

Table 9: The relationship between selected indicators and sustainability pillars
Source: Author elaboration

As it is shown, the indicators can use in three different levels: Metropolitan urban area, neighborhood levels and block. In this thesis, the analyzing of walkability of focusing on neighborhood level, firstly because of the importance of this level for shaping cities. Furthermore, in the case study the neighborhood levels are significant for shaping the city.

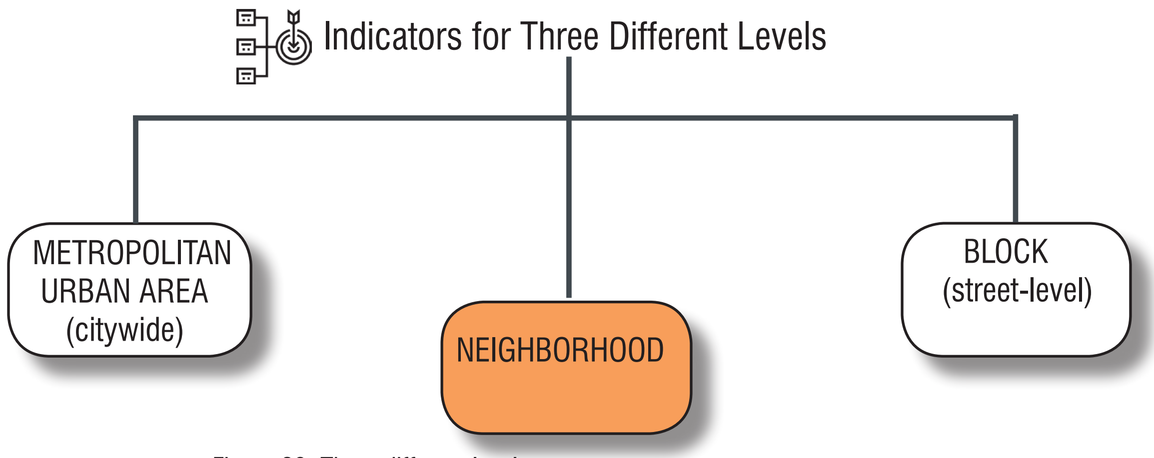


Figure 29: Three different levels
source: Institute for Transportation & Development Policy WWW.ITDP.ORG
Promoting sustainable and and equitable transportation worldwide

1-4: Thesis structure

After evaluating various researches and obtaining selected indicators, in this part, the further steps are divided into three chapters.
The first step is methodology framework which is categorized in two parts: indicators selection and impact assessment and afterwards all of the steps that must be done with different software.
The second part is related to the ways of data gathering and impact assessments. Therefore, every variable has been assessed and visualized to see the effects on the case study. Then, all of the layers of information will be put together to obtain the result.
The final part ends with conclusions, future developments and recommendation for future research in the walkability analysis.

2- Methodology

The methodology framework (as shown in the tables) has been divided into two parts: indicators selection and impact assessment of selected indicators. The indicators selection (as in the previous chapter explained) has been separated into four parts: Problem definition, preselection of indicators based on comprehensive studying of literature review, protocols and assessment tools. Then, analyzing the data availability and finally, selecting the relevant indexes and indicators. In addition, the impact assessment part of selected indicators has been categorized into four aspects: impact assessment, visualization, Suitability analysis and result. The primary step is the analyzing the case study and visualizing all of the data. Next, the suitability analysis has been used to obtain each specific map for each index.

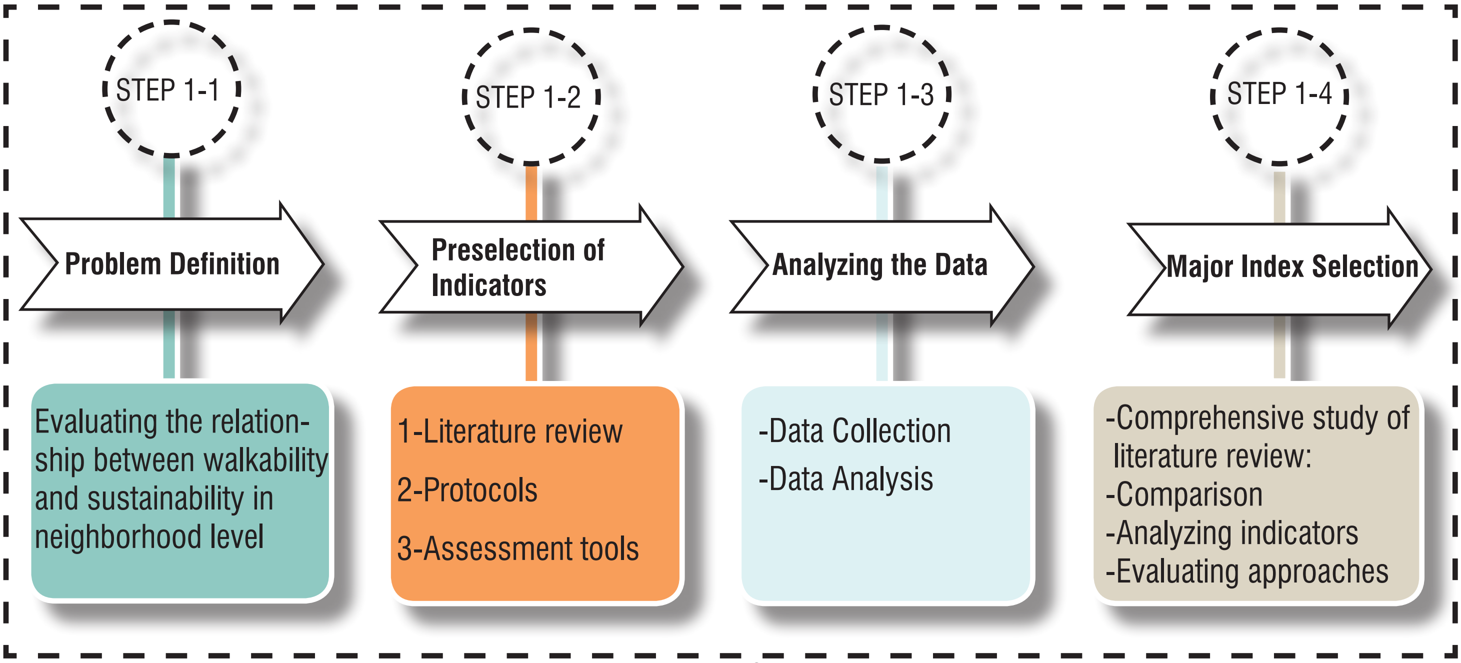


Figure 30: Indicators Selection
Source: Author elaboration

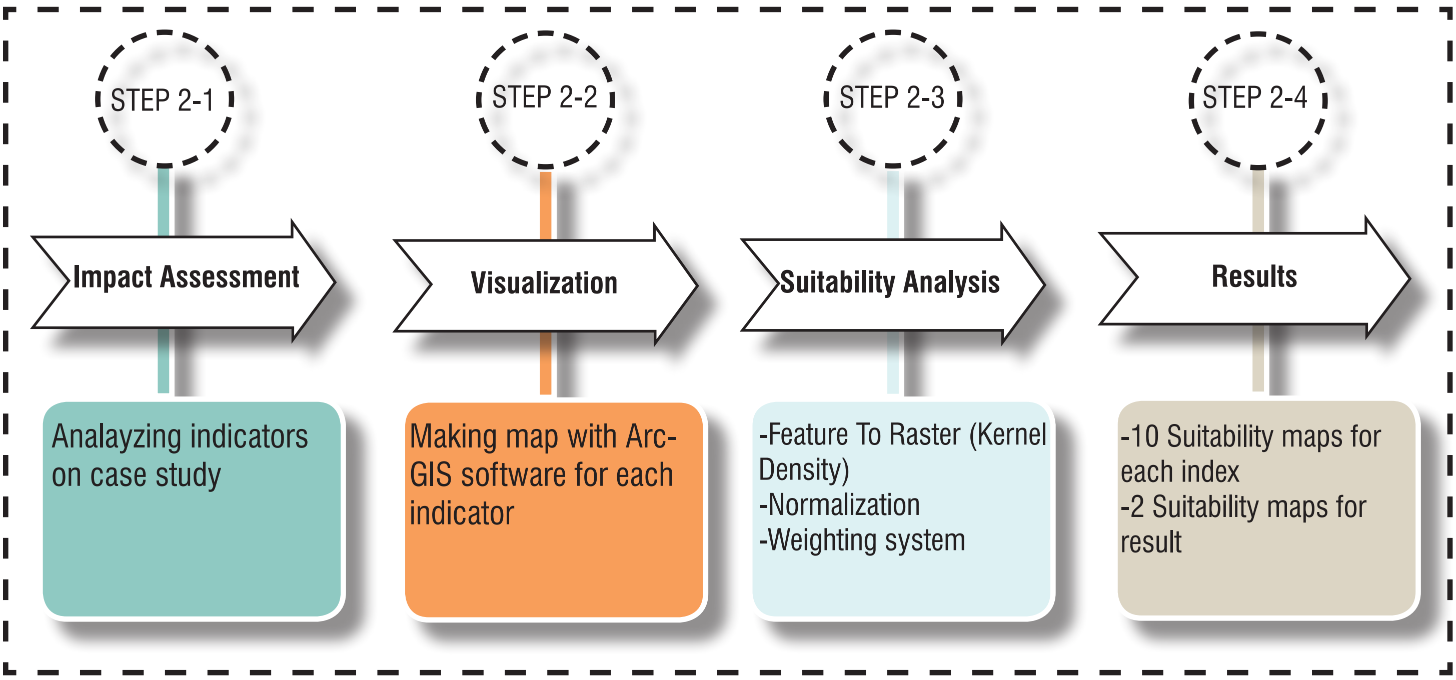


Figure 31: Impact Assessment
Source: Author elaboration

2-1- Methodological Approach

After obtaining the final list of indicators, the next step is the impact assessment on case study. Each indicator has been analyzed in the case study (San Salvario neighborhood in the Turin city) by gathering and collecting information. Then, each indicators is assessed visualized, which has been done by ArcGIS software (version 10.5)

For the visualization, Geographic information systems (GIS) has been applied to make walkability indexes. Since walkability study is a spatial concept, this software is fundamentally useful tool to gather, arrange and manage all the information associated to the walkability areas [81]. It has been applied in a wide range of investigations for comparing and processing different features on the case study. One of the essential advantageous of using ArcGIS is that it can show the various layers of information simultaneously to see the positive and negative points of the area [82]. By mapping different type of information, it will be immensely helpful for decision makers and investors to promote walkability in the places where there are lack of walkable environments [83].

Different Steps of the Methodology

For evaluating walkability by the software ArcGIS version 10.5, different procedures must be done, after putting all the indicators in the map, impact assessment step has started with five steps:
In the step one, all of the information related to the qualitative and quantitative indicators have been put in the ArcGIS. The information for qualitative indicator has been changed to quantitative aspects, for example in the indicators E1: sidewalk condition, information were categorized in five sections: from very poor to very good. Then, in the attribute table of ArcGIS, this information changed to one to five respectively for having ordinal scale. The first thing is that all of the map must have the same coordinates system in order to proceed. After defining the coordinate systems for each indicator, the next is that to specify the workspace in which the analysis must be done. For doing this, all of the map's extent must have completely the same extent. Then, the next step is that setting the same resolution for doing raster analysis, which are two meters and two meters for all of them.
Step two is that not only in the index all of the maps must be separated but also it is necessary for each indicator to subdivide different fields for doing feature to raster analysis. For the indicators, which are a location and points such as different locations, intersection and transportation (metro stops) the process is changing.

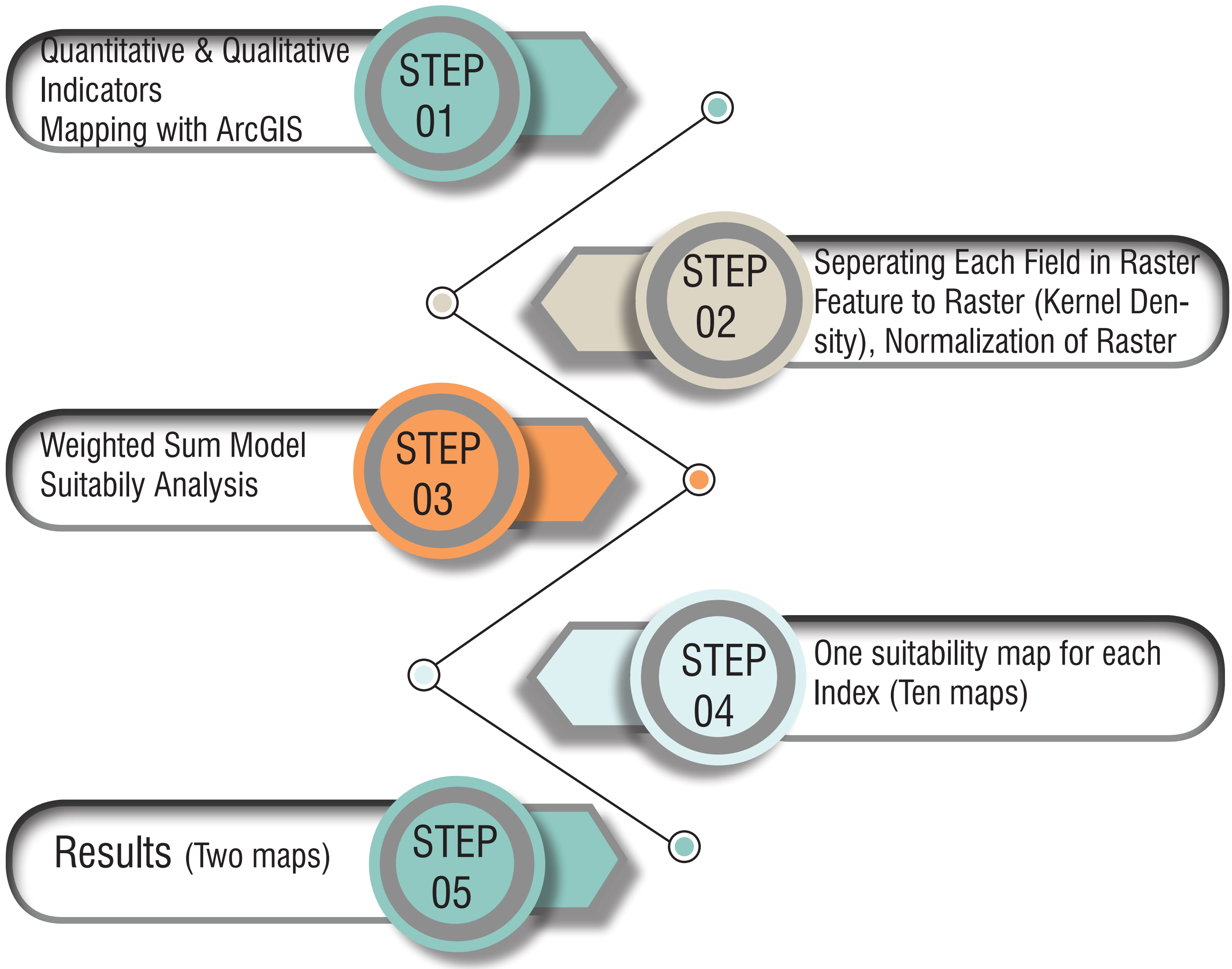
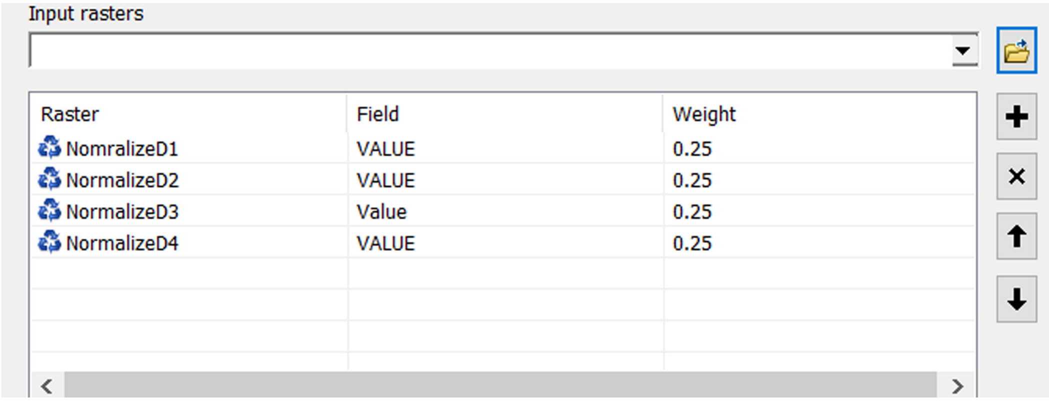


Figure 32: Different steps for doing visualization
Source: Author elaboration

Instead of raster analysis, the Kernel density has been done, because it is significant to know how much these specific places can affect the surrounding and then for having just the case study limitation, "extract by mask" must be applied for corresponding to the defined area (San Salvario). After that, all of the field will be normalized (by raster calculator) to the range between zero and one, by this formula:

("%X_raster%"- min) / (max-min)

In the step three, every indicator has a map with its own specific field and then with the weighted sum, one map for each index has been obtained. For example if an index has five parts, in weighted sum calculation, one is divided to five and for weighting part, 0.20 must be put and if the index has four parts in this calculation, one is divided to four and 0.25 will be put in the weighted sum section.



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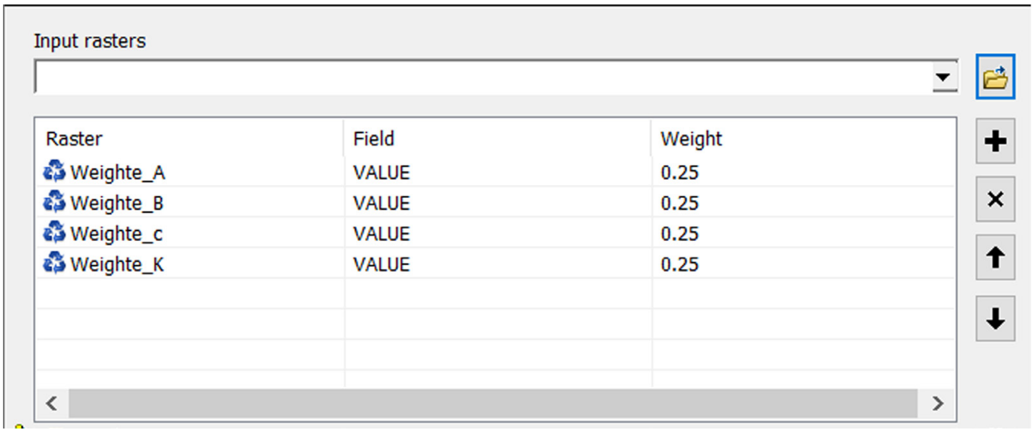

Figure 33: Screen shot from ArcGIS
Source: Author elaboration

Then, in the fourth step, after this computation, there are one suitability map for every index. In the final step, there are two sort of analysis with ArcGIS software that has been done. The group of indicators were analyzed by kernel density (block zones), the other groups that were calculated without kernel density (street zones). So that, for the first group again the procedure for the weighted sum has be done which contains these groups: D (Comfort), E (Accessibility), F (Attractiveness & Aesthetics), G (Pedestrian Infrastructure), I (Land Use Mix), and J (Street Connectivity).However, the second group consists of A (Demographic Characteristic), B (Density), C (Security) and K (Economy). Eventually, there are two suitability maps will be obtained by weighted sum of these groups that show the rate of walkability.

2-2- Case Study

This chapter explains the case study in which indicators will be applied for analyzing walkability. . This case study was selected because of the data availability and accessibility of this neighborhood, especially in case of In-situ analysis. Moreover, there are some important location in this district such as architecture campus and different hospitals, Cinema and churches. Another point is that this location was the case study of Dist (Interuniversity Department of Regional and Urban Studies and Planning) in Polytechnic and University of Turin. Hence, San Salvario district in Turin city was selected as a case study to analyze walkability

Turin

Turin is geographically located in the northwestern corner of Italy, which is in the Piedmont region. It is the fourth largest city in the Italy and has population approximately 875,698 and has a total area of 130.17 square kilometer. This metropolitan consist of 53 municipalities. In the recent years, the population of the city has reduced whereas the number of immigration in the last decades has growth from Eastern Europe and North African countries (Romania and Morocco above all), but also South America (Peru and Chile). Moreover, Turin has become famous as 'one company town' due to the presence of FIAT and other well-known factories in this city [84].

Figure 34: Location of Turin city in Italy map
Source: Torino Urban Profile (2016)

San Salvario

San Salvario (San Salvari in Piedmontese) is a historic district of the Circoscrizione 8 of Turin and it is located in the southeast of the historic center. In the eastern part is the Parco del Valentino, the big and popular park in Turin, along the left bank of the Po river. The faculty of architecture of the Polytechnic university of Turin is also located in the eastern park, in the Valentino Park. Currently, this neighborhood has a wide range of activities and a lively life night. Moreover, there is a place named Casa del Quartiere which is creating a positive connection between different class of residences such as immigrants, students and other incomes [85].

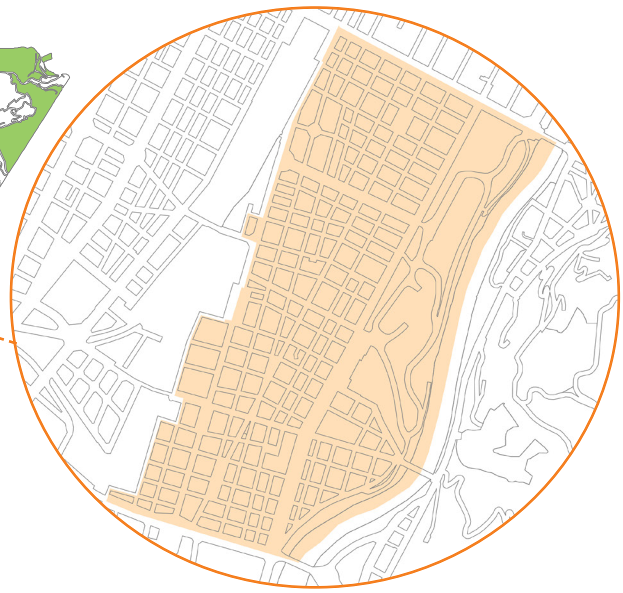

Figure 35: Location of San Salvario neighborhood in Turin map
Source: http://geoportale.comune.torino.it/web/

Figure 36: San Salvario neighborhood
Source: http://geoportale.comune.torino.it/web/

3- Application of methodology on case study

By analyzing the availability of data from various and authentic resources, three different categories in terms of gathering Information and impact assessment were considered:
The first category is associated the information that can be directly used. Mostly the resources are geoportale of comune di Torino, Torino atlas and LARTU (Laboratorio di Analisi e Rappresentazioni Territoriali e Urbane) in Polytechnic University of Turin.
The second one are related to the data without any information and there was a necessity of visiting the district. So that, during different months, visiting and obtaining information has been done. Six visiting has been done in March, April, May and August of 2019 to obtain information.
Finally, the third category is information that must have analyzed which means, the basic information exists but is was needed to be analyzed such as Autocad, calculation in ArcGIS and visiting to reach to the specific data.
The process of visualization is that all of the information had been put in the ArcGIS software. In addition, for the Toriono city, it is significant to just keep San Salvario district and delete extra information for the further step.

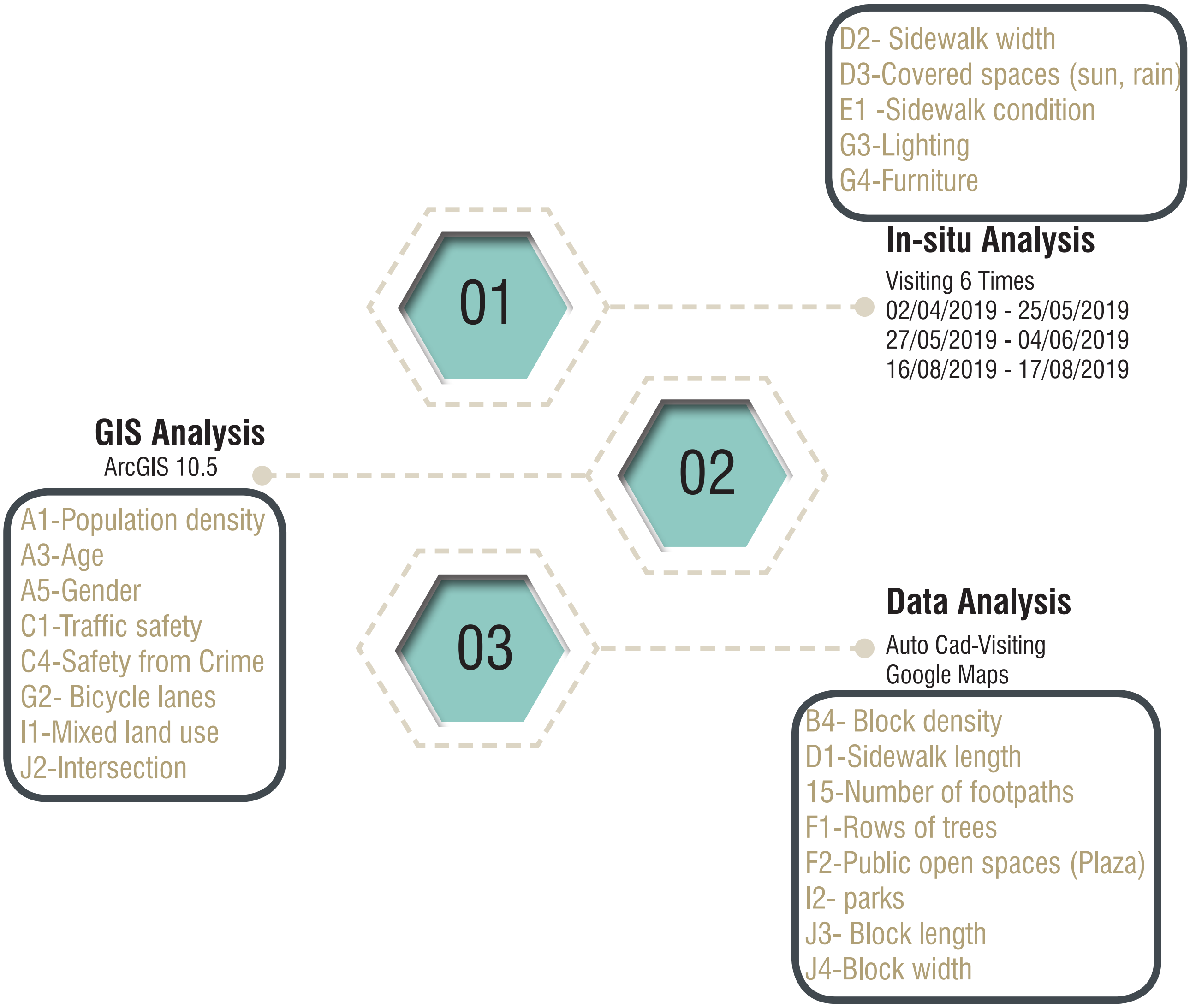

Figure 37: The Indicators in terms of information gathering are divided in three groups
Source: Author elaboration

Number	Category Index	Sub-Category Indicator	Description	Assessment Method	
1	Demographic Characteristic	A1- Population density	A measurement of population per unit area	Total population(Number) Total area (m2)	ArcGIS
2		A2- Employment density			
3		A3- Age density	A measurement of 3 age groups per unit area	Each age group population(Number) Total area (m2)	ArcGIS
4		A4- Education density			
5		A5- Gender density	A measurement of different gender (male and female) per unit area	Each gender population(Number) Total area (m2)	ArcGIS
6	Denisity	B1- Residential density			
7		B2- Net floor area density	The ratio of total net floor area of a building to the total lot area	Total net floor area Total area (m2)	ArcGIS AutoCAD
8		B3- Block density	A quantitative measure of the intensity with which land is occupied by block (surrounded by streets)	Total block area Total area (m2)	ArcGIS AutoCAD
9		B4- Retail density			
10	Secuirity	C1- Traffic safety	Methods and measures used to prevent road users from being killed or seriously injured.	Derived	ArcGIS
11		C2--Vacant building, Abandon building, Undesirable land use		Derived	ArcGIS
12		C3- Riding speed			
13		C4- Safety from Crime	The appraisal of a crime risk and the initiation of action to remove or reduce it.	Derived	ArcGIS
14	Comfort	D1-Sidewalk length	The straight line horizontal measurement of the overall length	Export from ArcGIS to AutoCAD for measuring	ArcGIS AutoCAD
15		D2-Sidewalk width	The straight line vertical measurement of the overall width	In situ Analysis	Visiting
16		D3-Covered spaces (sun, rain)	Covered footpath with roofs, arches and vaults	In situ Analysis	Visiting
17		D4-Parking lots	An area that is intended for parking vehicles	Derived	ArcGIS
18	Accessibility	E1 -Sidewalk condition	Analyzing sidewalk surface and its material condition	In situ Analysis	Visiting
19		E2 -Number of foot paths	Foothpath is a path for pedestrians in a built-up area; a pavement.	Calculation	ArcGIS
20		E3- Network integration in the urban fabric	Directed accessibility of footpaths to other part of the city	Derived	ArcGIS
21		E4 -Proximity to 13 categorie	Nearness to a variety of services and destinations (13 categorie)	Derived	ArcGIS
22	Attractiveness & Aesthetics	F1- F1-Rows of trees	A straight path or road with a line of trees	In situ Analysis - Derived	ArcGIS Visiting
23		F2-Public open spaces (Plaza)	A public square, marketplace, or similar open space in a built-up area	In situ Analysis - Derived	ArcGIS Visiting
24	Pedestrian Infrastructure	G1- Pedestrian slope (Disability)	Exsiting of ramps for passing from one street to reach another strees when two streets are intersecting	Derived from ArcGIS	ArcGIS
25		G2- Bicycle lanes	The lanes on the roadway for cyclists only	Derived	ArcGIS
26		G3- Lighting	A light illuminating a road, typically mounted on a tall post.	In situ Analysis	Visiting
27		G4-Furniture	placed or fixed in the street for public use	In situ Analysis	Visiting
28	Climatic and Environmental Factors	H1- Windy climate, Rainy climate (Climate comfort for the path)			
29	Land Use Mix	I1- Mixed land use	is a classification providing information on land cover, and the types of human activity involved	Derived	ArcGIS
30		I2- parks	A large public garden or area of land used for recreation	In situ Analysis - Derived	ArcGIS Visiting
31		J1- Continuity of walking path	A passage for walking that is not closed	In situ Analysis - Derived	ArcGIS Visiting
32	Street Connectivity	J2- Intersection	An intersection is a point where two streets cross	Derived	ArcGIS
33		J3- Block Length	The length distance measured along all that part of one side of a street which is between two intersecting or intercepting streets	Export from ArcGIS to AutoCAD for measuring	ArcGIS AutoCAD
34		J4-Block Width	The width distance measured along all that part of one side of a street which is between two intersecting or intercepting streets	Export from ArcGIS to AutoCAD for measuring	ArcGIS AutoCAD
35		J5-Public transportation	Buses, trains that are available to the public, charge set fares and run on fixed routes	Derived	ArcGIS Google map
36		J6-Modal distribution	The stations of taxi and different type of car sharing	Derived	ArcGIS
37	Economy	Home values	The worth of a piece of real estate based on the price that a buyer and seller agree upon	Cartography	ArcGIS

Table 10: Analysis of indicator feasibility
Source: Author elaboration

Type: Qualitative vs Quantitative	Parameters	Easiness of Data Access	Data Source	Year	Main identified Problems
Quantitative	population -Total Area	Easy	http://geoportale.comune.torino.it/web/	2016	N
Quantitative	3 age groups (0-14, 15-64, >65) - Total Area	Easy	http://geoportale.comune.torino.it/web/	2016	N
Quantitative	3 gender groups (males-female) - Total Area	Easy	http://geoportale.comune.torino.it/web/	2016	N
Quantitative	Neat floor area of each building - Total Area	Difficult	Lartu	2017	Gaining the parameters needed the calculation of the net floor area for existing buildings is high effort on district scale
Quantitative	Neat floor area of each building -Total Area	Medium	http://geoportale.comune.torino.it/web/	2017	In the scale of neighborhood, calculation of each block can be long-lasting
Qualitative	5 traffic levels groups (very smooth, fairly smooth, quite slowed down, very slow)	Easy	http://www.urbancenter.to.it/category/torino-atlas/	2016	N
Quantitative	Devided lands into 2 groups (Land with functions, Vacant and abandoned lands)	Easy	Lartu	2010	N
Quantitative	Pickpocketing- Thef- Robberies	Medium	http://www.urbancenter.to.it/category/torino-atlas/	2010	Accessign to up-dated information is inevitably hard.
Quantitative	Deviding Length street into 5 different categories (< 100, 100-500, 501-1000, 1001-2000, >2000)	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Deviding Length street into 3 differen (1-2, 2.1-3, >3)	Difficult	visitng	2019	The application is only possible by visitng and directed visiting due to the fact that there was not any information.
Quantitative	_	Easy	visitng	2019	N
Quantitative	Deviding the capacity of parking into two groups (250-500, >500)	Easy	https://www.google.com/maps/ http://geoportale.comune.torino.it/web/	2019	N
Qualitative	Each pathway segment is assigned a rating using a 5-level system (very good, good, fair, poor, very poor)	Medium	1- Pathway Asset Management Plan 2017, Strategic Asset Management Team, July 2017 2- Visiting	2019	Visiting the scale of neighborhood for assessing the sidewalk condition is high effort on distrcit scale.
Quantitative	Counting the number of footpaths	Easy	http://geoportale.comune.torino.it/web/ https://www.openstreetmap.org/	2019	N
Quantitative	The streest which are Connceted city with other roads out of distrcit	Easy	http://geoportale.comune.torino.it/web/ https://www.google.com/maps/	2019	N
Quantitative	1- grocery store, 2-coffee shop, 3-movie theater, 4- park, 5-bookstore, 6- drug store, 7-clothing and music store, 8-restaurant, 9- bar, 10- school, 11- library, 12-fitness, 13-hardware store)	Easy	http://geoportale.comune.torino.it/web/ https://www.google.com/maps/	2019	N
Quantitative	Counting the number of streets which have rows of trees (Plant, Empty Plant Space, Stump)	Easy	http://geoportale.comune.torino.it/web/ visitng	2019	N
Quantitative	Counting the number of streets which have direct relationship with plazas	Easy	https://www.google.com/maps/ visitng	2019	N
Quantitative	Rmaps- Slopes	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	On road cycle-lane	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Benches, Sitting Area	Easy	Visitng	2019	N
Quantitative	Street lamp-Lmappost	Medium	Visitng	2019	Visiting the scale of neighborhood for assessing the availability of furnitures is high effort on distrcit scale.
Quantitative	Specifying the function of land	Easy	Lartu Visitng	2010	N
Quantitative	The streest which are directly Connceted to the parks	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Identifying the streets which are not deadend	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Counting the number of Intersection in each street	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Measuring the Length of each block in AutoCAD	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Measuring the width of each block in AutoCAD	Easy	http://geoportale.comune.torino.it/web/	2019	N
Quantitative	Metro and Bus Stations	Easy	http://geoportale.comune.torino.it/web/ https://www.google.com/maps	2019	N
Quantitative	Taxi stop areas-Car sharing	Easy	http://geoportale.comune.torino.it/web/ https://www.google.com/maps	2019	N
Quantitative	The medium price of homes in 2 categories (Residential and New/Completely Renovated Residential Segment) in 3 aggregates	Easy	http://www.oict.polito.it/en/microzones_and_values	2017	N

Table 10: Analysis of indicator feasibility
Source: Author elaboration

ArcGIS Model

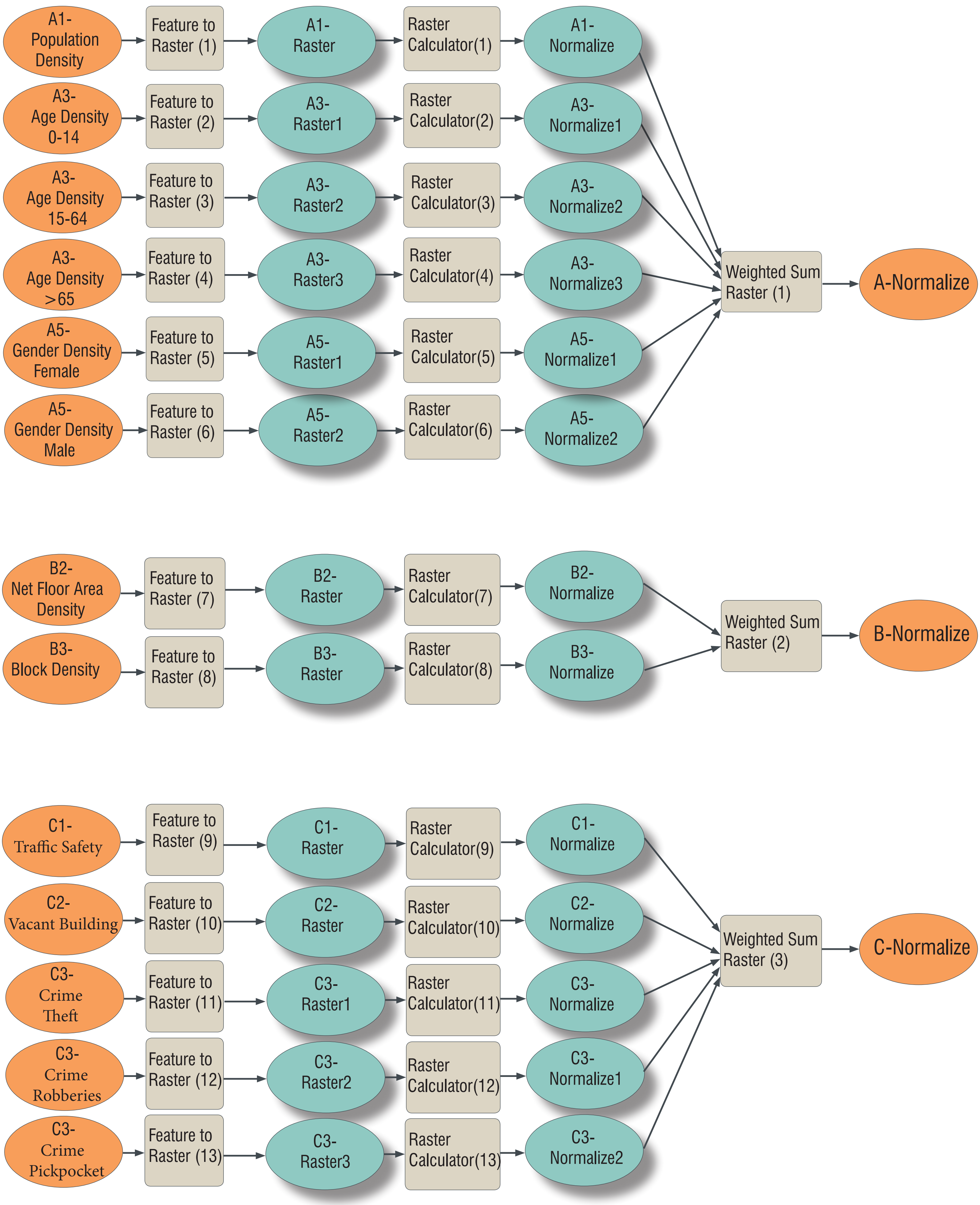

Figure 38: ArcGIS model
Source: Author elaboration

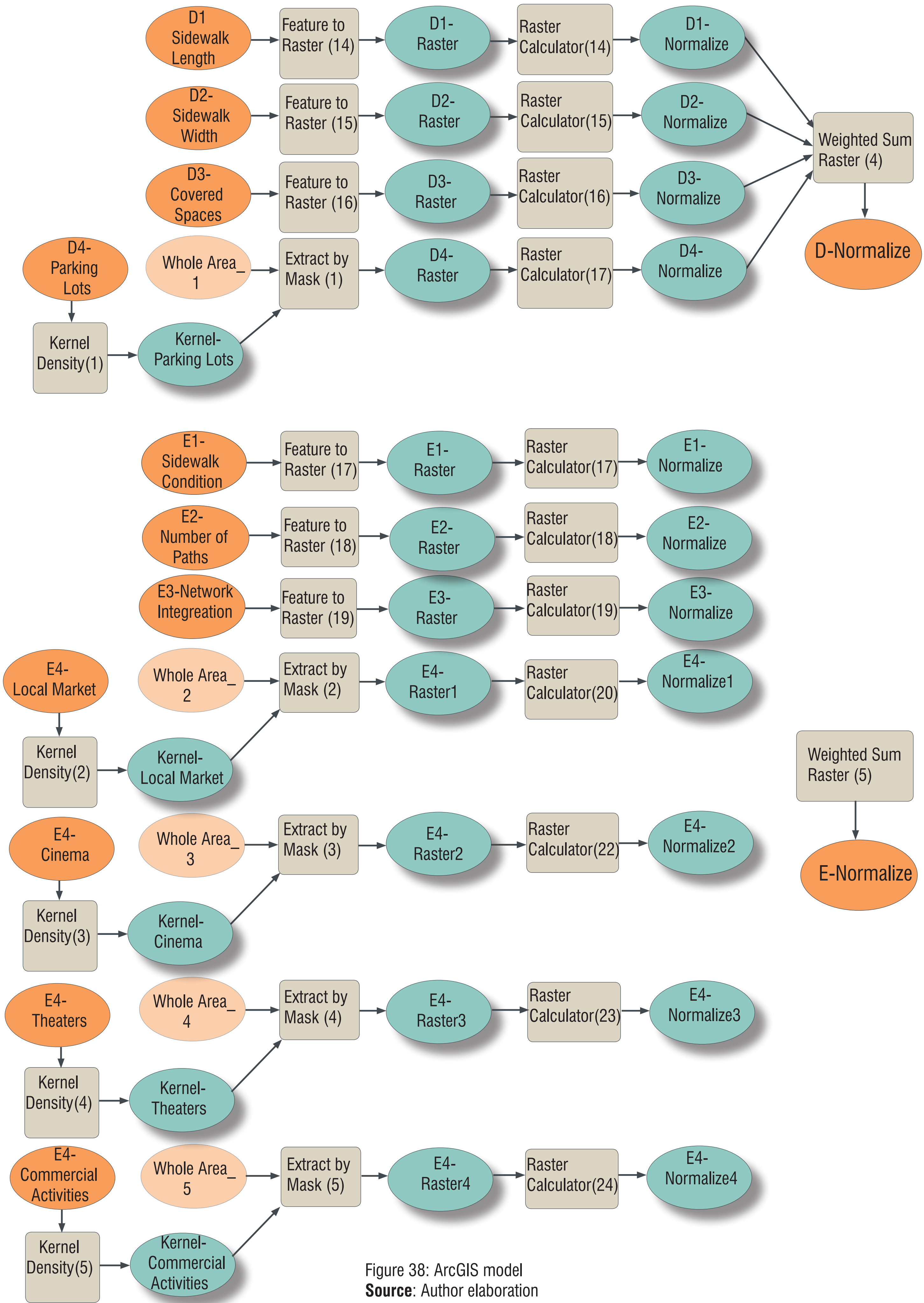

Figure 38: ArcGIS model
Source: Author elaboration

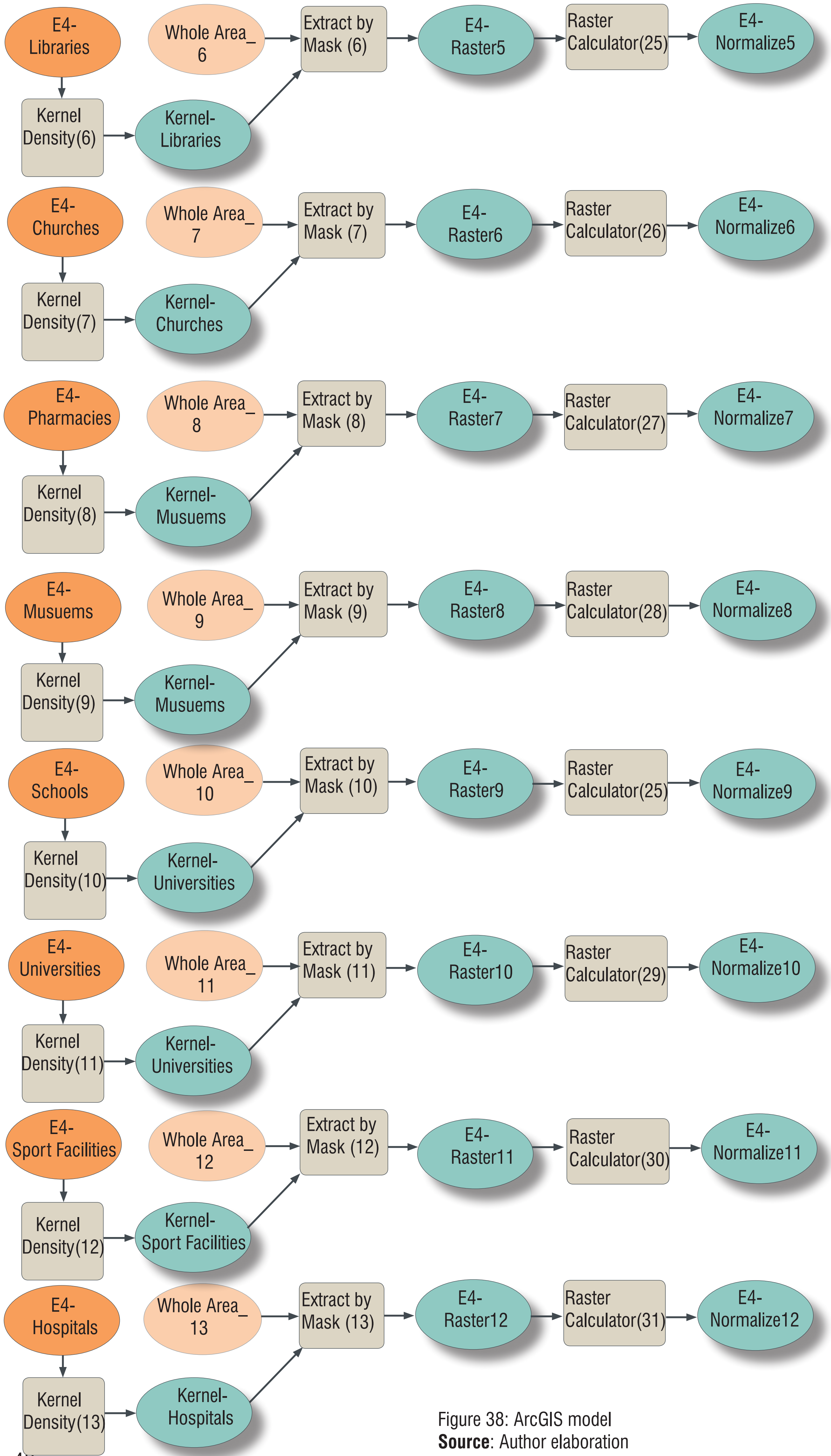

Figure 38: ArcGIS model
Source: Author elaboration

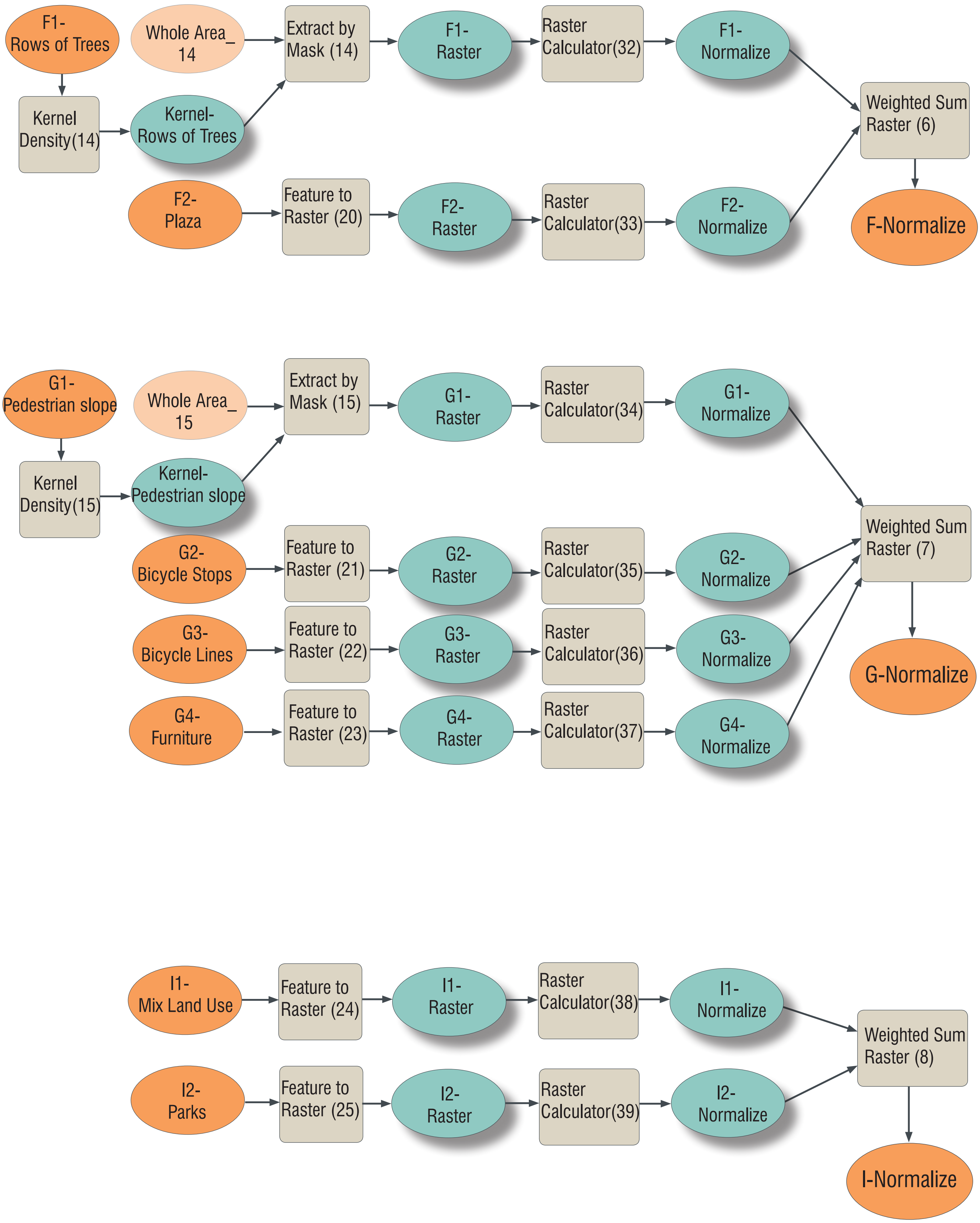

Figure 38: ArcGIS model
Source: Author elaboration

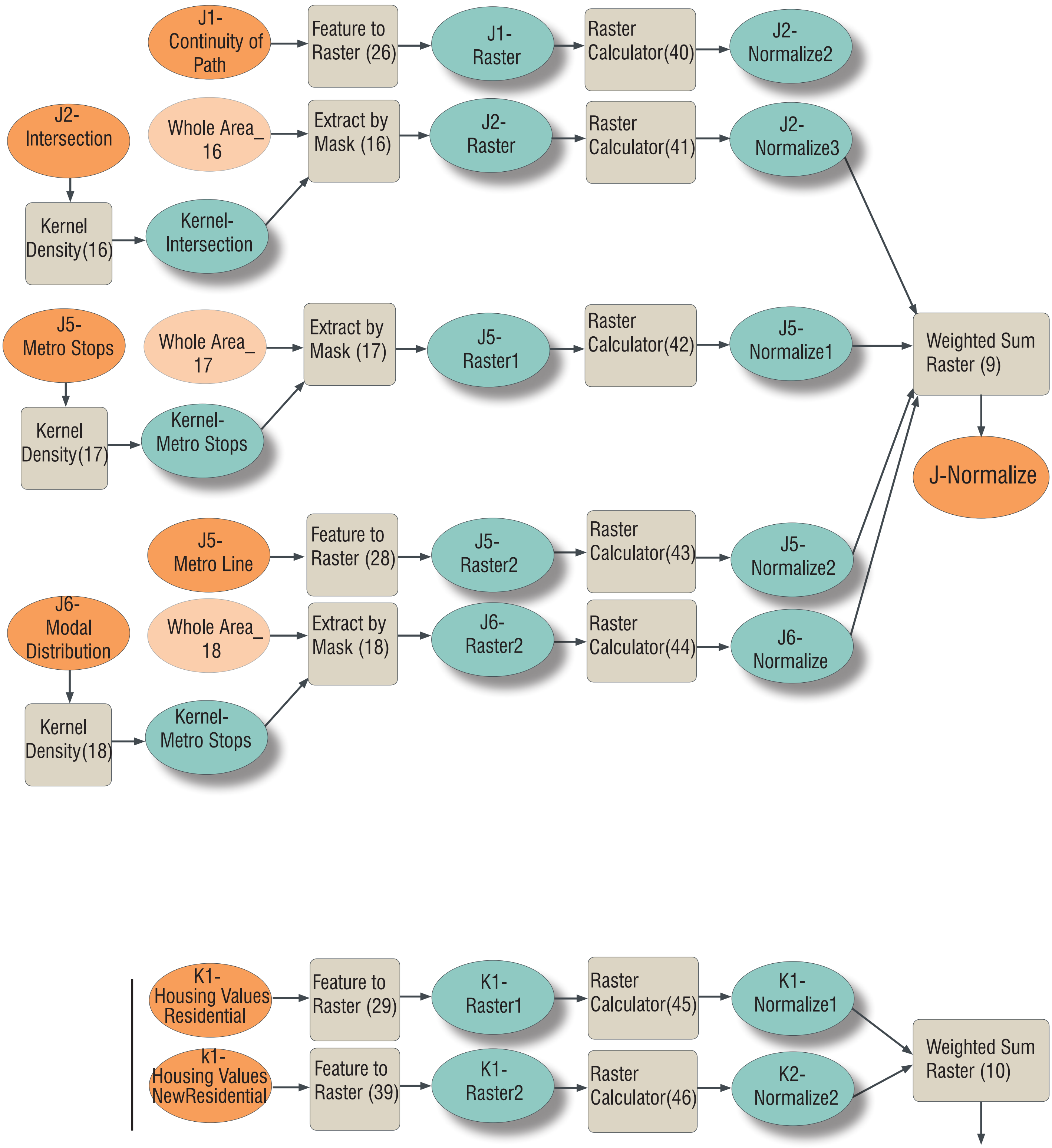

Figure 38: ArcGIS model
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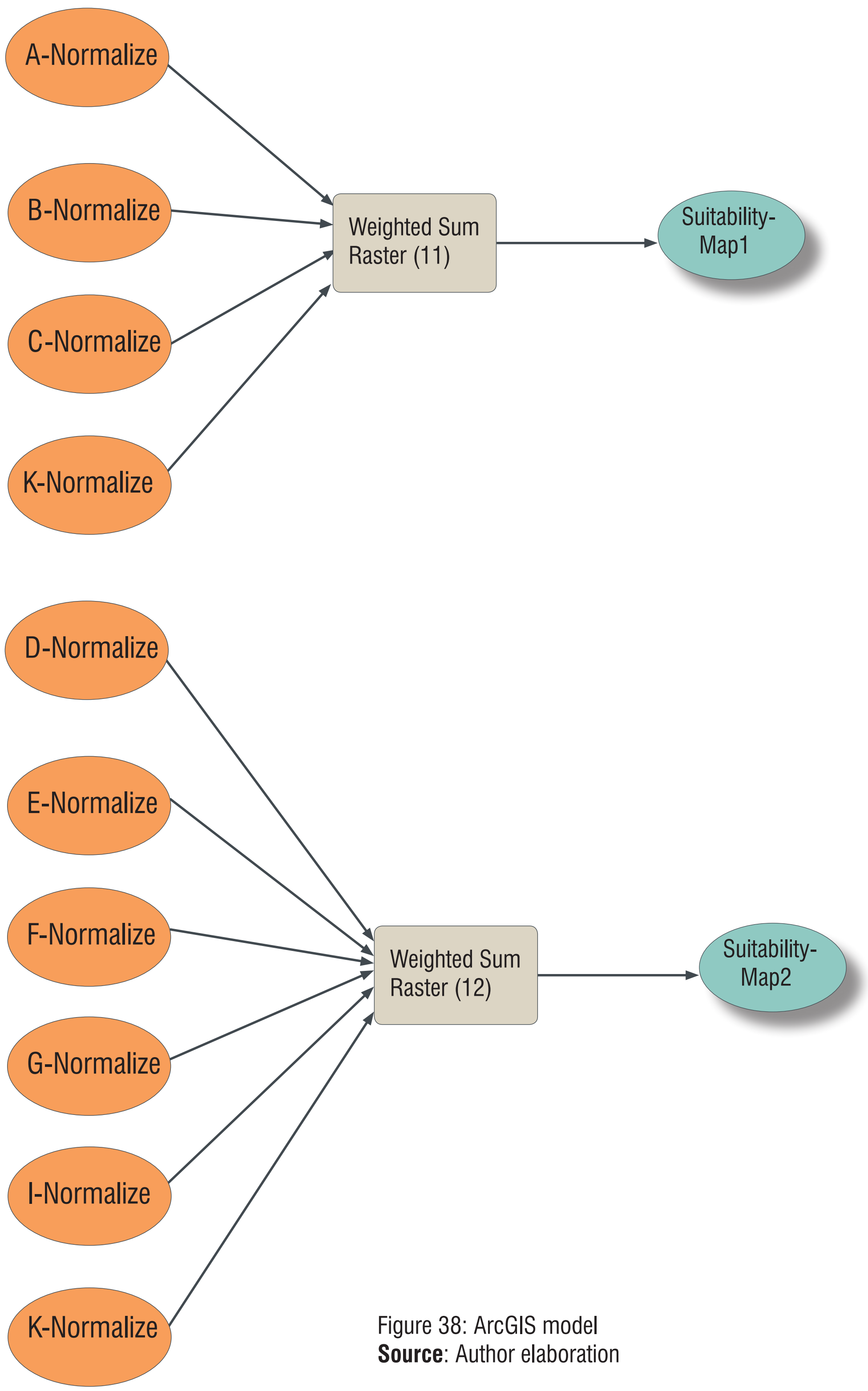


Figure 38: ArcGIS model
Source: Author elaboration

Impact Assessments

In this part, all of the indicators have been investigated respectively. For each indicator, information visualized by ArcGIS with the limitation of San Salvario map. Due to the characteristic of Turin city's map that has made of grid, analyzing different streets are important. All of the streets in this strict have direct connection to each other and there is just one dead-end street in this neighborhood. For each map, all of the calculation are showing beside the map with related specific images. The red indicators are those which the information have not found by author (table 8: The highest relevant indicators)

A-Demographic Characteristics

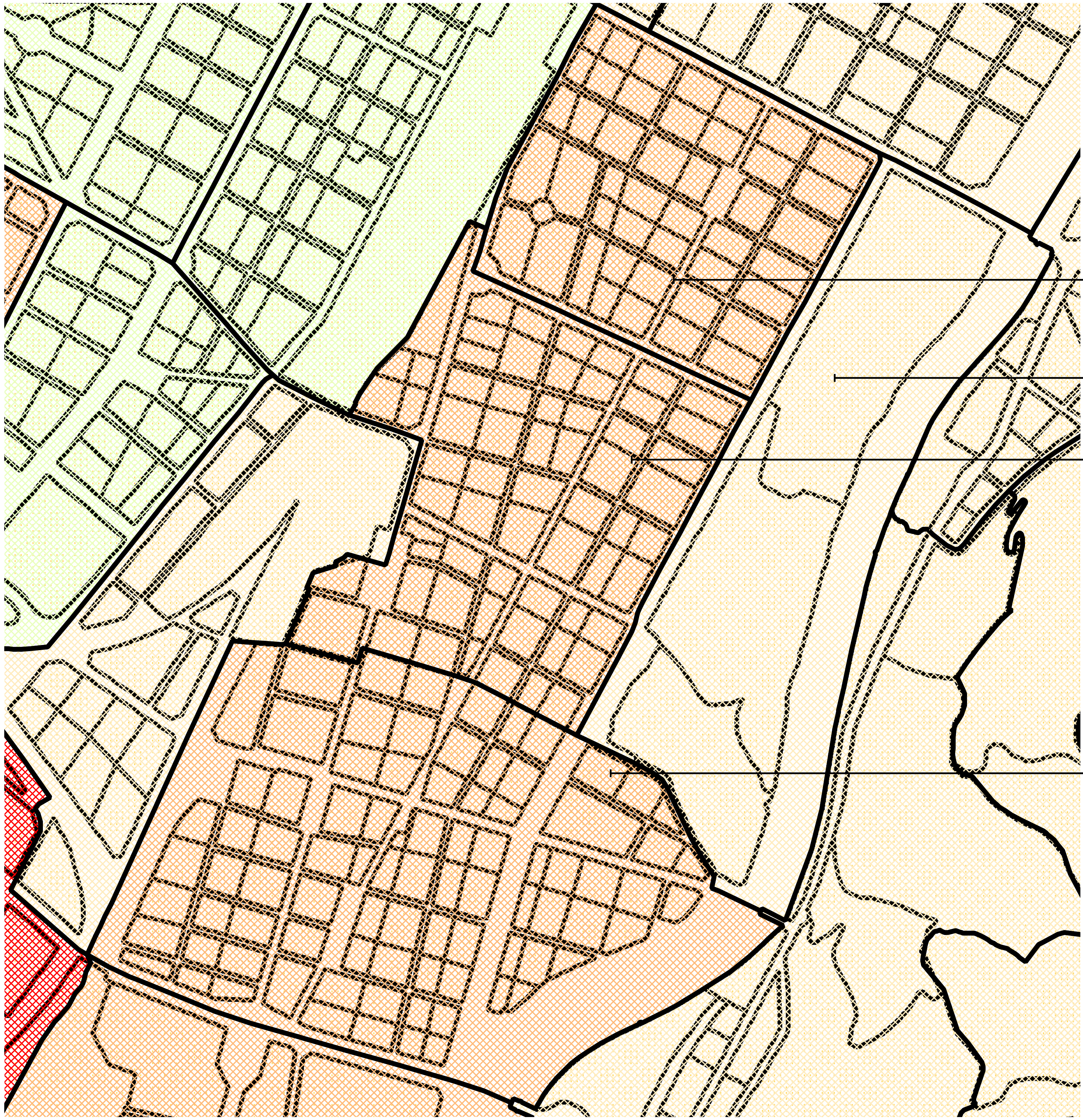
A1: Population Density

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2016

Assessment Method: $\frac{\text{Total population(Number)}}{\text{Total area (m2)}}$ - ArcGIS



Density of Poulation in San Salvario: $\frac{\text{San Salvario Population}}{\text{Total San Salvario Area}} = \frac{36376}{2460000} = 1.5\% \frac{\text{Res}}{\text{M}^2}$

11170

21

10627

14558

San Salvario Population: 36376

San Salvario Area: 246 Ha

Number of Turin Population Residence

- 1-5000
- 5001-10000
- 10001-15000
- 15001-20000
- >2001

Total Population in Turin: 888921

Map 1: Population density

A-Demographic Characteristics

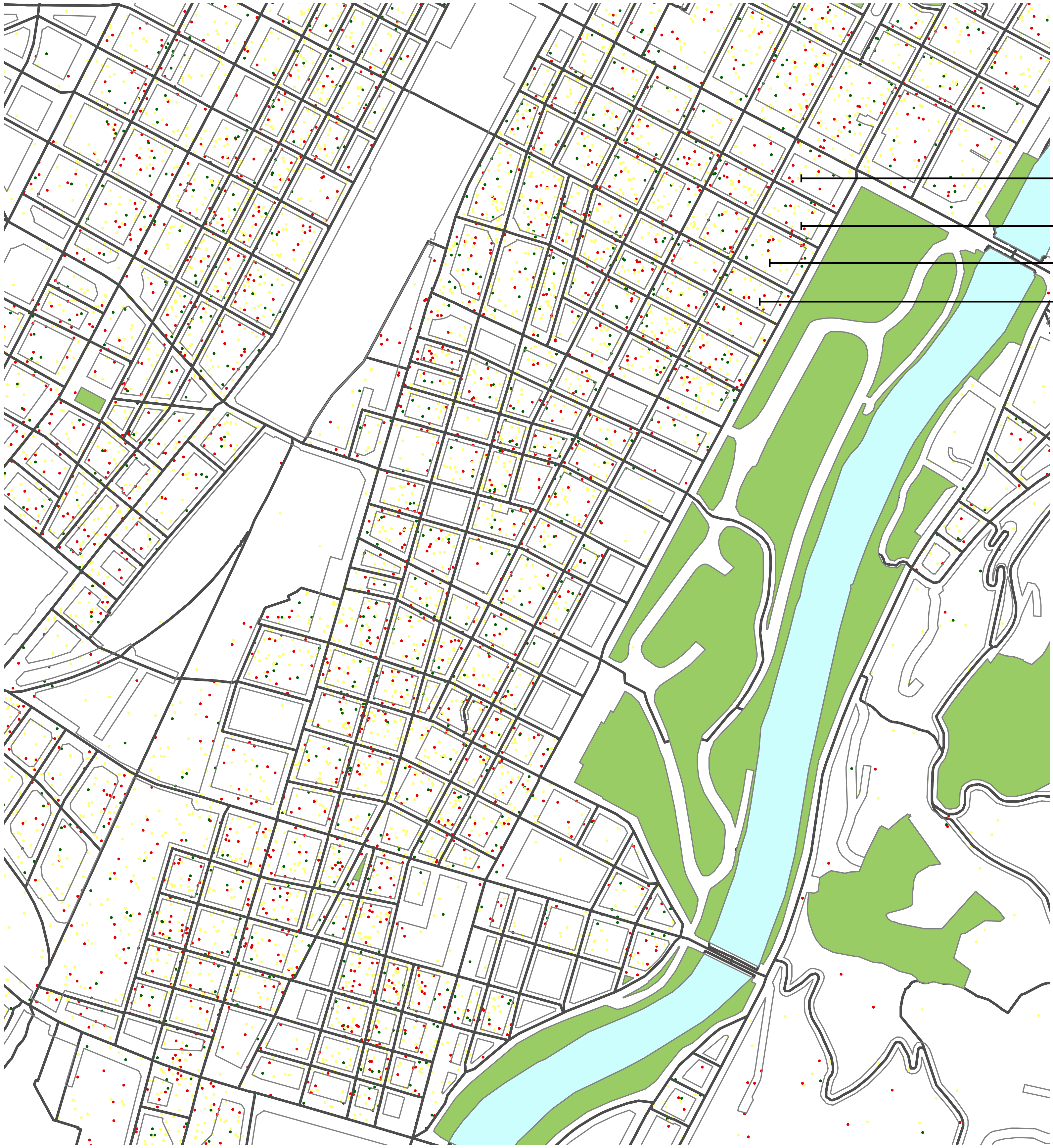
A3: Age Density

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2016

Assessment Method: $\frac{\text{Each age group population(Number)}}{\text{Total area (m2)}}$ - ArcGIS



Map 2: Age density

Age 0-14: 13, Age 15-64: 91, Age >65: 73

Age 0-14: 37, Age 15-64: 122, Age >65: 56

Age 0-14: 45, Age 15-64: 192, Age >65: 57

Age 0-14: 38, Age 15-64: 202, Age >65: 58

- Age 0-14: 4162 People in San Salvario
- Age 15-64: 22250 People in San Salvario
- Age >65: 8423 People in San Salvario

Density of Age 0-14 Poulation in San Salvario: $\frac{\text{Age 0-14 Population}}{\text{Total San Salvario Area}} = \frac{4162}{246000} = 0.20\% \frac{\text{Res}}{M^2}$

Density of Age 15-64 Poulation in San Salvario: $\frac{\text{Age 15-64 Population}}{\text{Total San Salvario Area}} = \frac{22250}{2460000} = 0.90\% \frac{\text{Res}}{M^2}$

Density of Age >65 Poulation in San Salvario: $\frac{\text{San Salvario Population}}{\text{Total San Salvario Area}} = \frac{8423}{2460000} = 0.40\% \frac{\text{Res}}{M^2}$

1 Dot: 8 People

A-Social Demographic Factors

A5: Gender Density

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2016

Assessment Method: $\frac{\text{Each gender population(Number)}}{\text{Total area (m2)}}$ - ArcGIS

Map 3: Gender density

Density of male Poulation in San Salvario: $\frac{\text{San Salvario Male Population}}{\text{Total San Salvario Area}} = \frac{16492}{2460000} = 0.7\% \frac{\text{Res}}{\text{M}^2}$

Density of Female Poulation in San Salvario: $\frac{\text{San Salvario Female Population}}{\text{Total San Salvario Area}} = \frac{19097}{2460000} = 0.8\% \frac{\text{Res}}{\text{M}^2}$

B- Density

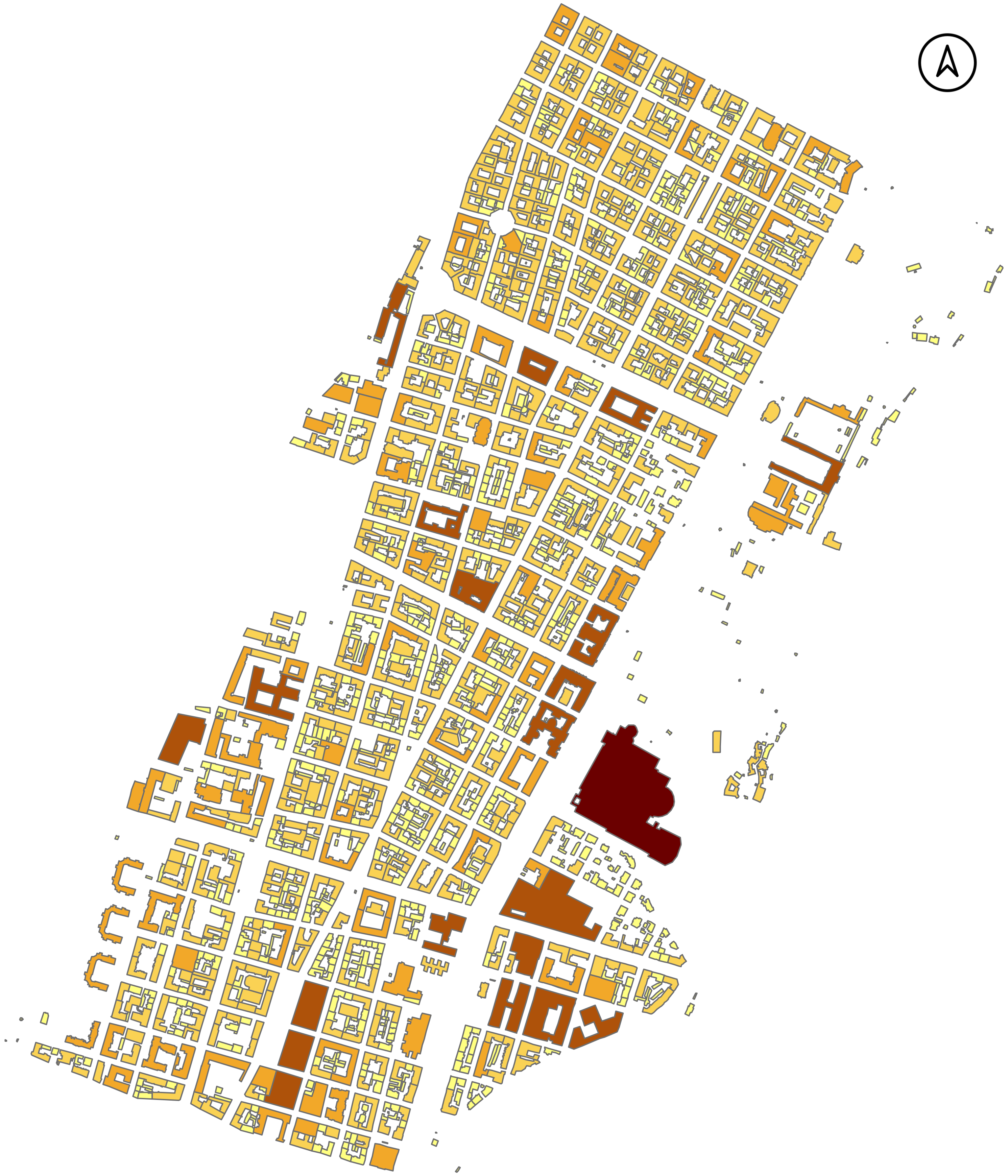
B2: Net Floor Area Density

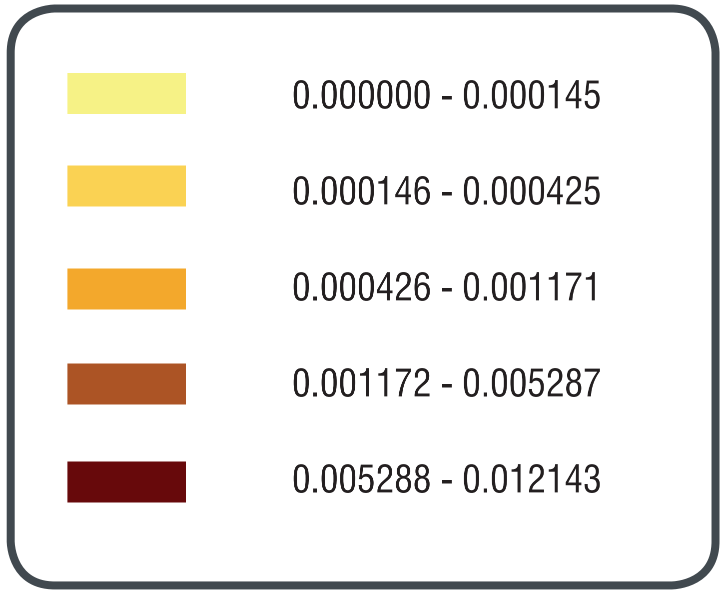
-Quantitative

Source of Data: Lartu

Date: 2017

Assessment Method: $\frac{\text{Total net floor area}}{\text{Total area (m2)}}$ - ArcGIS - AutoCAD





Map 4: Net floor area

B- Density

B3: Block Density

-Quantitative

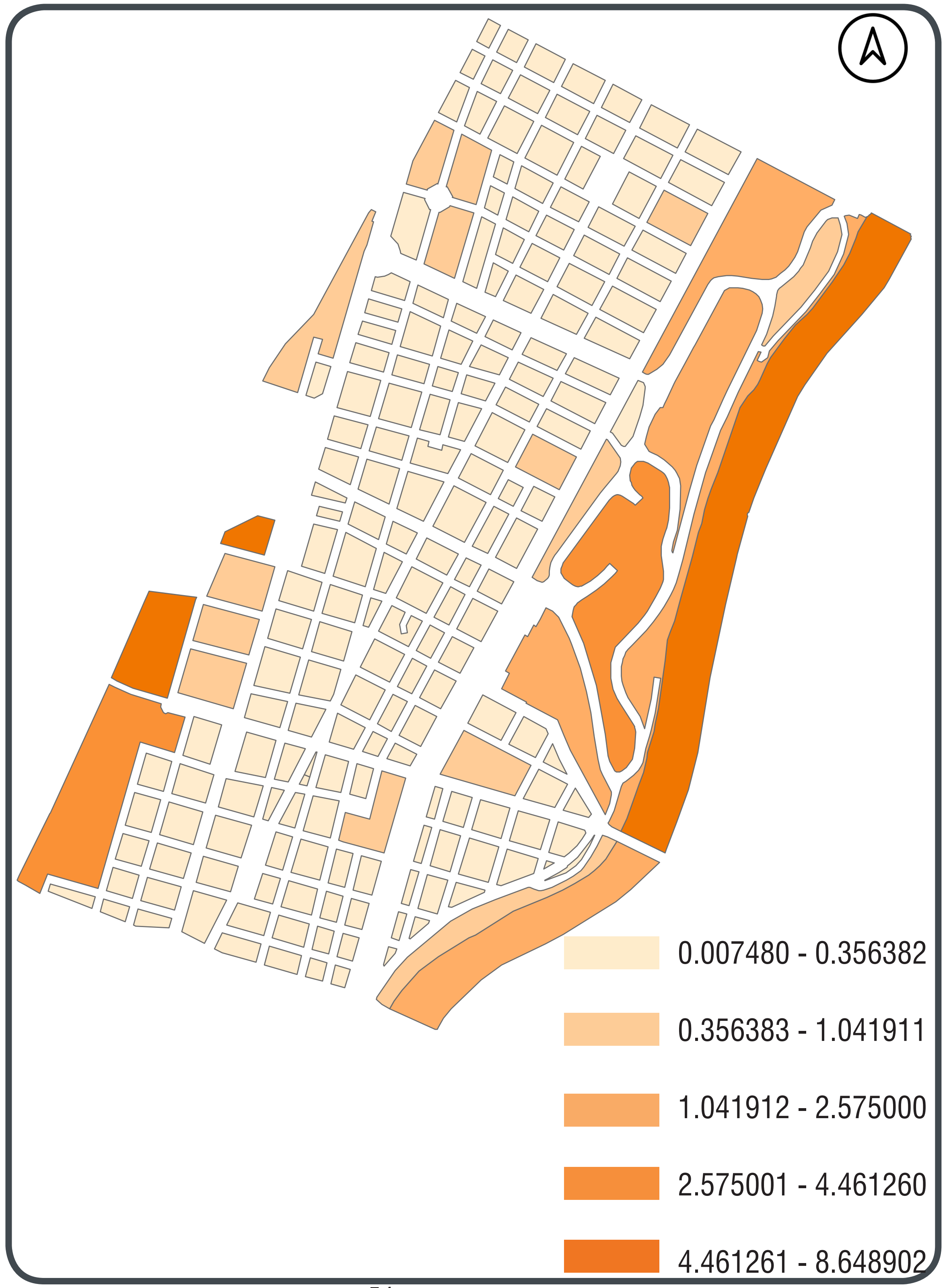
Source of Data: http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: $\frac{\text{Total block area}}{\text{Total area (m2)}}$ - ArcGIS - AutoCAD

Map 5: Area

Density of Block in San Salvario: $\frac{\text{San Salvario Block Area}}{\text{Total San Salvario Area}}$



Map 6: Block density

C- Security

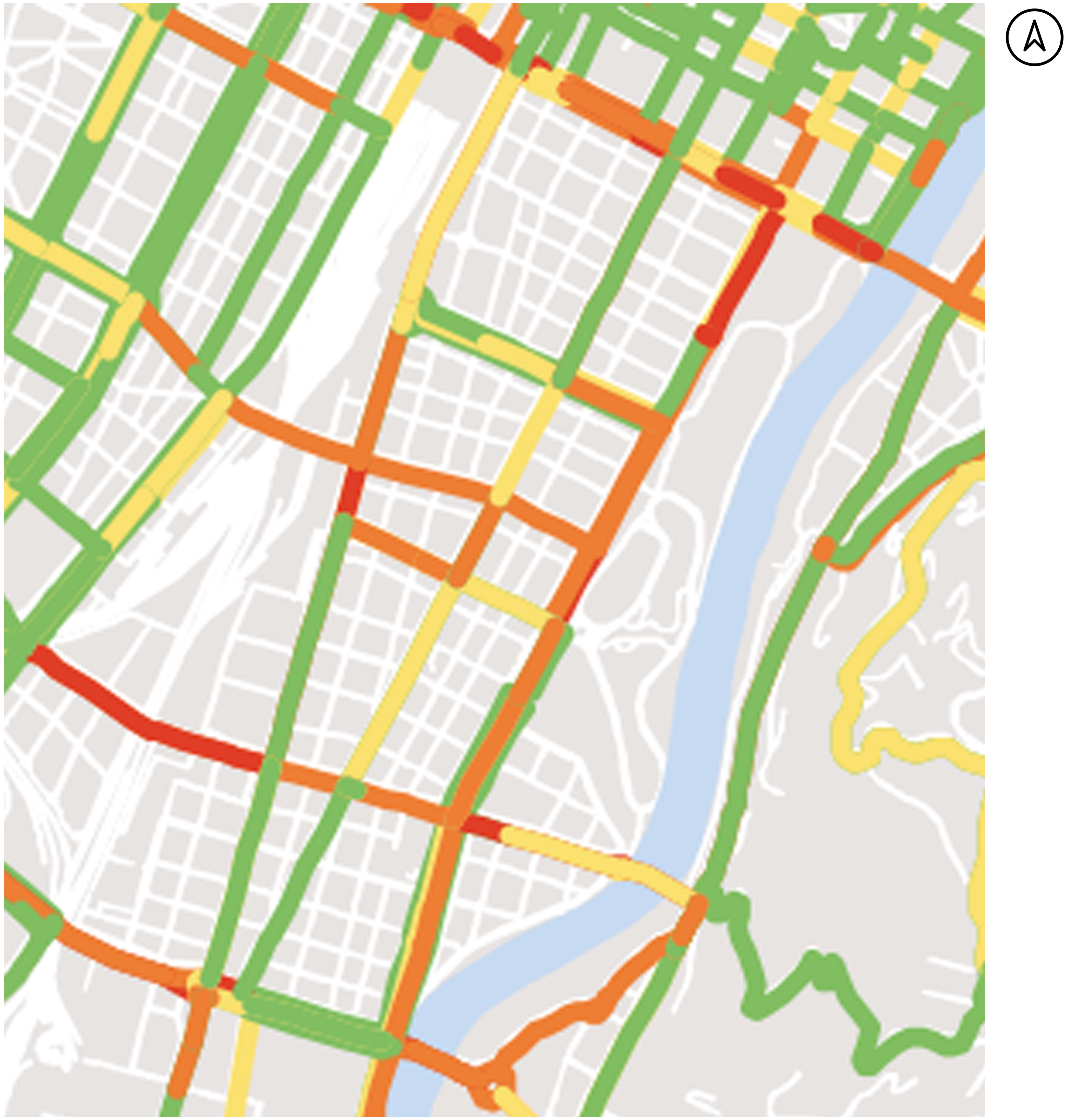
C1-Traffic safety

-Quantitative

Source of Data: http://www.urbancenter.to.it/category/torino-atlas/

Date: 2016

Assessment Method: Derived from ArcGIS



Map 7: Traffic levels

Traffic Levels

- Very smooth
- Fairly smooth
- Quite slowed down
- Very slow

C- Security

C2-Vacant building, Abandon building, Undesirable land use

-Quantitative

Source of Data: Lartu

Date: 2010

Assessment Method: Derived from ArcGIS

Map 8: Vacant buildings

Vacant and abandoned lands

Land with functions

C- Security

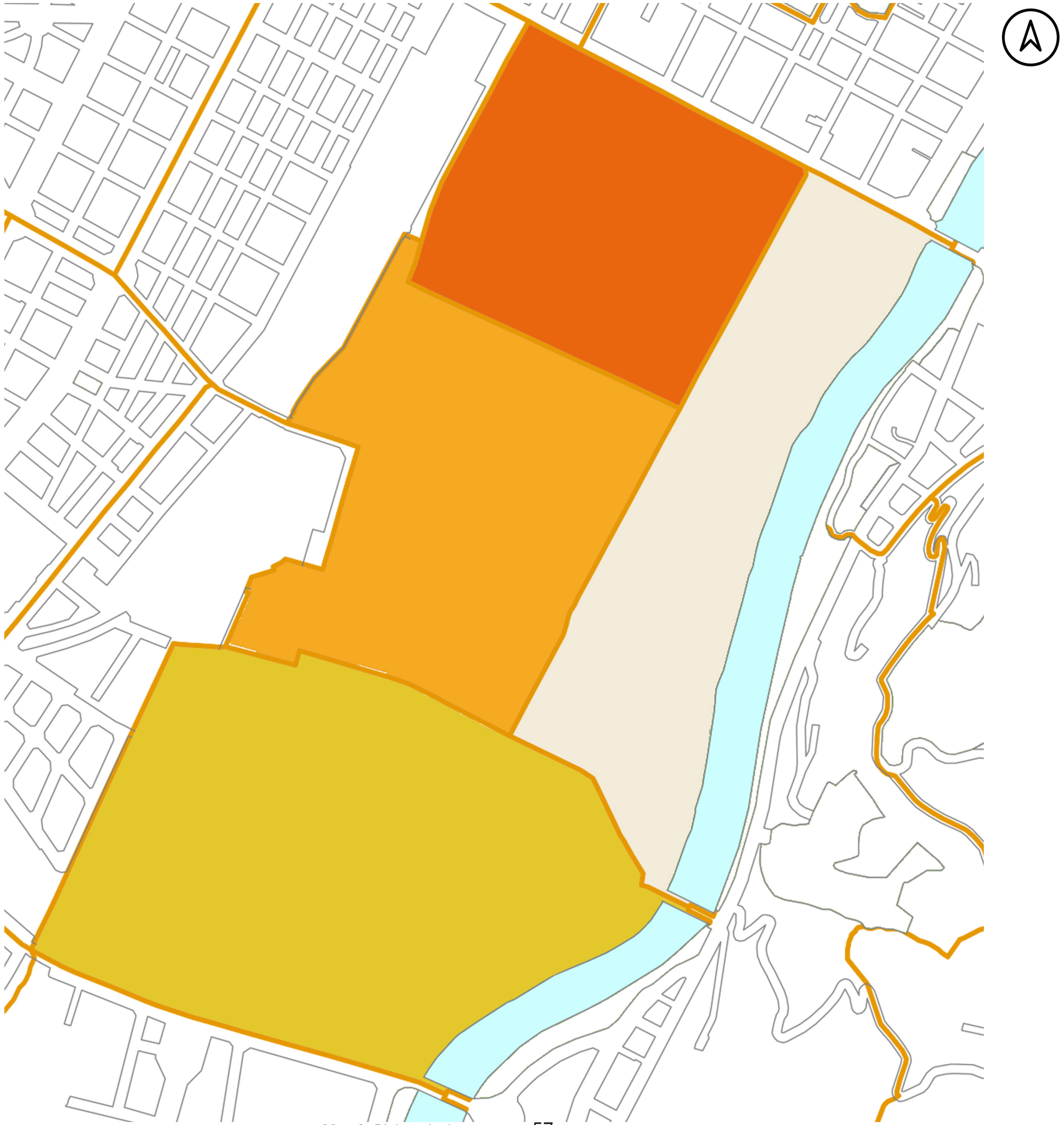
C4-Safety from Crime

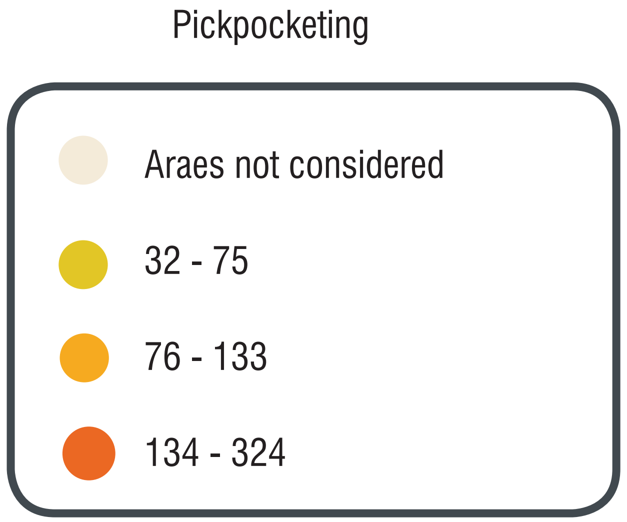
-Quantitative

Source of Data: http://www.urbancenter.to.it/category/torino-atlas/

Date: 2010

Assessment Method: Derived from ArcGIS





Map 9: Pickpocketing

C- Security

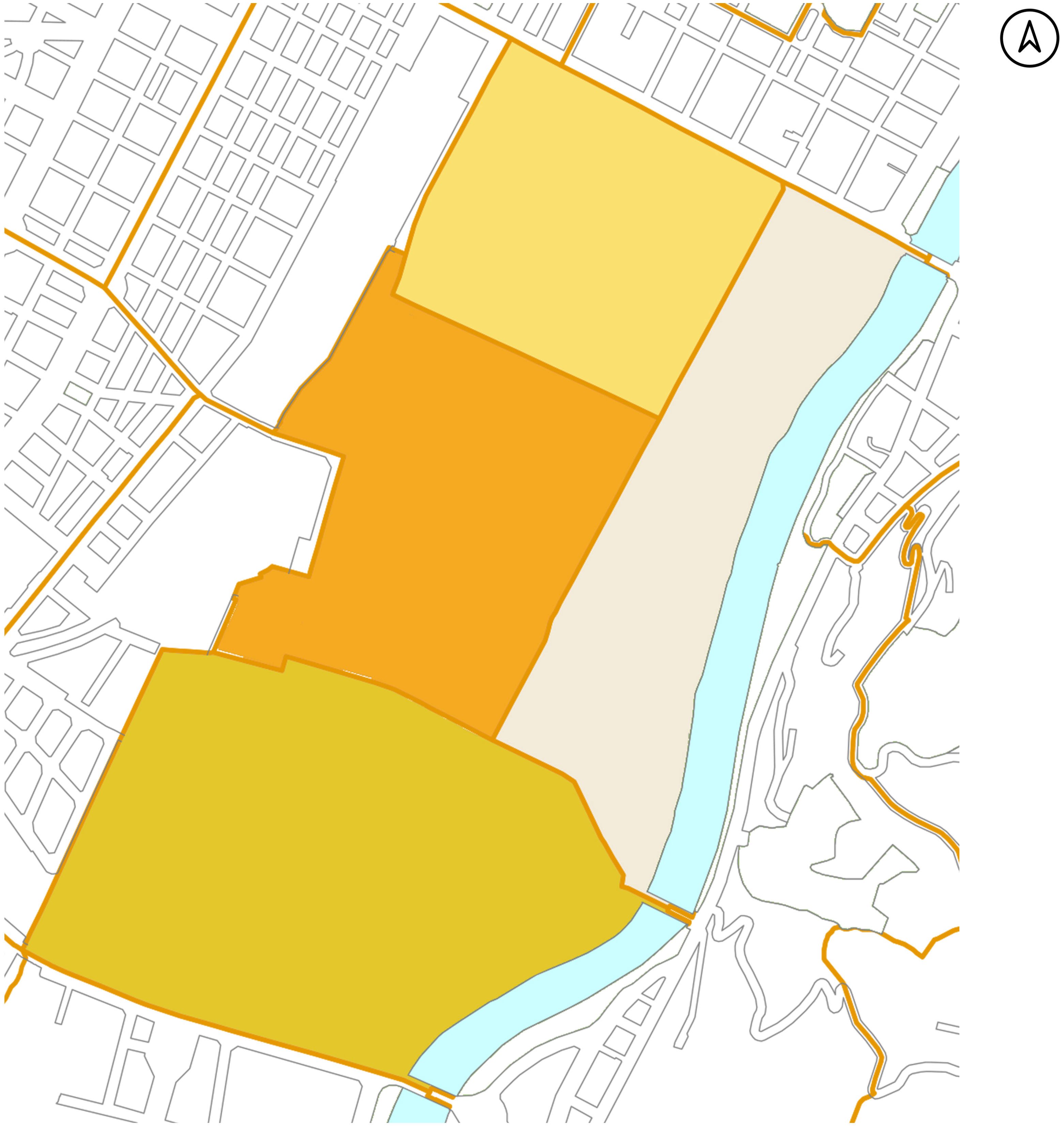
C4-Safety from Crime

-Quantitative

Source of Data: http://www.urbancenter.to.it/category/torino-atlas/

Date: 2010

Assessment Method: Derived from ArcGIS



Map 10: Theft

Theft

- Araes not considered
- 0 - 97
- 98 - 271
- 272 - 446

C- Security

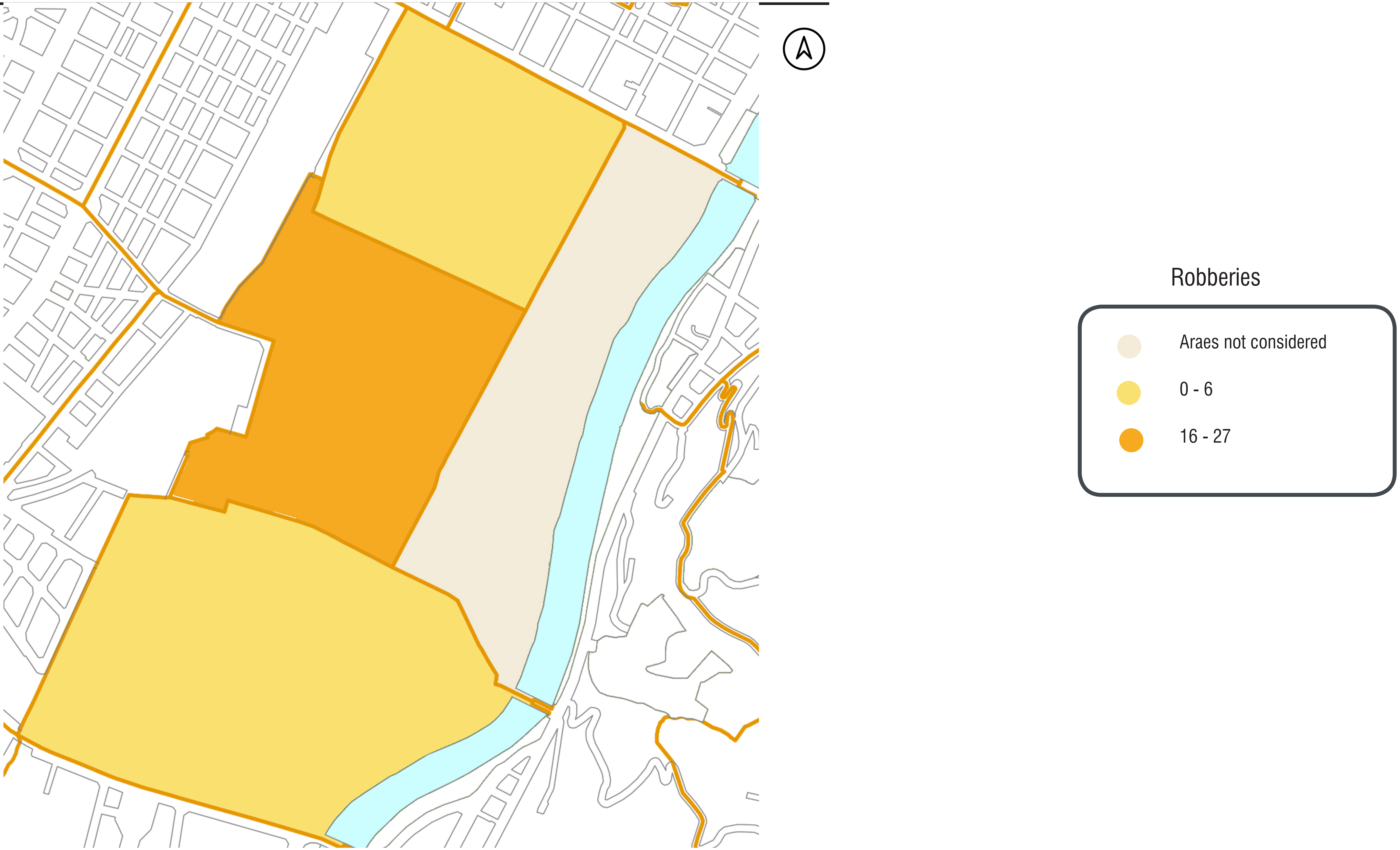
C4-Safety from Crime

-Quantitative

Source of Data: http://www.urbancenter.to.it/category/torino-atlas/

Date: 2010

Assessment Method: Derived from ArcGIS



Map 11: Robberies

D- Comfort

D1-Sidewalk length

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: Export from ArcGIS to AutoCAD for measuring

Map 12: Sidewalk length

1	Corso Bramante	730.7m
2	Via Luigi Federico Menabrea	398.6m
3	Via Benevuto Cellini	726.1m
4	Via Antonio Canova	782.5m
5	Via Tiziano Vecellio	908.7m
6	Via Ilarione Petitti	553m
7	Corso Dante Alighieri	982.8m
8	Via Ugo Foscolo	411m
9	Via Vicenzo Monti	754.5m
10	Via Frencesco Petrarca	710.8m
11	Via Gaetano Donizetti	447.8m
12	Via Michelangelo Buonarroti	741.9m
13	Corso Raffaello	506.6m
14	Via Giorgio Bidone	528.5m
15	Via Valperga Caluso	545.1m
16	Via Oddino Morgari	567.8m
17	Via Federico Campana	581.5m
18	Via Giuseppe Giacosa	598m
19	Corso Guglielmo Marconi	574.5m
20	Via cesare Lombroso	383m
21	Via Giuseppe Baretti	643.5m
22	Via Silvio Pellico	471.3m
23	Via Claudio Luigi Berthollet	652.4m
24	Via Bernardino Galliari	652.8m
25	Via San Pio V	611.5m
26	Corso Vittorio Emanuel 2	653.4m
27	Via Edoardo Calvo	55.4m
28	Via Conte Emanuele Theasuro	79.5m
29	Via Leonardo da Vinici	47.1m
30	Via Correggio	329.9m
31	Via Pio Foa	320.9m
32	Via Ormea	2150.5m
33	Via Giotto	501.3m
34	Via Madama Cristina	1971.9m
35	Via Nizza	2114.4m
36	Via Tommaso Grossi	539.8m
37	Via Ludovico Antonio Murato	399m
38	Via Pietro Giuria	872.5m
39	Vi Belfiore	1143.6m
40	Via Saluzzo	1896.3m
41	Via Principe Tommaso	924.9m
42	Via Sant Anselmo	563.4m
43	Corso Massimo d Azeglio	2126.6m
44	Via Gian Battista Tiepolo	198.8m
45	Via Carlo Marenco	348.7m
46	Via Gabriele Chiabrera	255.9m
47	Via Carlo Morachetti	350.4m
48	Piazza De Amicis	95.9m
49	Piazzetta Primo Levi	41.7m
50	Piazza Arturo Graf	200.5m
51	Corso Calileo Galilei	875.9m

5	< 100: 9.8%
13	100-500: 25.4%
27	501-1000: 53%
3	1001-2000: 5.9%
3	>2000: 5.9%

D- Comfort

D2-Sidewalk width

-Quantitative

Source of Data: Visiting

Date: 2019

Assessment Method: In situ Analysis

Map 13: Sidewalk width

1	Corso Bramante	3m
2	Via Luigi Federico Menabrea	1.5m
3	Via Benevuto Cellini	1.5m
4	Via Antonio Canova	1.5m
5	Via Tiziano Vecellio	1.5m
6	Via Ilarione Petitti	1.5m
7	Corso Dante Alighieri	2m
8	Via Ugo Foscolo	1.5m
9	Via Vicenzo Monti	1.5m
10	Via Frencesco Petrarca	1.5m
11	Via Gaetano Donizetti	1.5m
12	Via Michelangelo Buonarroti	1.5m
13	Corso Raffaello	2.5m
14	Via Giorgio Bidone	1.5m
15	Via Valperga Caluso	1.5m
16	Via Oddino Morgari	1.5m
17	Via Federico Campana	1.2m
18	Via Giuseppe Giacosa	1.5m
19	Corso Guglielmo Marconi	2.2m
20	Via cesare Lombroso	1.5m
21	Via Giuseppe Baretti	1.5m
22	Via Silvio Pellico	1.5m
23	Via Claudio Luigi Berthollet	2m
24	Via Bernardino Galliari	2m
25	Via San Pio V	1.5m
26	Corso Vittorio Emanuel 2	3.5m
27	Via Edoardo Calvo	1.5m
28	Via Conte Emanuele Theasuro	1.5m
29	Via Leonardo da Vinici	1.5m
30	Via Correggio	1.5m
31	Via Pio Foa	1.5m
32	Via Ormea	1.5m
33	Via Giotto	1.5m
34	Via Madama Cristina	2m
35	Via Nizza	2.5m
36	Via Tommaso Grossi	1.2m
37	Via Ludovico Antonio Murato	1.5m
38	Via Pietro Giuria	1.5m
39	Vi Belfiore	2m
40	Via Saluzzo	2m
41	Via Principe Tommaso	2m
42	Via Sant Anselmo	1.5m
43	Corso Massimo d Azeglio	2.5m
44	Via Gian Battista Tiepolo	1.5m
45	Via Carlo Marenco	1.5m
46	Via Gabriele Chiabrera	1.5m
47	Via Carlo Morachetti	1.2m
48	Piazza De Amicis	_
49	Piazzetta Primo Levi	_
50	Piazza Arturo Graf	_
51	Corso Calileo Galilei	2.5m

41	1-2: 85.5%
6	2.1-3: 12.5%
1	>3: 2%

D- Comfort

D3-Covered spaces (sun, rain)

-Quantitative

Source of Data: Visiting

Date: 2019

Assessment Method: In situ Analysis

Map 14: Covered spaces

1	Corso Bramante	X
2	Via Luigi Federico Menabrea	X
3	Via Benevuto Cellini	X
4	Via Antonio Canova	X
5	Via Tiziano Vecellio	X
6	Via Ilarione Petitti	X
7	Corso Dante Alighieri	X
8	Via Ugo Foscolo	X
9	Via Vicenzo Monti	X
10	Via Frencesco Petrarca	X
11	Via Gaetano Donizetti	X
12	Via Michelangelo Buonarroti	X
13	Corso Raffaello	✓
14	Via Giorgio Bidone	X
15	Via Valperga Caluso	X
16	Via Oddino Morgari	X
17	Via Federico Campana	X
18	Via Giuseppe Giacosa	X
19	Corso Guglielmo Marconi	X
20	Via cesare Lombroso	X
21	Via Giuseppe Baretti	X
22	Via Silvio Pellico	X
23	Via Claudio Luigi Berthollet	X
24	Via Bernardino Galliari	X
25	Via San Pio V	X
26	Corso Vittorio Emanuel 2	✓
27	Via Edoardo Calvo	X
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	X
30	Via Correggio	X
31	Via Pio Foa	X
32	Via Ormea	X
33	Via Giotto	X
34	Via Madama Cristina	X
35	Via Nizza	✓
36	Via Tommaso Grossi	X
37	Via Ludovico Antonio Murato	X
38	Via Pietro Giuria	X
39	Vi Belfiore	X
40	Via Saluzzo	X
41	Via Principe Tommaso	X
42	Via Sant Anselmo	X
43	Corso Massimo d Azeglio	X
44	Via Gian Battista Tiepolo	X
45	Via Carlo Marenco	X
46	Via Gabriele Chiabrera	X
47	Via Carlo Morachetti	X
48	Piazza De Amicis	X
49	Piazzetta Primo Levi	X
50	Piazza Arturo Graf	X
51	Corso Calileo Galilei	X


Figure 39: Via Nizza (35)
Date: 16/08/2019
Source: Captured by author

2 Streets

Not covered-streets

D- Comfort

D3-Parking lots

-Quantitative

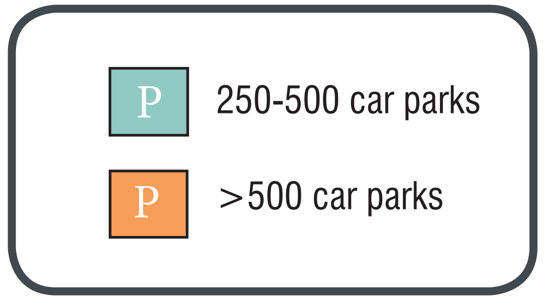
Source of Data: https://www.google.com/maps/ - http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: Derived from ArcGIS

Map 15: Parking lots

1 Corso Bramante
2 Via Luigi Federico Menabrea
3 Via Benevuto Cellini
4 Via Antonio Canova
5 Via Tiziano Vecellio
6 Via Ilarione Petitti
7 Corso Dante Alighieri
8 Via Ugo Foscolo
9 Via Vicenzo Monti
10 Via Frencesco Petrarca
11 Via Gaetano Donizetti
12 Via Michelangelo Buonarroti
13 Corso Raffaello
14 Via Giorgio Bidone
15 Via Valperga Caluso
16 Via Oddino Morgari
17 Via Federico Campana
18 Via Giuseppe Giacosa
19 Corso Guglielmo Marconi
20 Via cesare Lombroso
21 Via Giuseppe Baretti
22 Via Silvio Pellico
23 Via Claudio Luigi Berthollet
24 Via Bernardino Galliari
25 Via San Pio V
26 Corso Vittorio Emanuel 2
27 Via Edoardo Calvo
28 Via Conte Emanuele Theasuro
29 Via Leonardo da Vinici
30 Via Correggio
31 Via Pio Foa
32 Via Ormea
33 Via Giotto
34 Via Madama Cristina
35 Via Nizza
36 Via Tommaso Grossi
37 Via Ludovico Antonio Murato
38 Via Pietro Giuria
39 Vi Belfiore
40 Via Saluzzo
41 Via Principe Tommaso
42 Via Sant Anselmo
43 Corso Massimo d Azeglio
44 Via Gian Battista Tiepolo
45 Via Carlo Marenco
46 Via Gabriele Chiabrera
47 Via Carlo Morachetti
48 Piazza De Amicis
49 Piazzetta Primo Levi
50 Piazza Arturo Graf
51 Corso Calileo Galilei



E-Accessibility

E1: Sidewalk condition

-Qualitative

Source of Data: Pathway Asset Management Plan 2017, Strategic Asset Management Team, July 2017

Date: 2019

Assessment Method: In situ Analysis

Condition Rating Description

1- (New/Very good) The pathway is in ‘as new’ condition and therefore no intervention is warranted.

2- (Good) Some minor defects or concerns with the pathway segment, however nothing is significant in nature or extent.

3- (Fair) Some moderate defects or concerns with the pathway segment, some of these may be appropriate for planned or immediate maintenance.

4- (Poor) Pathway defects are significant and the segment is no longer considered to be providing an acceptable level of service. Segment requires significant renewal/rehabilitation.

5- (Very poor) Pathway has significant defects in both severity and extent, such that the pathway is not useable. Segment requires full replacement.

Figure 40: New/Very good

Figure 41: Good

Figure 42: Fair

Figure 43: Poor

Figure 44: Very poor

E-Accessibility

E1: Sidewalk condition

-Qualitative

Source of Data: Pathway Asset Management Plan 2017, Strategic Asset Management Team, July 2017, Visiting

Date: 2019

Assessment Method: In situ Analysis

5	4	3	2	1
Very Good	Good	Fair	Poor	Very poor

Figure 45: Via Antonio Canova (4)
Date: 25/05/2019
Source: Captured by author

Figure 46: Corso Raffaello (13)
Date: 02/04/2019
Source: Captured by author

Figure 47: Via Oddino Morgari (16)
Date: 02/04/2019
Source: Captured by author

Figure 48: Via Valperga Caluso (15)
Date: 02/04/2019
Source: Captured by author

Figure 49: Via Saluzzo (40)
Date: 02/04/2019
Source: Captured by author

Figure 50: Corso Massimo d Azeglioo (43)
Date: 27/05/2019
Source: Captured by author

Figure 51: Via Carlo Morachetti (47)
Date: 09/06/2019
Source: Captured by author

Figure 52: Via Gabriele Chiabrera (46)
Date: 09/06/2019
Source: Captured by author

Figure 53: Via Ormea (32)
Date: 27/05/2019
Source: Captured by author

Figure 54: Via Tiziano Vecellio (5)
Date: 25/05/2019
Source: Captured by author

Figure 55: Corso Bramante (1)
Date: 25/05/2019
Source: Captured by author

Figure 56: Corso Guglielmo Marconi (19)
Date: 25/05/2019
Source: Captured by author

Figure 57: Via Luigi Federico Menabrea(2)
Date: 25/05/2019
Source: Captured by author

Figure 58: Via Ludovico Antonio Muratori(37)
Date: 04/06/2019
Source: Captured by author

Figure 59: Via Edoardo Calvo(27)
Date: 02/04/2019
Source: Captured by author

Figure 60: Piazza Arturo Graf(50)
Date: 04/06/2019
Source: Captured by author

Figure 61: Via Tommaso Grossi(36)
Date: 04/06/2019
Source: Captured by author

1	Corso Bramante	fair
2	Via Luigi Federico Menabrea	very poor
3	Via Benevuto Cellini	fair
4	Via Antonio Canova	**very good**
5	Via Tiziano Vecellio	good
6	Via Ilarione Petitti	very poor
7	Corso Dante Alighieri	poor
8	Via Ugo Foscolo	fair
9	Via Vicenzo Monti	poor
10	Via Frencesco Petrarca	poor
11	Via Gaetano Donizetti	good
12	Via Michelangelo Buonarroti	poor
13	Corso Raffaello	good
14	Via Giorgio Bidone	very poor
15	Via Valperga Caluso	poor
16	Via Oddino Morgari	fair
17	Via Federico Campana	poor
18	Via Giuseppe Giacosa	good
19	Corso Guglielmo Marconi	poor
20	Via cesare Lombroso	fair
21	Via Giuseppe Baretti	very poor
22	Via Silvio Pellico	fair
23	Via Claudio Luigi Berthollet	good
24	Via Bernardino Galliari	good
25	Via San Pio V	poor
26	Corso Vittorio Emanuel 2	good
27	Via Edoardo Calvo	fair
28	Via Conte Emanuele Theasuro	fair
29	Via Leonardo da Vinici	good
30	Via Correggio	very poor
31	Via Pio Foa	very poor
32	Via Ormea	very poor
33	Via Giotto	very poor
34	Via Madama Cristina	poor
35	Via Nizza	poor
36	Via Tommaso Grossi	very poor
37	Via Ludovico Antonio Muratori	good
38	Via Pietro Giuria	good
39	Vi Belfiore	very poor
40	Via Saluzzo	very poor
41	Via Principe Tommaso	very poor
42	Via Sant Anselmo	poor
43	Corso Massimo d Azeglio	good
44	Via Gian Battista Tiepolo	good
45	Via Carlo Marenco	good
46	Via Gabriele Chiabrera	poor
47	Via Carlo Morachetti	fair
48	Piazza De Amicis	poor
49	Piazzetta Primo Levi	good
50	Piazza Arturo Graf	poor
51	Corso Calileo Galilei	good

1	Very good: 2%
15	Good: 29.4%
9	Fair: 17.6%
14	Poor: 27.5%
12	Very Poor: 23.5%

1 2 3

E-Accessibility

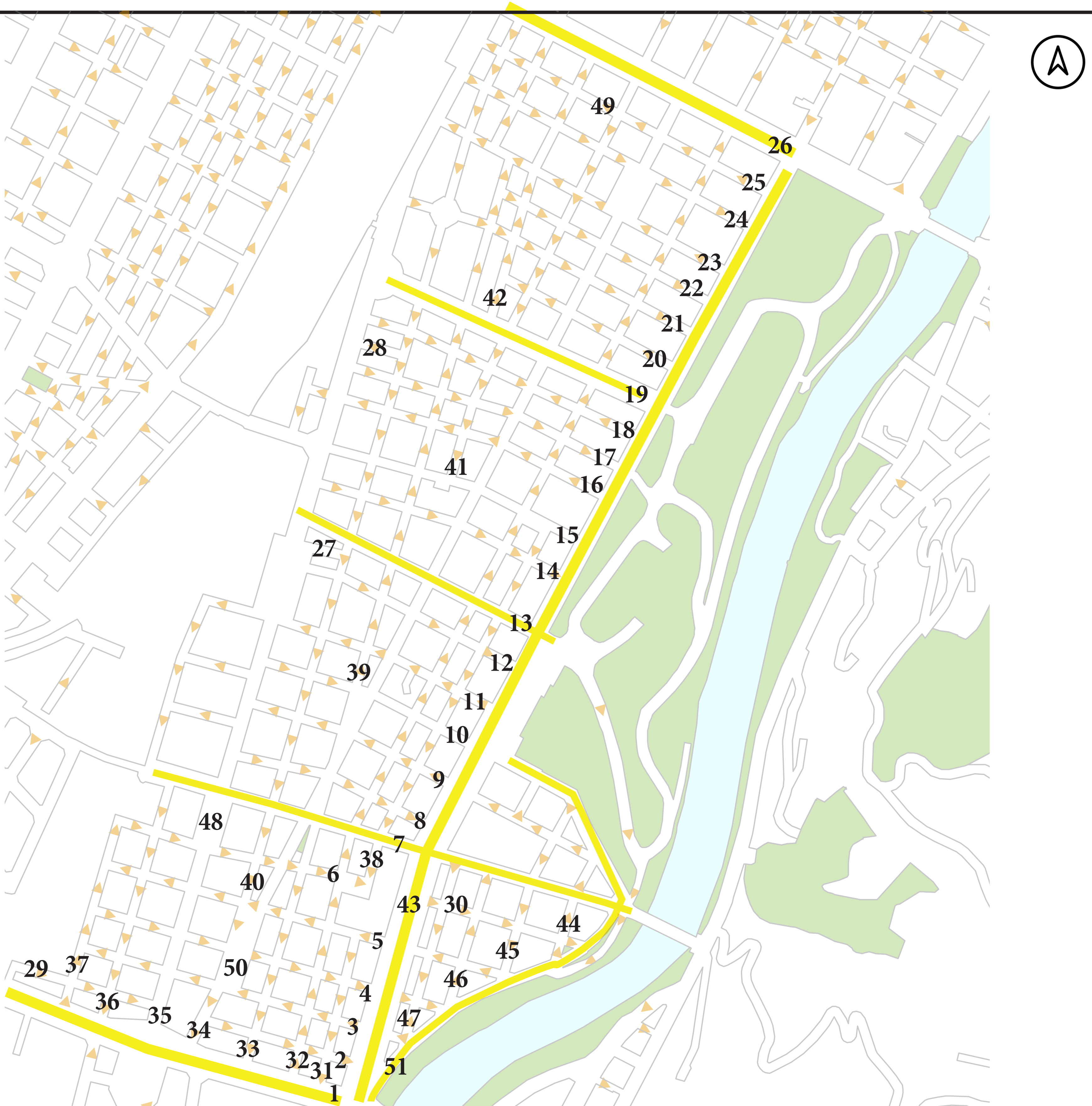
E2- Number of FootPaths

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, https://www.openstreetmap.org/

Date: 2019

Assessment Method: Calculation



Map 16: Number of Footpaths

Horizontal Streets

1 **Corso Bramante**
2 Via Luigi Federico Menabrea
3 Via Benevuto Cellini
4 Via Antonio Canova
5 Via Tiziano Vecellio
6 Via Ilarione Petitti
7 **Corso Dante Alighieri**
8 Via Ugo Foscolo
9 Via Vicenzo Monti
10 Via Frencesco Petrarca
11 Via Gaetano Donizetti
12 Via Michelangelo Buonarroti
13 **Corso Raffaello**
14 Via Giorgio Bidone
15 Via Valperga Caluso
16 Via Oddino Morgari
17 Via Federico Campana
18 Via Giuseppe Giacosa
19 **Corso Guglielmo Marconi**
20 Via cesare Lombroso
21 Via Giuseppe Baretti
22 Via Silvio Pellico
23 Via Claudio Luigi Berthollet
24 Via Bernardino Galliari
25 Via San Pio V
26 **Corso Vittorio Emanuel 2**
27 Via Edoardo Calvo
28 Via Conte Emanuele Theasuro
29 Via Leonardo da Vinici
30 Via Correggio

Vertical Streets

31 Via Pio Foa
32 Via Ormea
33 Via Giotto
34 Via Madama Cristina
35 Via Nizza
36 Via Tommaso Grossi
37 Via Ludovico Antonio Muratori
38 Via Pietro Giuria
39 Vi Belfiore
40 Via Saluzzo
41 Via Principe Tommaso
42 Via Sant Anselmo
43 **Corso Massimo d Azeglio**
44 Via Gian Battista Tiepolo
45 Via Carlo Marenco
46 Via Gabriele Chiabrera
47 Via Carlo Morachetti
48 Piazza De Amicis
49 Piazzetta Primo Levi
50 Piazza Arturo Graf
51 **Corso Calileo Galilei**

30 Horizontal Streets

21 Vertical Streets

7 Main Streets

102 Foot paths

E-Accessibility

E3- Network integration in the urban fabric

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, https://www.google.com/maps/

Date: 2019

Assessment Method: Derived from ArcGIS

Map 17: Network integration in the urban fabric

1	Corso Bramante	✓
2	Via Luigi Federico Menabrea	X
3	Via Benevuto Cellini	X
4	Via Antonio Canova	X
5	Via Tiziano Vecellio	X
6	Via Ilarione Petitti	X
7	Corso Dante Alighieri	✓
8	Via Ugo Foscolo	X
9	Via Vicenzo Monti	X
10	Via Frencesco Petrarca	X
11	Via Gaetano Donizetti	X
12	Via Michelangelo Buonarroti	X
13	Corso Raffaello	X
14	Via Giorgio Bidone	X
15	Via Valperga Caluso	✓
16	Via Oddino Morgari	X
17	Via Federico Campana	X
18	Via Giuseppe Giacosa	X
19	Corso Guglielmo Marconi	X
20	Via cesare Lombroso	X
21	Via Giuseppe Baretti	X
22	Via Silvio Pellico	X
23	Via Claudio Luigi Berthollet	X
24	Via Bernardino Galliari	X
25	Via San Pio V	X
26	Corso Vittorio Emanuel 2	✓
27	Via Edoardo Calvo	X
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	X
30	Via Correggio	X
31	Via Pio Foa	X
32	Via Ormea	X
33	Via Giotto	X
34	Via Madama Cristina	X
35	Via Nizza	✓
36	Via Tommaso Grossi	X
37	Via Ludovico Antonio Murato	X
38	Via Pietro Giuria	X
39	Vi Belfiore	X
40	Via Saluzzo	X
41	Via Principe Tommaso	X
42	Via Sant Anselmo	X
43	Corso Massimo d Azeglio	✓
44	Via Gian Battista Tiepolo	X
45	Via Carlo Marenco	X
46	Via Gabriele Chiabrera	X
47	Via Carlo Morachetti	X
48	Piazza De Amicis	X
49	Piazzetta Primo Levi	X
50	Piazza Arturo Graf	X
51	Corso Calileo Galilei	✓

6 Streets

E- Accessibility

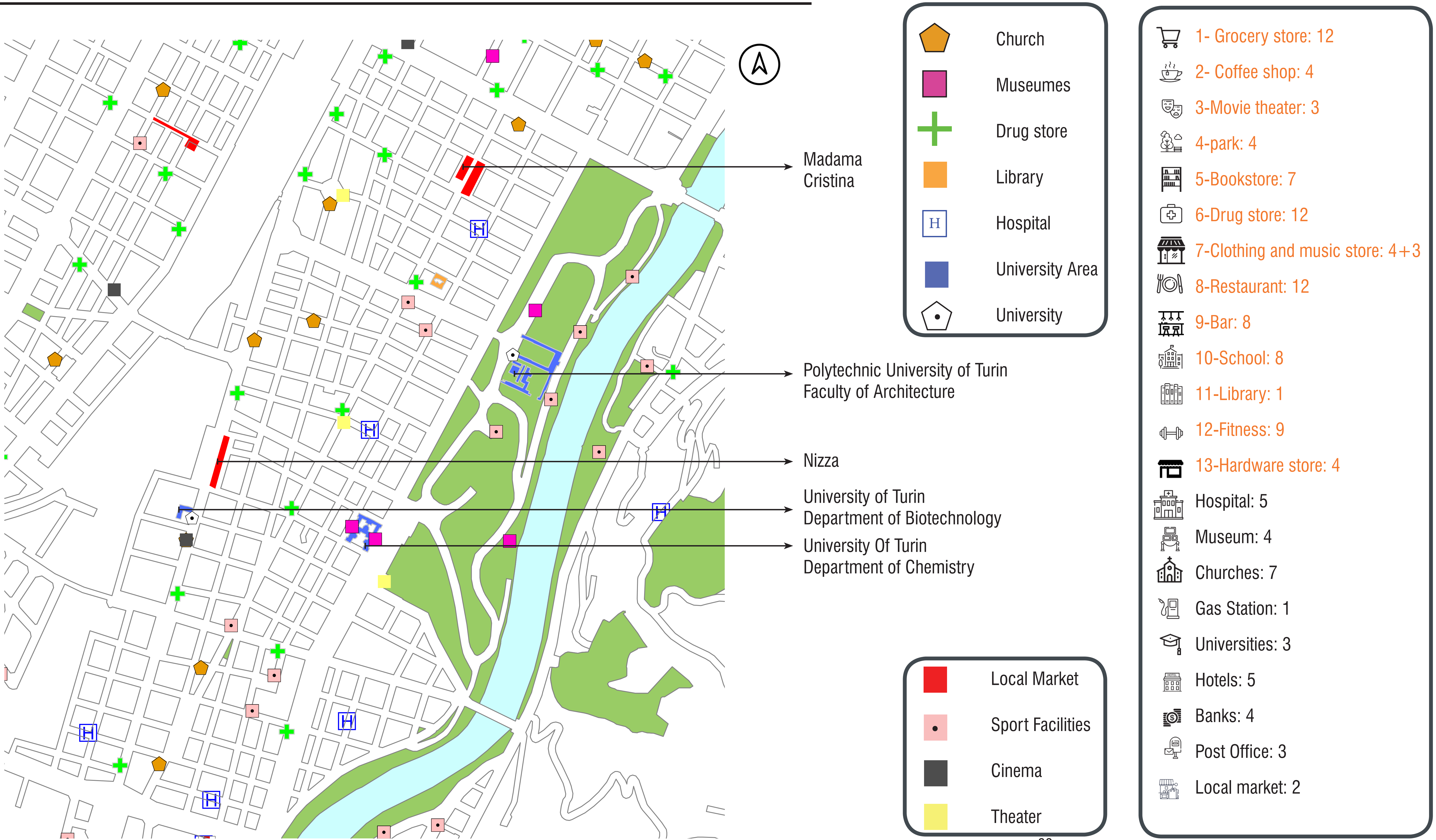
E4-Proximity to 13 categories (1- grocery store, 2-coffee shop, 3-movie theater, 4- park, 5-bookstore, 6- drug store, 7-clothing and music store, 8-restaurant, 9- bar, 10- school, 11- library, 12-fitness, 13-hardware store)

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, https://www.google.com/maps/

Date: 2019

Assessment Method: Derived from ArcGIS



Map 18: Proximity

E- Accessibility

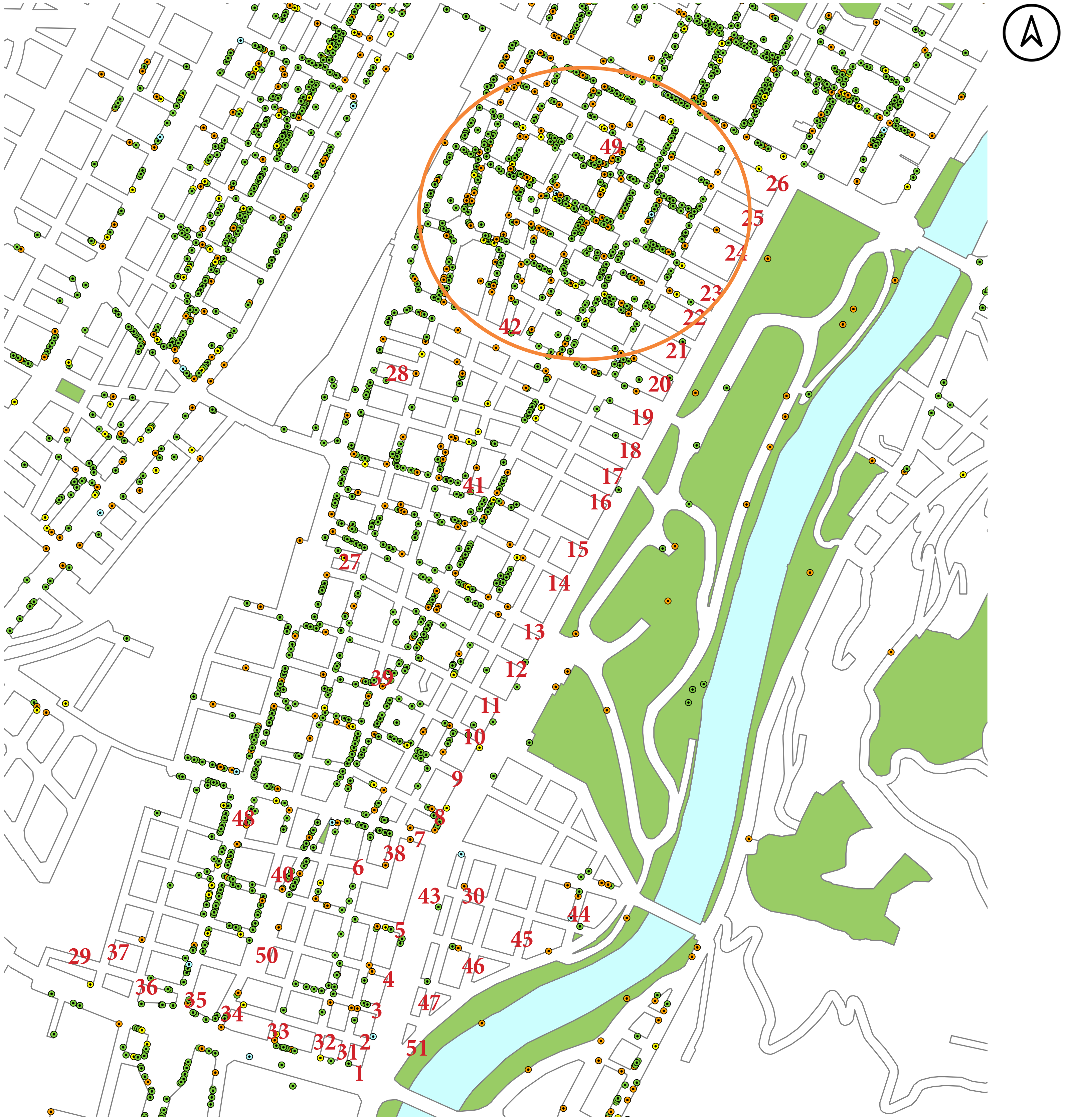
E4-Proximity to 13 categories (1- grocery store, 2-coffee shop, 3-movie theater, 4- park, 5-bookstore, 6- drug store, 7-clothing and music store, 8-restaurant, 9- bar, 10- school, 11- library, 12-fitness, 13-hardware store)

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: ArcGIS



Map 19: Commercial places

1	Corso Bramante
2	Via Luigi Federico Menabrea
3	Via Benevuto Cellini
4	Via Antonio Canova
5	Via Tiziano Vecellio
6	Via Ilarione Petitti
7	Corso Dante Alighieri
8	Via Ugo Foscolo
9	Via Vicenzo Monti
10	Via Frencesco Petrarca
11	Via Gaetano Donizetti
12	Via Michelangelo Buonarroti
13	Corso Raffaello
14	Via Giorgio Bidone
15	Via Valperga Caluso
16	Via Oddino Morgari
17	Via Federico Campana
18	Via Giuseppe Giacosa
19	Corso Guglielmo Marconi
20	Via cesare Lombroso
21	Via Giuseppe Baretti
22	Via Silvio Pellico
23	Via Claudio Luigi Berthollet
24	Via Bernardino Galliari
25	Via San Pio V
26	Corso Vittorio Emanuel 2
27	Via Edoardo Calvo
28	Via Conte Emanuele Theasuro
29	Via Leonardo da Vinici
30	Via Correggio
31	Via Pio Foa
32	Via Ormea
33	Via Giotto
34	Via Madama Cristina
35	Via Nizza
36	Via Tommaso Grossi
37	Via Ludovico Antonio Murato
38	Via Pietro Giuria
39	Vi Belfiore
40	Via Saluzzo
41	Via Principe Tommaso
42	Via Sant Anselmo
43	Corso Massimo d Azeglio
44	Via Gian Battista Tiepolo
45	Via Carlo Marenco
46	Via Gabriele Chiabrera
47	Via Carlo Morachetti
48	Piazza De Amicis
49	Piazzetta Primo Levi
50	Piazza Arturo Graf
51	Corso Calileo Galilei

- Newsstands (Edicole)
- Commercial activities in fixed place (Commercio in sede fissa)
- BarberShop (Acconciatori/Estetisti)
- public space for restuarant (Pubblici esercizi)

F- Attractiveness & Aesthetics

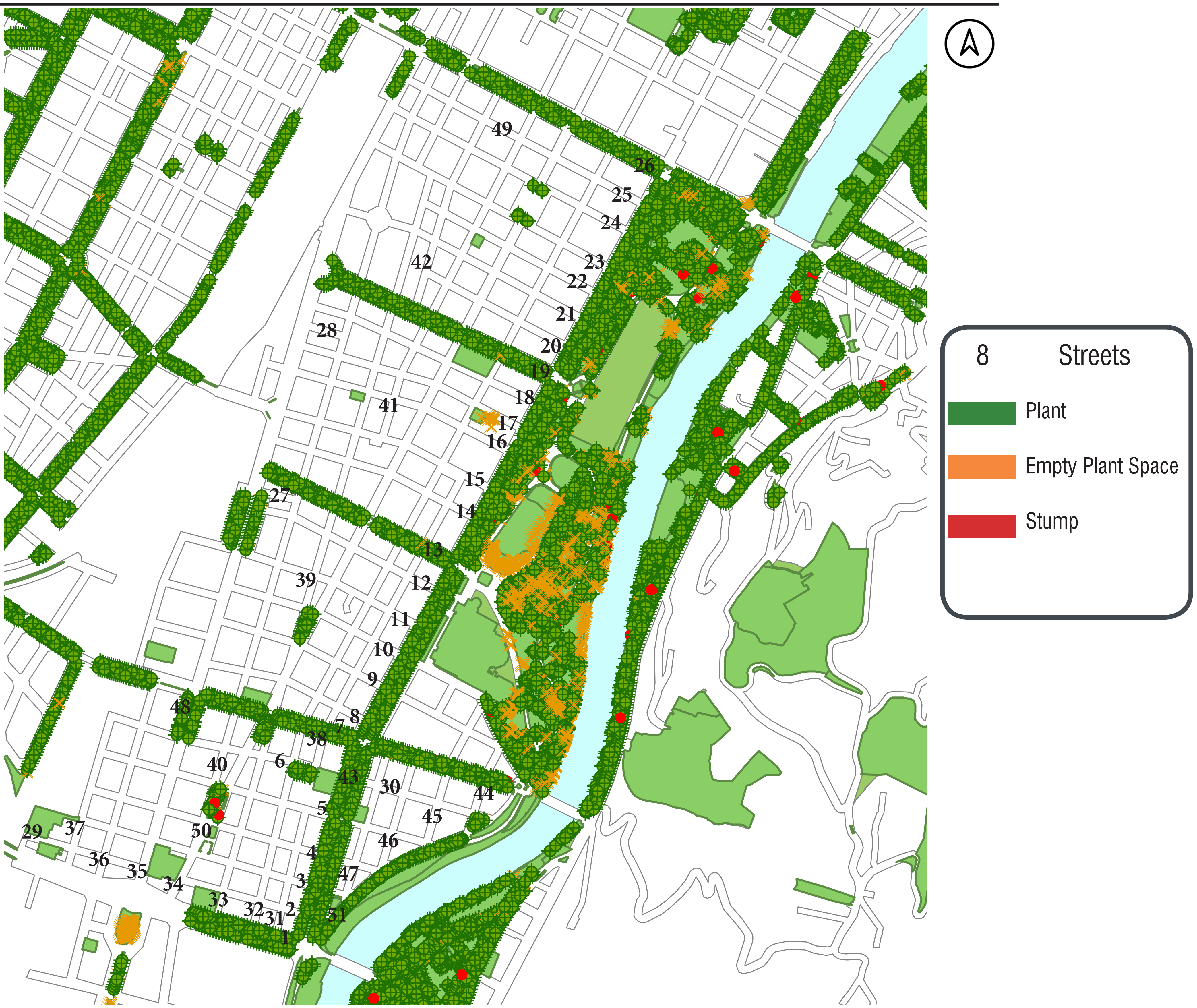
F1-Rows of trees

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/ - Visiting

Date: 2019

Assessment Method: Derived from ArcGIS - Insitu Analysis



Map 20: Rows of trees

1	Corso Bramante	✓
2	Via Luigi Federico Menabrea	X
3	Via Benevuto Cellini	X
4	Via Antonio Canova	X
5	Via Tiziano Vecellio	X
6	Via Ilarione Petitti	X
7	Corso Dante Alighieri	✓
8	Via Ugo Foscolo	X
9	Via Vicenzo Monti	X
10	Via Frencesco Petrarca	X
11	Via Gaetano Donizetti	X
12	Via Michelangelo Buonarroti	X
13	Corso Raffaello	✓
14	Via Giorgio Bidone	X
15	Via Valperga Caluso	X
16	Via Oddino Morgari	X
17	Via Federico Campana	X
18	Via Giuseppe Giacosa	X
19	Corso Guglielmo Marconi	✓
20	Via cesare Lombroso	X
21	Via Giuseppe Baretti	X
22	Via Silvio Pellico	X
23	Via Claudio Luigi Berthollet	X
24	Via Bernardino Galliari	X
25	Via San Pio V	X
26	Corso Vittorio Emanuel 2	✓
27	Via Edoardo Calvo	X
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	X
30	Via Correggio	X
31	Via Pio Foa	X
32	Via Ormea	X
33	Via Giotto	X
34	Via Madama Cristina	X
35	Via Nizza	✓
36	Via Tommaso Grossi	X
37	Via Ludovico Antonio Muratori	X
38	Via Pietro Giuria	X
39	Vi Belfiore	X
40	Via Saluzzo	X
41	Via Principe Tommaso	X
42	Via Sant Anselmo	X
43	Corso Massimo d Azeglio	✓
44	Via Gian Battista Tiepolo	X
45	Via Carlo Marenco	X
46	Via Gabriele Chiabrera	X
47	Via Carlo Morachetti	X
48	Piazza De Amicis	X
49	Piazzetta Primo Levi	X
50	Piazza Arturo Graf	X
51	Corso Calileo Galilei	✓

Figure 62: Corso Massimo d Azeglio(43)
Date: 09/06/2019
Source: Captured by author

Figure 63: Corso Vittorio Emanuel 2 (26)
Date: 25/05/2019
Source: Captured by author

Figure 64: Corso Calileo Galilei (51)
Date: 09/06/2019
Source: Captured by author

F- Attractiveness & Aesthetics

F2-Public open spaces (Plaza)

-Quantitative

Source of Data: https://www.google.com/maps/ - Visiting

Date: 2019

Assessment Method: Derived from ArcGIS - In situ Analysis

Map 21: Public open spaces (Plaza)

1	Corso Bramante	X
2	Via Luigi Federico Menabrea	X
3	Via Benevuto Cellini	✓
4	Via Antonio Canova	✓
5	Via Tiziano Vecellio	✓
6	Via Ilarione Petitti	✓
7	Corso Dante Alighieri	✓
8	Via Ugo Foscolo	X
9	Via Vicenzo Monti	✓
10	Via Frencesco Petrarca	✓
11	Via Gaetano Donizetti	✓
12	Via Michelangelo Buonarroti	✓
13	Corso Raffaello	X
14	Via Giorgio Bidone	X
15	Via Valperga Caluso	X
16	Via Oddino Morgari	X
17	Via Federico Campana	X
18	Via Giuseppe Giacosa	X
19	Corso Guglielmo Marconi	X
20	Via cesare Lombroso	X
21	Via Giuseppe Baretti	X
22	Via Silvio Pellico	X
23	Via Claudio Luigi Berthollet	✓
24	Via Bernardino Galliari	✓
25	Via San Pio V	✓
26	Corso Vittorio Emanuel 2	X
27	Via Edoardo Calvo	✓
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	X
30	Via Correggio	X
31	Via Pio Foa	X
32	Via Ormea	X
33	Via Giotto	X
34	Via Madama Cristina	✓
35	Via Nizza	✓
36	Via Tommaso Grossi	X
37	Via Ludovico Antonio Muratori	X
38	Via Pietro Giuria	X
39	Vi Belfiore	✓
40	Via Saluzzo	X
41	Via Principe Tommaso	X
42	Via Sant Anselmo	✓
43	Corso Massimo d Azeglio	X
44	Via Gian Battista Tiepolo	X
45	Via Carlo Marenco	X
46	Via Gabriele Chiabrera	X
47	Via Carlo Morachetti	X
48	Piazza De Amicis	✓
49	Piazzetta Primo Levi	✓
50	Piazza Arturo Graf	✓
51	Corso Calileo Galilei	X

Figure 65: Piazza Arturo Graf
Date: 04/06/2019
Source: Captured by author

Figure 66: Piazza Nizza
Date: 02/04/2019
Source: Captured by author

Figure 67: Piazzetta Primo Levi
Date: 17/08/2019
Source: Captured by author

6	Plazas
19	Streets

G- Pedestrian Infrastructure

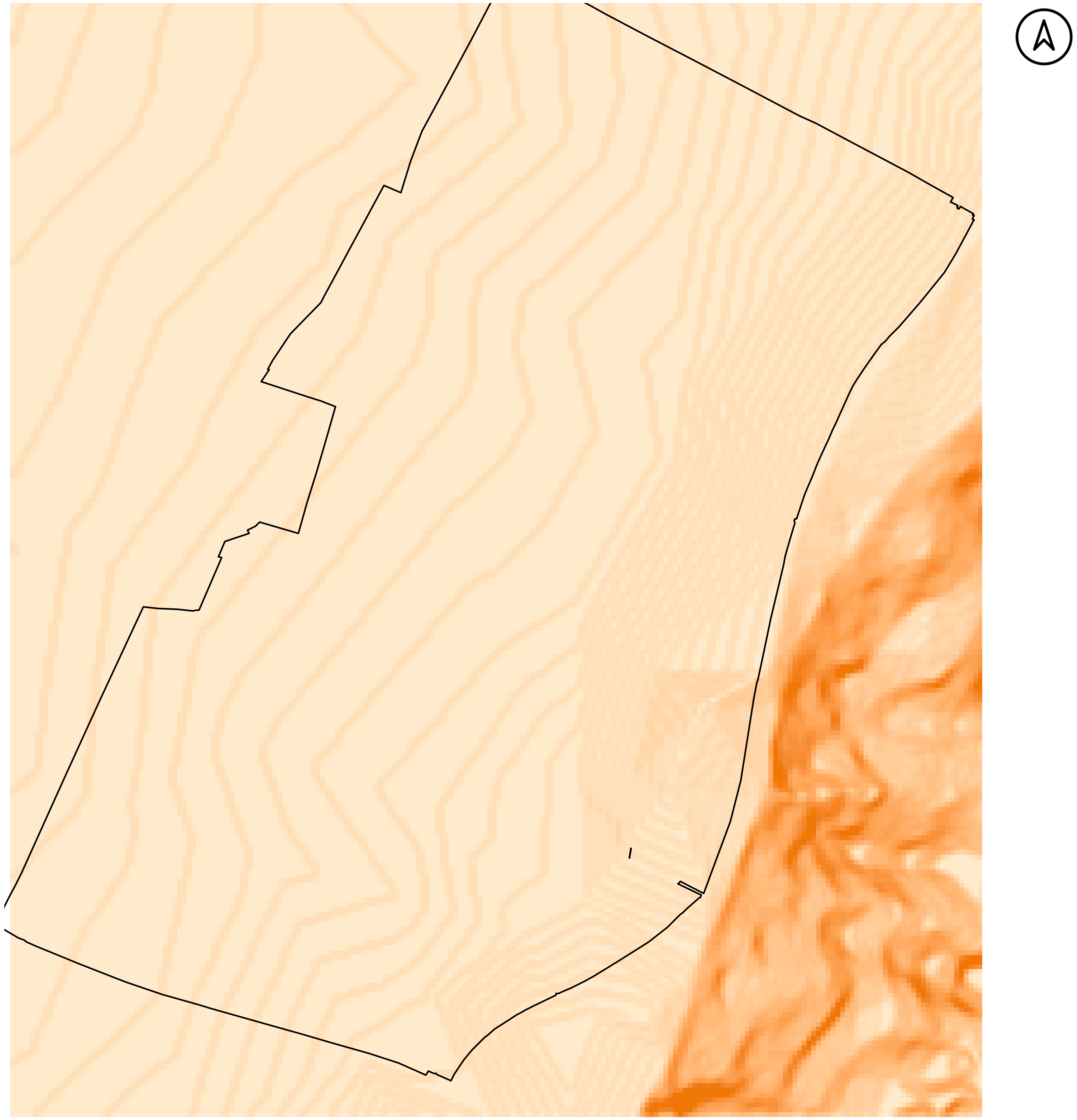
G1- Pedestrian slope (Disability)

-Quantitative

Source of Data:

Date: 2019

Assessment Method: Derived from ArcGIS



Map 22: Pedestrian slope

All of the streets have slopes for disable people.

High value: 78.3463

Low value: -0.419876

G- Pedestrian Infrastructure

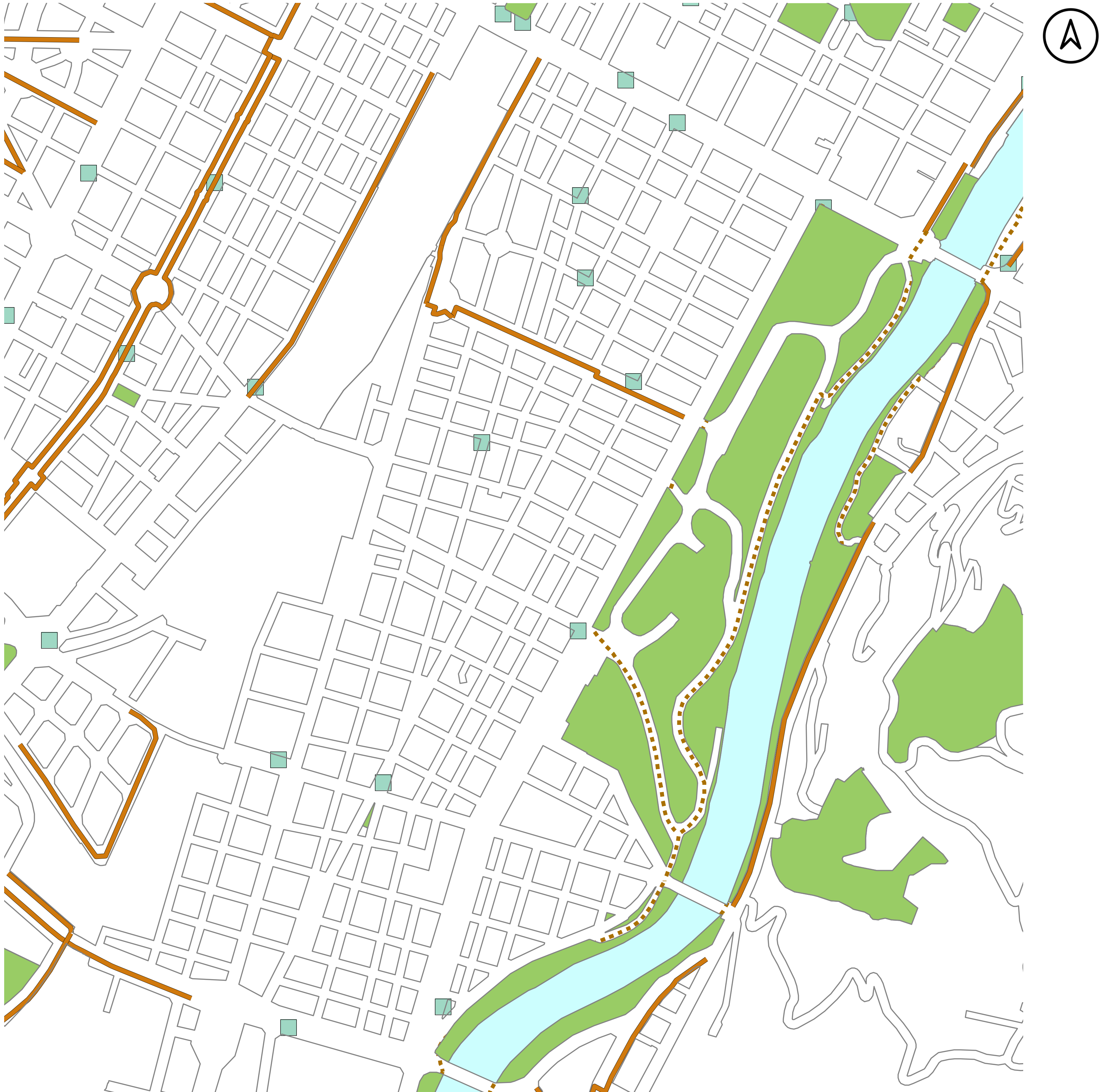
G2- Bicycle lanes

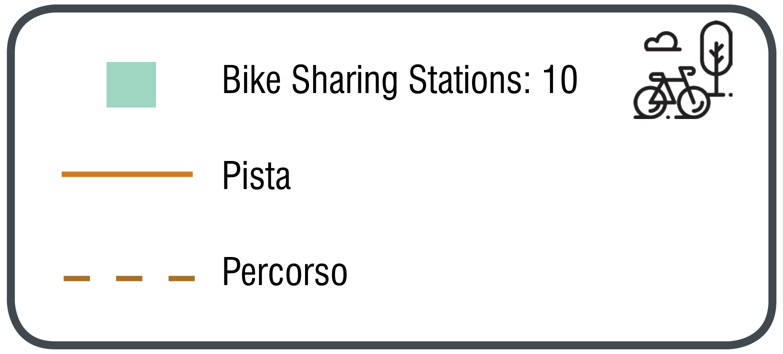
-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: Derived from ArcGIS





Map 23: Bicycle lanes

G- Pedestrian Infrastructure

G3- Lighting

-Quantitative

Source of Data: Visiting

Date: 2019

Assessment Method: In situ Analysis

Map 24: Lighting

1street does not have any lighting

1	Corso Bramante	✓
2	Via Luigi Federico Menabrea	✓
3	Via Benevuto Cellini	✓
4	Via Antonio Canova	✓
5	Via Tiziano Vecellio	✓
6	Via Ilarione Petitti	✓
7	Corso Dante Alighieri	✓
8	Via Ugo Foscolo	✓
9	Via Vicenzo Monti	✓
10	Via Frencesco Petrarca	✓
11	Via Gaetano Donizetti	✓
12	Via Michelangelo Buonarroti	✓
13	Corso Raffaello	✓
14	Via Giorgio Bidone	✓
15	Via Valperga Caluso	✓
16	Via Oddino Morgari	✓
17	Via Federico Campana	✓
18	Via Giuseppe Giacosa	✓
19	Corso Guglielmo Marconi	✓
20	Via cesare Lombroso	✓
21	Via Giuseppe Baretti	✓
22	Via Silvio Pellico	✓
23	Via Claudio Luigi Berthollet	✓
24	Via Bernardino Galliari	✓
25	Via San Pio V	✓
26	Corso Vittorio Emanuel 2	✓
27	Via Edoardo Calvo	✓
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	✓
30	Via Correggio	✓
31	Via Pio Foa	✓
32	Via Ormea	✓
33	Via Giotto	✓
34	Via Madama Cristina	✓
35	Via Nizza	✓
36	Via Tommaso Grossi	✓
37	Via Ludovico Antonio Murato	✓
38	Via Pietro Giuria	✓
39	Vi Belfiore	✓
40	Via Saluzzo	✓
41	Via Principe Tommaso	✓
42	Via Sant Anselmo	✓
43	Corso Massimo d Azeglio	✓
44	Via Gian Battista Tiepolo	✓
45	Via Carlo Marenco	✓
46	Via Gabriele Chiabrera	✓
47	Via Carlo Morachetti	✓
48	Piazza De Amicis	✓
49	Piazzetta Primo Levi	✓
50	Piazza Arturo Graf	✓
51	Corso Calileo Galilei	✓

Figure 68: Via Benevuto Cellini (3)
Date: 16/08/2019
Source: Captured by author

Figure 69: Via Giotto (33)
Date: 17/08/2019
Source: Captured by author

Figure 70: Via San Pio V (25)
Date: 17/08/2019
Source: Captured by author

Figure 71: Via Conte Emanuele Theasuro (28)
Date: 16/08/2019
Source: Captured by author

G- Pedestrian Infrastructure

G4- Furniture

-Quantitative

Source of Data: Visiting

Date: 2019

Assessment Method: In situ Analysis

Map 25: Furniture

1	Corso Bramante	X
2	Via Luigi Federico Menabrea	X
3	Via Benevuto Cellini	X
4	Via Antonio Canova	X
5	Via Tiziano Vecellio	X
6	Via Ilarione Petitti	X
7	Corso Dante Alighieri	X
8	Via Ugo Foscolo	X
9	Via Vicenzo Monti	X
10	Via Frencesco Petrarca	X
11	Via Gaetano Donizetti	X
12	Via Michelangelo Buonarroti	X
13	Corso Raffaello	X
14	Via Giorgio Bidone	X
15	Via Valperga Caluso	X
16	Via Oddino Morgari	X
17	Via Federico Campana	X
18	Via Giuseppe Giacosa	X
19	Corso Guglielmo Marconi	X
20	Via cesare Lombroso	X
21	Via Giuseppe Baretti	X
22	Via Silvio Pellico	X
23	Via Claudio Luigi Berthollet	X
24	Via Bernardino Galliari	X
25	Via San Pio V	X
26	Corso Vittorio Emanuel 2	X
27	Via Edoardo Calvo	X
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	X
30	Via Correggio	X
31	Via Pio Foa	X
32	Via Ormea	X
33	Via Giotto	X
34	Via Madama Cristina	X
35	Via Nizza	X
36	Via Tommaso Grossi	X
37	Via Ludovico Antonio Murato	✓
38	Via Pietro Giuria	X
39	Vi Belfiore	X
40	Via Saluzzo	X
41	Via Principe Tommaso	X
42	Via Sant Anselmo	X
43	Corso Massimo d Azeglio	X
44	Via Gian Battista Tiepolo	X
45	Via Carlo Marenco	X
46	Via Gabriele Chiabrera	X
47	Via Carlo Morachetti	X
48	Piazza De Amicis	✓
49	Piazzetta Primo Levi	X
50	Piazza Arturo Graf	✓
51	Corso Calileo Galilei	✓

Figure 72: Corso Calileo Galilei (51)
Date: 17/08/2019
Source: Captured by author

Figure 73: Via Ludovico Antonio Murato (37)
Date: 17/08/2019
Source: Captured by author

Figure 74: Piazza De Amicis (48)
Date: 17/08/2019
Source: Captured by author

Figure 75: Playground of the city of Turin
Date: 16/08/2019
Source: Captured by author

I- Land Use Mix

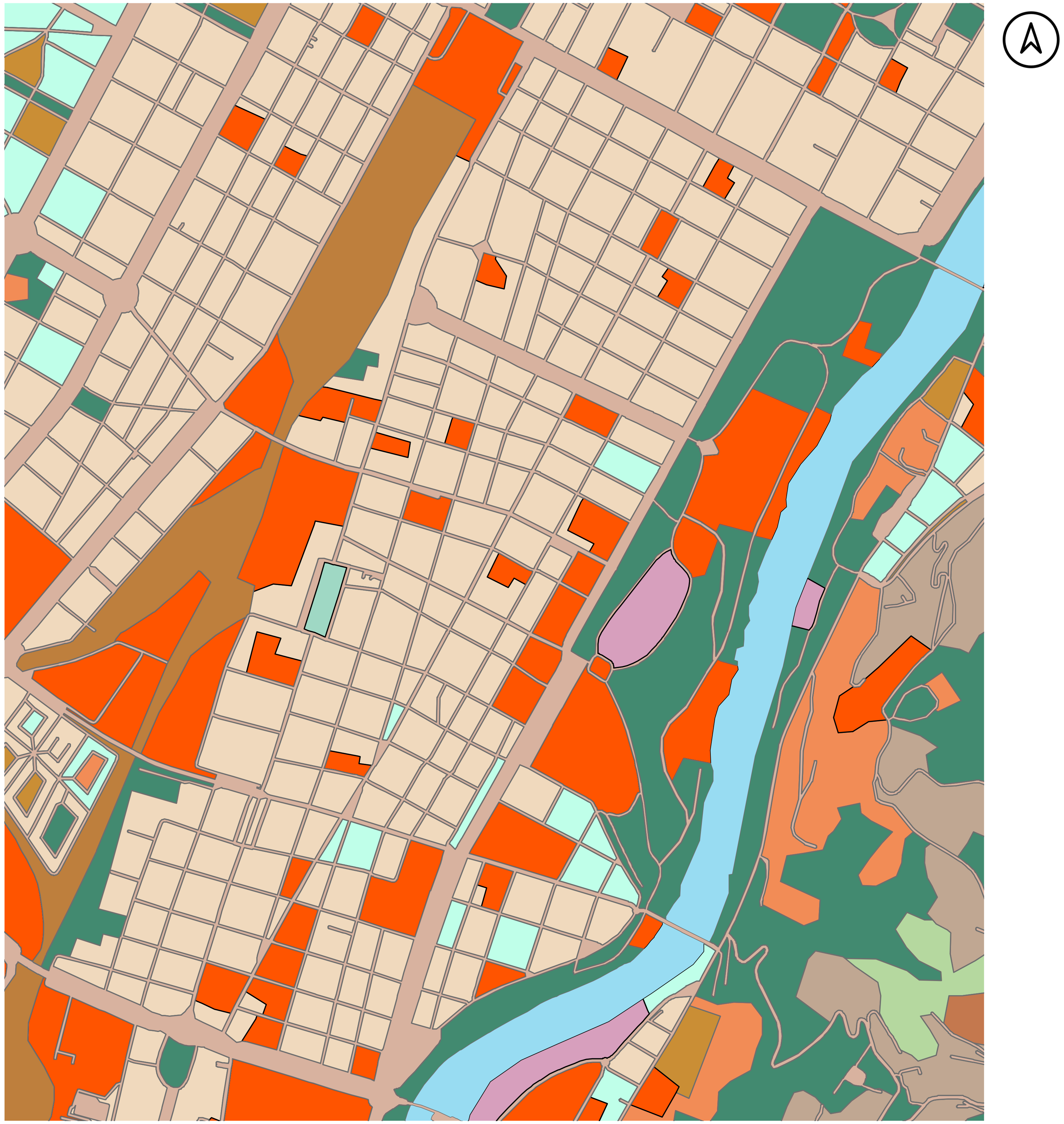
I1- Mixed land use

-Quantitative

Source of Data: Lartu

Date: 2010

Assessment Method: Derived from ArcGIS



Map 26: Mixed land use

- Continuous Urban Fabric (S.L >80%)
- Green urban areas
- Sports and leisure facilities
- Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)
- Other roads and associated land
- Discontinuous Medium Density Urban Fabric (S.L. : 30% - 50%)
- Industrial, commercial, public, military and private units
- Water bodies
- Discontinuous Very Low Density Urban Fabric (S.L. < 10%)
- Discontinuous Low Density Urban Fabric (S.L. : 10% - 30%)
- Agricultural + Semi-natural areas + Wetlands
- Land without current use

I- Land Use Mix

I2- Parks

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, Visitng

Date: 2019

Assessment Method: Derive from ArcGIS - In situ Analysis

Map 27: Parks

1	Corso Bramante	X
2	Via Luigi Federico Menabrea	X
3	Via Benevuto Cellini	X
4	Via Antonio Canova	X
5	Via Tiziano Vecellio	✓
6	Via Ilarione Petitti	✓
7	Corso Dante Alighieri	✓
8	Via Ugo Foscolo	X
9	Via Vicenzo Monti	X
10	Via Frencesco Petrarca	X
11	Via Gaetano Donizetti	X
12	Via Michelangelo Buonarroti	X
13	Corso Raffaello	✓
14	Via Giorgio Bidone	✓
15	Via Valperga Caluso	✓
16	Via Oddino Morgari	✓
17	Via Federico Campana	✓
18	Via Giuseppe Giacosa	✓
19	Corso Guglielmo Marconi	✓
20	Via cesare Lombroso	✓
21	Via Giuseppe Baretti	✓
22	Via Silvio Pellico	✓
23	Via Claudio Luigi Berthollet	✓
24	Via Bernardino Galliari	✓
25	Via San Pio V	✓
26	Corso Vittorio Emanuel 2	✓
27	Via Edoardo Calvo	X
28	Via Conte Emanuele Theasuro	X
29	Via Leonardo da Vinici	✓
30	Via Correggio	X
31	Via Pio Foa	X
32	Via Ormea	✓
33	Via Giotto	✓
34	Via Madama Cristina	✓
35	Via Nizza	X
36	Via Tommaso Grossi	X
37	Via Ludovico Antonio Muratori	X
38	Via Pietro Giuria	✓
39	Vi Belfiore	X
40	Via Saluzzo	✓
41	Via Principe Tommaso	X
42	Via Sant Anselmo	X
43	Corso Massimo d Azeglio	✓
44	Via Gian Battista Tiepolo	X
45	Via Carlo Marenco	X
46	Via Gabriele Chiabrera	X
47	Via Carlo Morachetti	X
48	Piazza De Amicis	X
49	Piazzetta Primo Levi	X
50	Piazza Arturo Graf	✓
51	Corso Calileo Galilei	X

Figure 76: Pizzale Ferruccio Parri
Date: 17/08/2019
Source: Captured by author

Figure 77: Giorgio Anglesio Garden
Date: 09/06/2019
Source: Captured by author

Figure 78: Louis Braille Garden
Date: 04/06/2019
Source: Captured by author

7	Parks
24	Streets

J- Street Connectivity

J1- Continuity of walking path

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, Visiting

Date: 2019

Assessment Method: Derive from ArcGIS - In situ Analysis

Map 28: Continuity of walking path

1	Corso Bramante	✓
2	Via Luigi Federico Menabrea	✓
3	Via Benevuto Cellini	✓
4	Via Antonio Canova	✓
5	Via Tiziano Vecellio	✓
6	Via Ilarione Petitti	✓
7	Corso Dante Alighieri	✓
8	Via Ugo Foscolo	✓
9	Via Vicenzo Monti	✓
10	Via Frencesco Petrarca	✓
11	Via Gaetano Donizetti	✓
12	Via Michelangelo Buonarroti	✓
13	Corso Raffaello	✓
14	Via Giorgio Bidone	✓
15	Via Valperga Caluso	✓
16	Via Oddino Morgari	✓
17	Via Federico Campana	✓
18	Via Giuseppe Giacosa	✓
19	Corso Guglielmo Marconi	✓
20	Via cesare Lombroso	✓
21	Via Giuseppe Baretti	✓
22	Via Silvio Pellico	✓
23	Via Claudio Luigi Berthollet	✓
24	Via Bernardino Galliari	✓
25	Via San Pio V	✓
26	Corso Vittorio Emanuel 2	✓
27	Via Edoardo Calvo	✓
28	Via Conte Emanuele Theasuro	✓
29	Via Leonardo da Vinici	✓
30	Via Correggio	✓
31	Via Pio Foa	✓
32	Via Ormea	✓
33	Via Giotto	✓
34	Via Madama Cristina	✓
35	Via Nizza	✓
36	Via Tommaso Grossi	✓
37	Via Ludovico Antonio Murato	✓
38	Via Pietro Giuria	✓
39	Vi Belfiore	✓
40	Via Saluzzo	✓
41	Via Principe Tommaso	✓
42	Via Sant Anselmo	✓
43	Corso Massimo d Azeglio	✓
44	Via Gian Battista Tiepolo	✓
45	Via Carlo Marenco	✓
46	Via Gabriele Chiabrera	✓
47	Via Carlo Morachetti	✓
48	Piazza De Amicis	✓
49	Piazzetta Primo Levi	✓
50	Piazza Arturo Graf	✓
51	Corso Calileo Galilei	✓

Due to the Grid urban plan of Turin, all of the streets are not deadend.

J- Street Connectivity

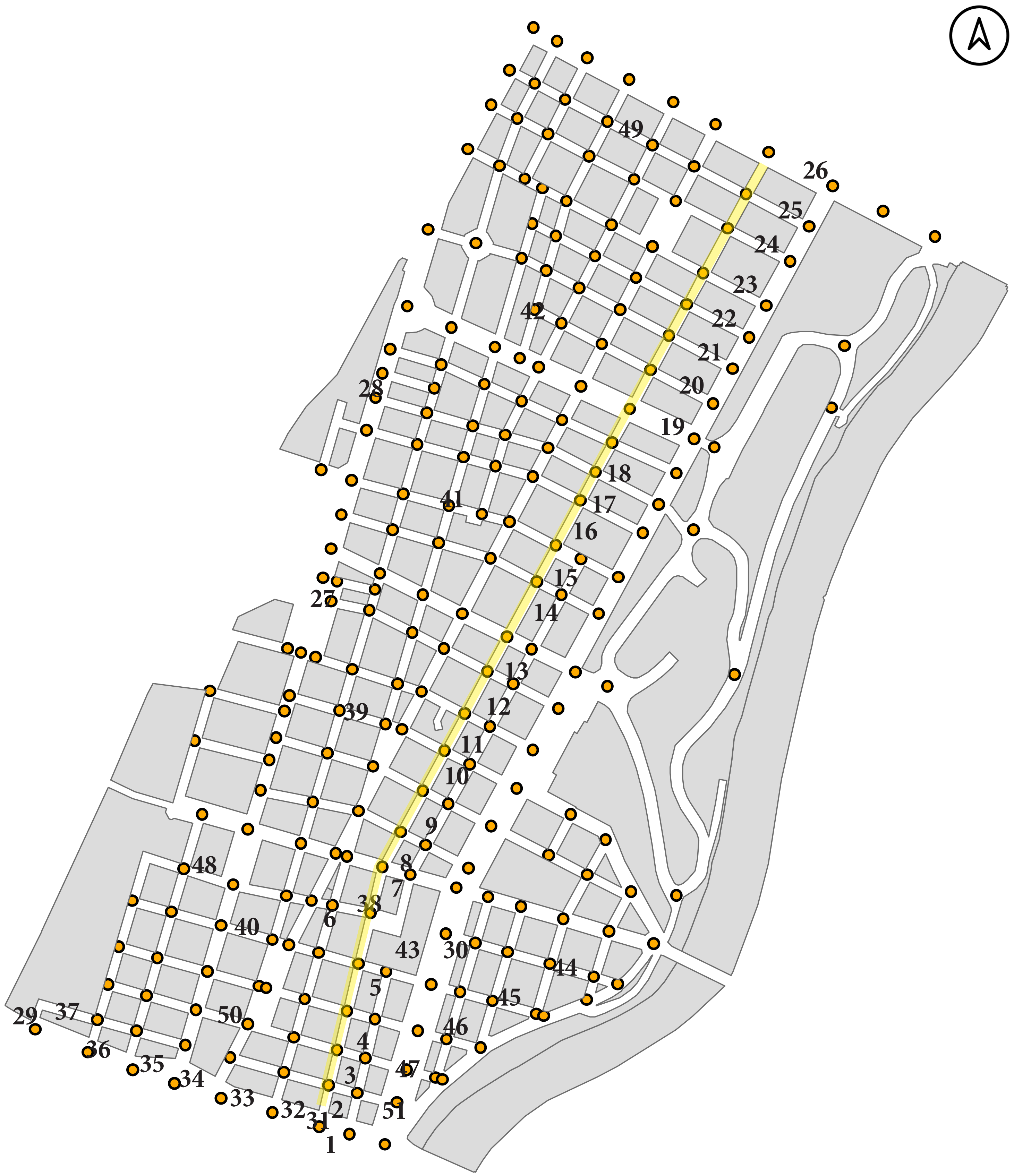
J2- Intersection

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: Derived from ArcGIS



Map 29: Intersection

1	Corso Bramante	21
2	Via Luigi Federico Menabrea	24
3	Via Benevuto Cellini	32
4	Via Antonio Canova	36
5	Via Tiziano Vecellio	42
6	Via Ilarione Petitti	26
7	Corso Dante Alighieri	41
8	Via Ugo Foscolo	20
9	Via Vicenzo Monti	20
10	Via Frencesco Petrarca	22
11	Via Gaetano Donizetti	24
12	Via Michelangelo Buonarroti	24
13	Corso Raffaello	24
14	Via Giorgio Bidone	24
15	Via Valperga Caluso	24
16	Via Oddino Morgari	24
17	Via Federico Campana	24
18	Via Giuseppe Giacosa	24
19	Corso Guglielmo Marconi	26
20	Via cesare Lombroso	16
21	Via Giuseppe Baretti	28
22	Via Silvio Pellico	20
23	Via Claudio Luigi Berthollet	28
24	Via Bernardino Galliari	28
25	Via San Pio V	24
26	Corso Vittorio Emanuel 2	26
27	Via Edoardo Calvo	4
28	Via Conte Emanuele Theasuro	4
29	Via Leonardo da Vinici	24
30	Via Correggio	18
31	Via Pio Foa	16
32	Via Ormea	104
33	Via Giotto	23
34	Via Madama Cristina	98
35	Via Nizza	65
36	Via Tommaso Grossi	24
37	Via Ludovico Antonio Murato	12
38	Via Pietro Giuria	3
39	Vi Belfiore	48
40	Via Saluzzo	80
41	Via Principe Tommaso	42
42	Via Sant Anselmo	26
43	Corso Massimo d Azeglio	62
44	Via Gian Battista Tiepolo	10
45	Via Carlo Marenco	17
46	Via Gabriele Chiabrera	12
47	Via Carlo Morachetti	17
48	Piazza De Amicis	69
49	Piazzetta Primo Levi	4
50	Piazza Arturo Graf	4
51	Corso Calileo Galilei	18

J- Street Connectivity

J3- Block length J4- Block width

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/

Date: 2019

Assessment Method: Export from ArcGIS to AutoCAD for measuring

Map 30: Block length and width

1 Corso Bramante
2 Via Luigi Federico Menabrea
3 Via Benevuto Cellini
4 Via Antonio Canova
5 Via Tiziano Vecellio
6 Via Ilarione Petitti
7 Corso Dante Alighieri
8 Via Ugo Foscolo
9 Via Vicenzo Monti
10 Via Frencesco Petrarca
11 Via Gaetano Donizetti
12 Via Michelangelo Buonarroti
13 Corso Raffaello
14 Via Giorgio Bidone
15 Via Valperga Caluso
16 Via Oddino Morgari
17 Via Federico Campana
18 Via Giuseppe Giacosa
19 Corso Guglielmo Marconi
20 Via cesare Lombroso
21 Via Giuseppe Baretti
22 Via Silvio Pellico
23 Via Claudio Luigi Berthollet
24 Via Bernardino Galliari
25 Via San Pio V
26 Corso Vittorio Emanuel 2
27 Via Edoardo Calvo
28 Via Conte Emanuele Theasuro
29 Via Leonardo da Vinici
30 Via Correggio
31 Via Pio Foa
32 Via Ormea
33 Via Giotto
34 Via Madama Cristina
35 Via Nizza
36 Via Tommaso Grossi
37 Via Ludovico Antonio Murato
38 Via Pietro Giuria
39 Vi Belfiore
40 Via Saluzzo
41 Via Principe Tommaso
42 Via Sant Anselmo
43 Corso Massimo d Azeglio
44 Via Gian Battista Tiepolo
45 Via Carlo Marenco
46 Via Gabriele Chiabrera
47 Via Carlo Morachetti
48 Piazza De Amicis
49 Piazzetta Primo Levi
50 Piazza Arturo Graf
51 Corso Calileo Galilei

181 Blocks

J- Street Connectivity

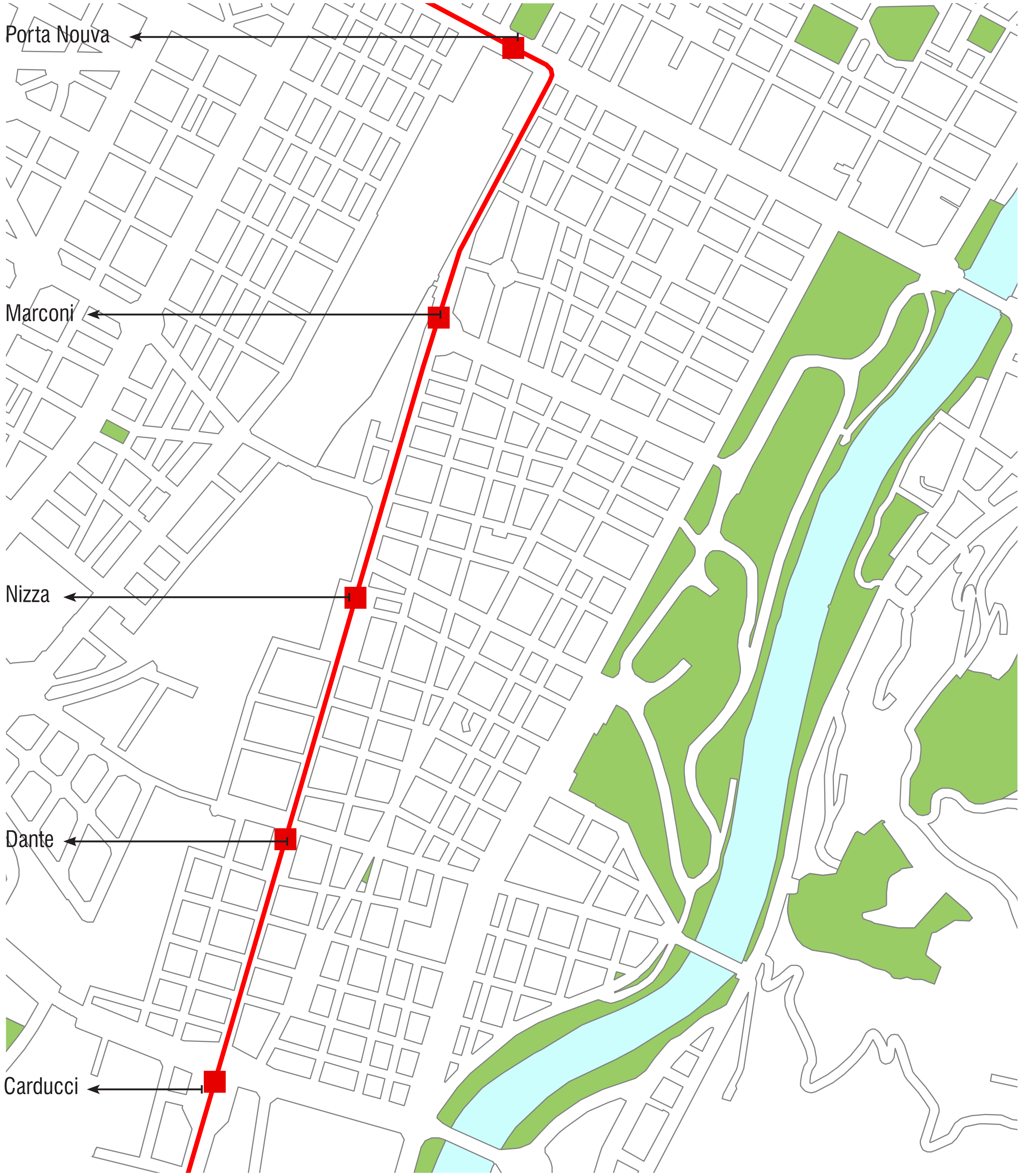
J5- Public transportation

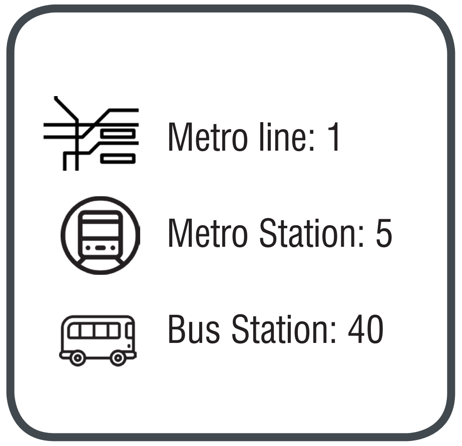
-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, https://www.google.com/maps

Date: 2019

Assessment Method: Derived from ArcGIS





Map 31: Public transportation

J- Street Connectivity

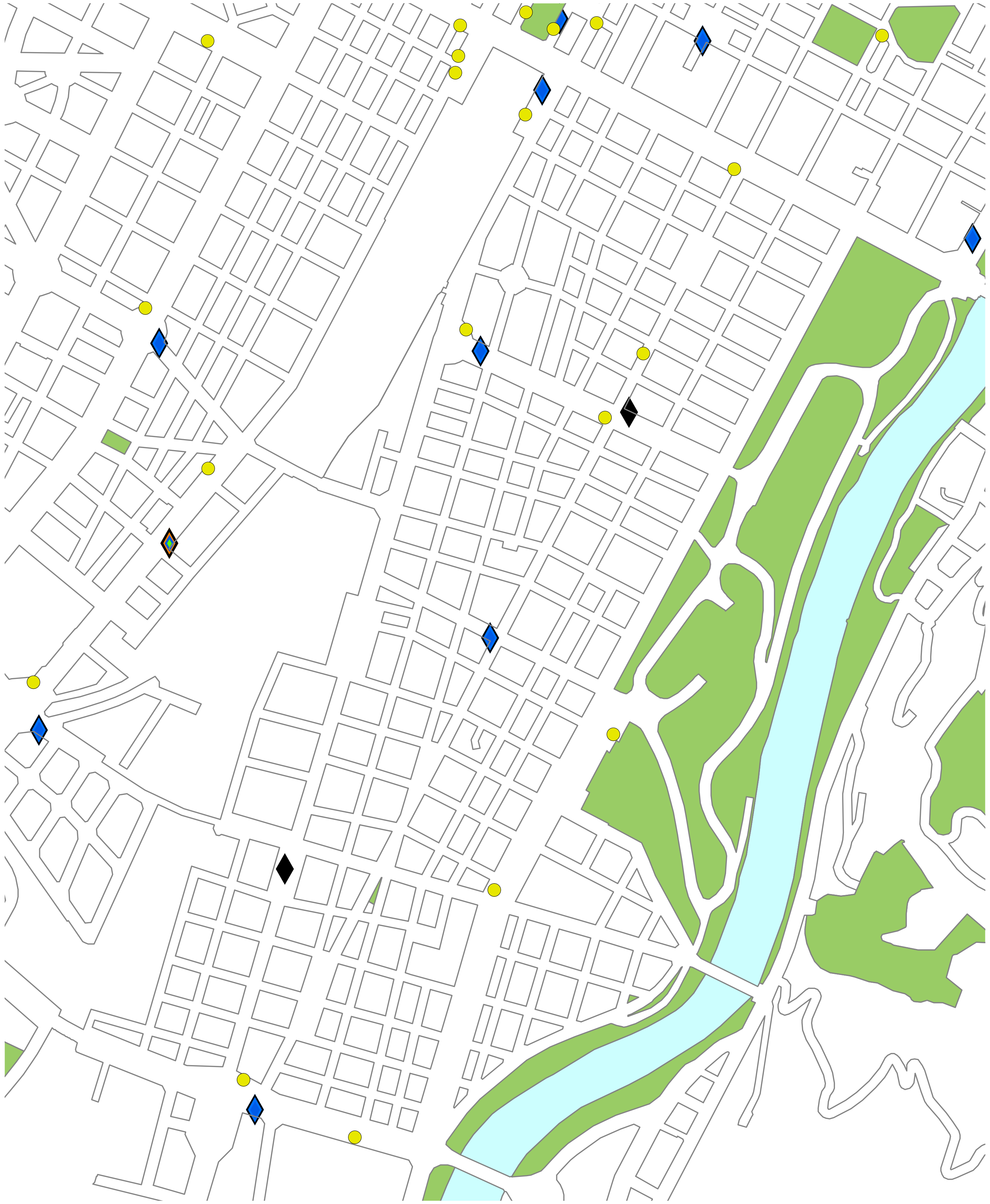
J6- Modal distribution

-Quantitative

Source of Data: http://geoportale.comune.torino.it/web/, https://www.google.com/maps

Date:

Assessment Method: Derived from ArcGIS



Map 32: Modal distribution

K- Economy

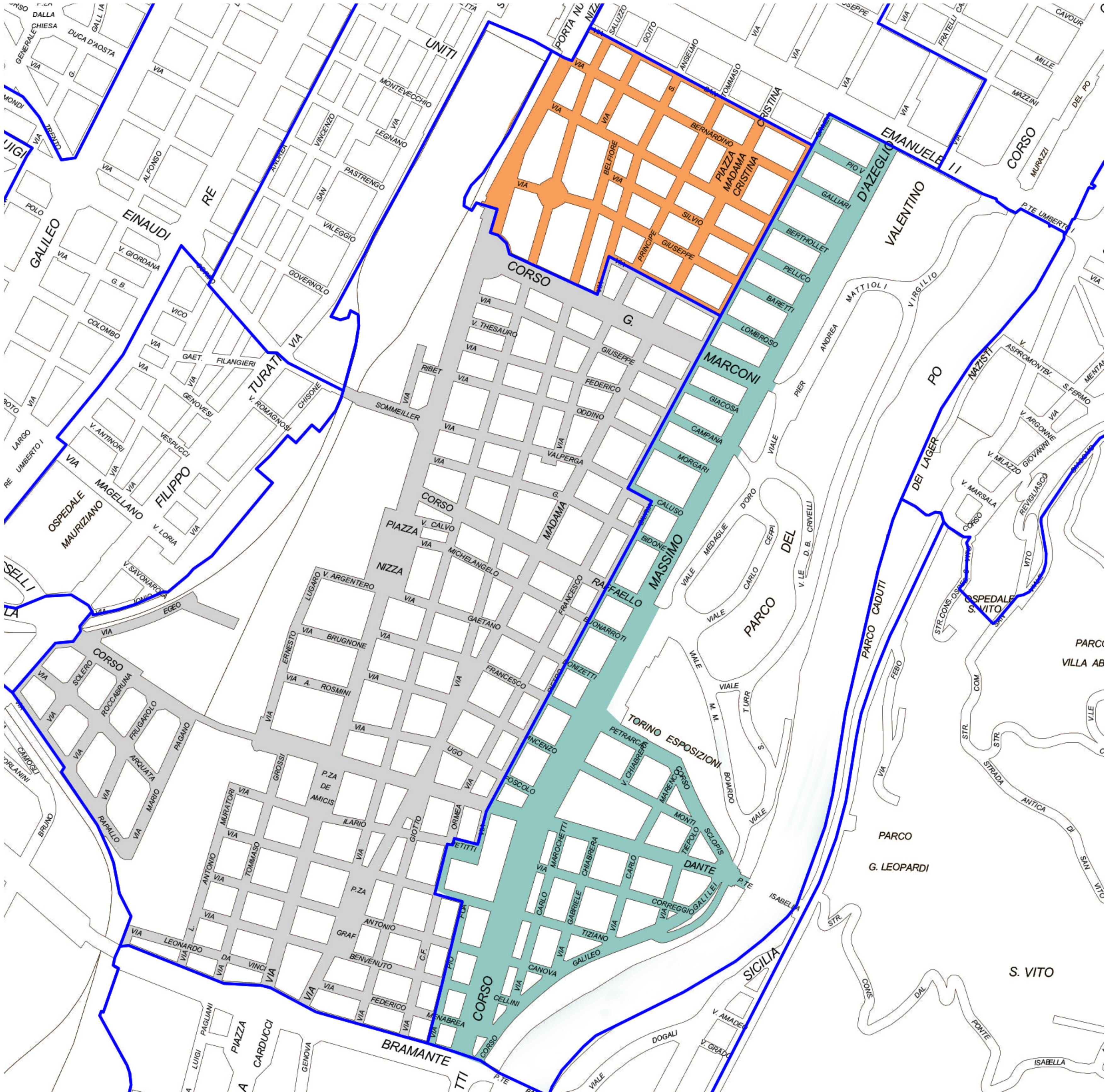
K-1- Housing values

-Quantitative

Source Of Data: http://www.oict.polito.it/en/microzones_and_values

Date: 2017

Assessment Method: Cartography



Map 33: Housing values

New/Completely Renovated Residential Segment

- 1- 3.531 €/mq
- 2- 2.780 €/mq
- 3 - 3.246 €/mq

Residential Segment

- 1- 2.686 €/mq
- 2- 2.069 €/mq
- 3- 2.151 €/mq

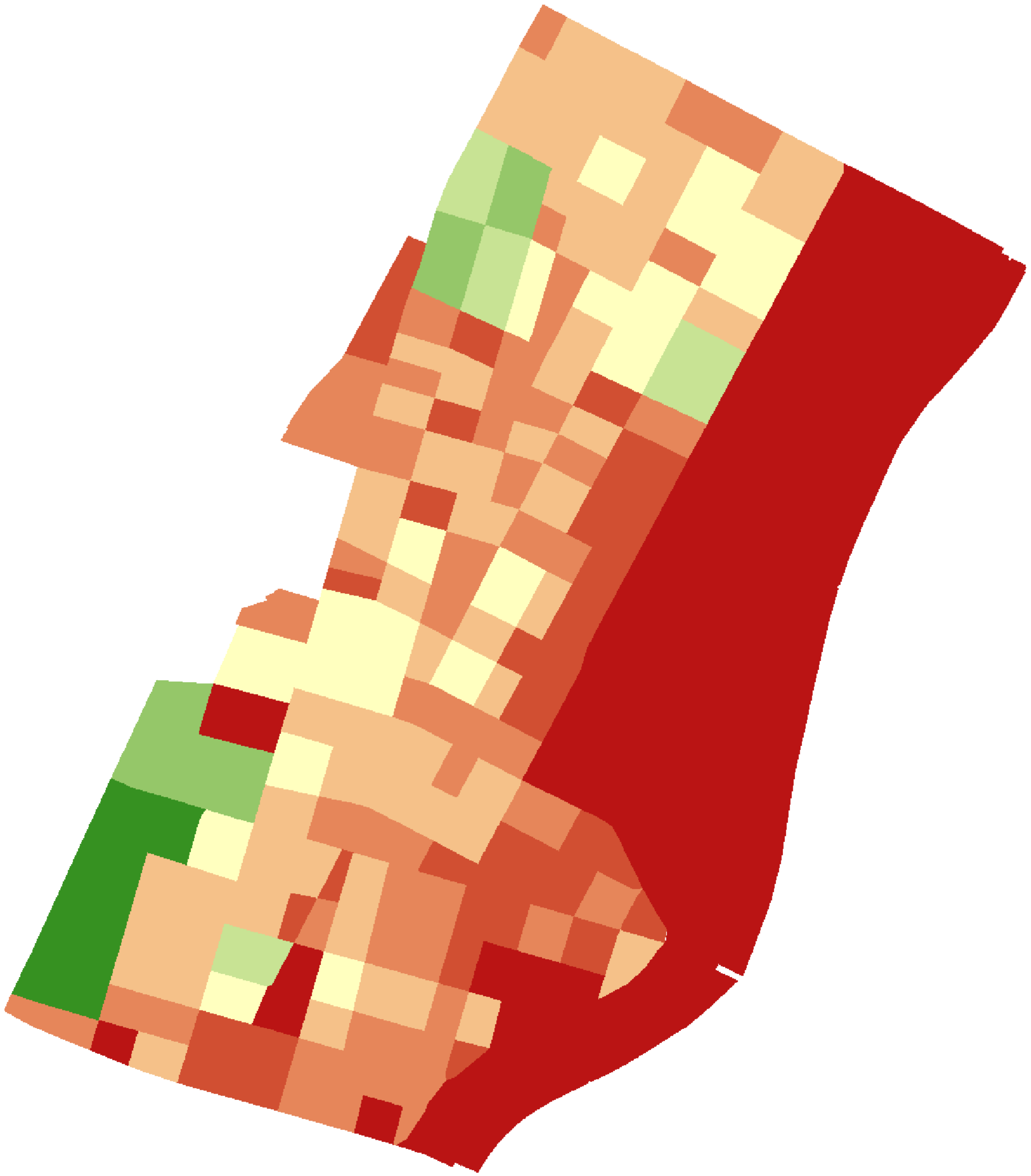
Result

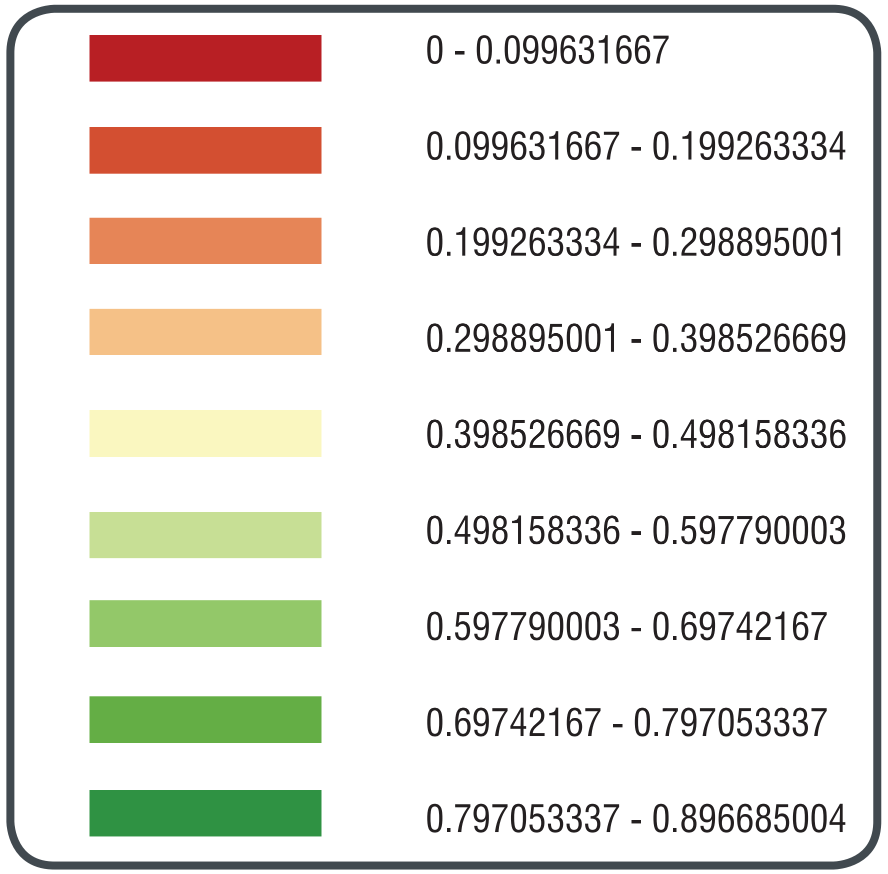
A Index Suitability Map

Demographic Characteristic

Date: 2019

Case Study: San Salvario





A1-Population density
A3-Age
A5-Gender

As already mentioned, in the east side of the San Salvario neighborhood, there is a park (parco del Valentine). Due to the greenery spaces, obviously the population density here is low. Obviously, the population density more in some parts that are closer to the city center.

Map 34: Demographic characteristic

Result

B Index Suitability Map

Density

Date: 2019

Case Study: San Salvario

Map 35: Density

- 0.000873442 - 0.067251023
- 0.067251023 - 0.133628603
- 0.133628603 - 0.200006184
- 0.200006184 - 0.266383765
- 0.266383765 - 0.332761345
- 0.332761345 - 0.399138926
- 0.399138926 - 0.465516507
- 0.465516507 - 0.531894087
- 0.531894087 - 0.598271668

B2-Net floor area density
B3-Block density

It can be seen that the block density is not high here and more that ninety percent of building have low density. Also, in the parts which have high population density, the block density are increasing.

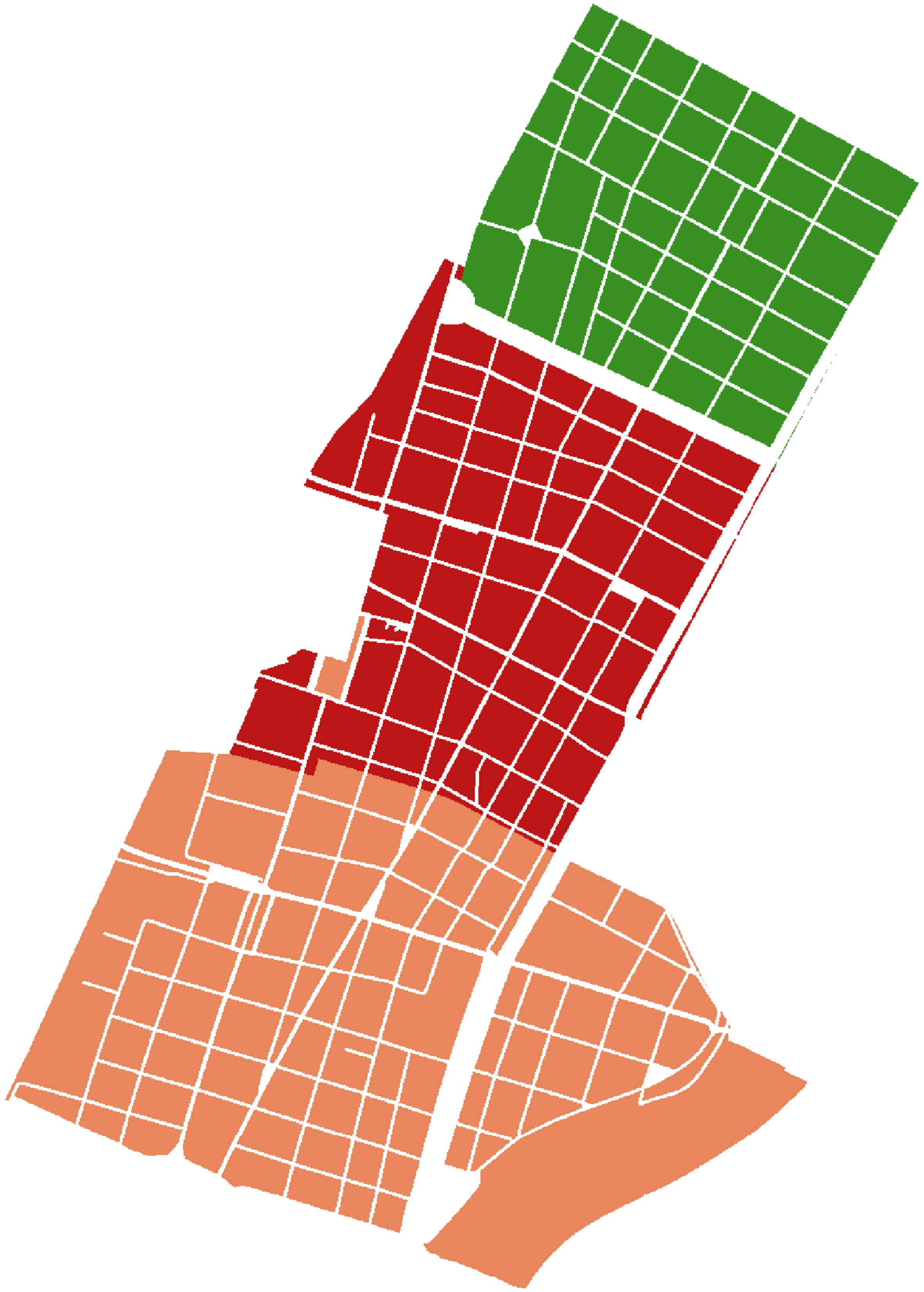
Result

C Index Suitability Map

Security

Date: 2019

Case Study: San Salvario



Map 36: Security

(red)	0 - 0.083333333
(red-orange)	0.083333333 - 0.166666667
(orange)	0.166666667 - 0.25
(light orange)	0.25 - 0.333333333
(light yellow)	0.333333333 - 0.416666667
(light green)	0.416666667 - 0.5
(green)	0.5 - 0.583333333
(medium green)	0.583333333 - 0.666666667
(dark green)	0.666666667 - 0.75

C1-Traffic safety
C2-Vacant building, Abandon building, Undesirable land use
C3-Riding speed
C4-Safety from Crime

In this suitability map, as it is presented, the areas which are close to the center, the rate of security has been decreased. In contrast, in the parts which are far from the city center, the secuirity level has been diminished.

Result

D Index Suitability Map

Comfort

Date: 2019

Case Study: San Salvario

Map 37: Comfort

	0.053362012 - 0.124031776
	0.124031776 - 0.194701539
	0.194701539 - 0.265371303
	0.265371303 - 0.336041066
	0.336041066 - 0.40671083
	0.40671083 - 0.477380594
	0.477380594 - 0.548050357
	0.548050357 - 0.618720121
	0.618720121 - 0.689389885

- D1-Sidewalk length
  D2-Sidewalk width
  D3-Covered spaces (sun, rain)
  D4-Parking lots

- This suitability map gives information about the comfort which is associated to sidewalk length and width, covered spaces and parking lots. Regarding to these factors, the comfortable zones are near Parco del Valentino that are long streets and near to the parking areas.

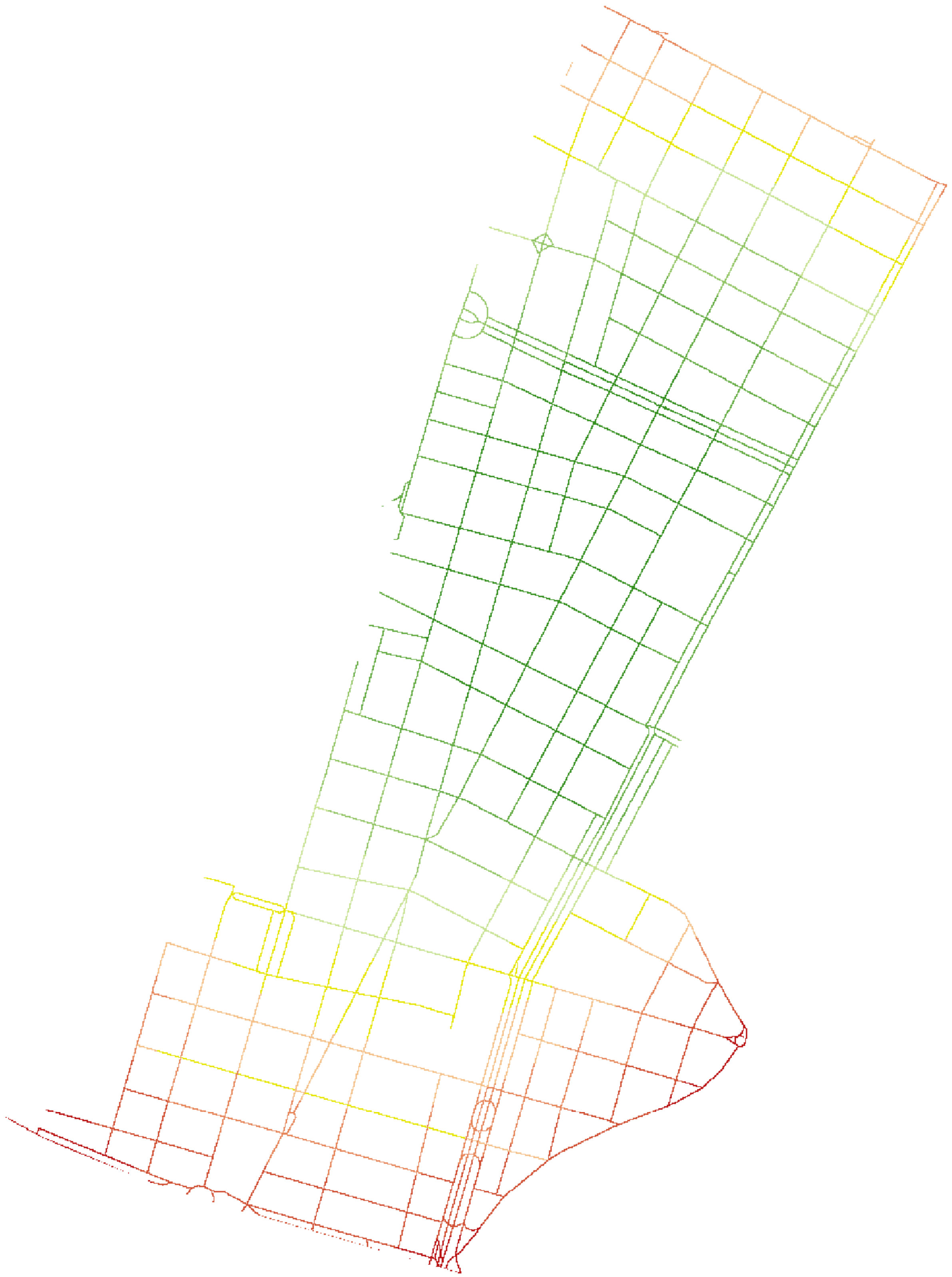
Result

E Index Suitability Map

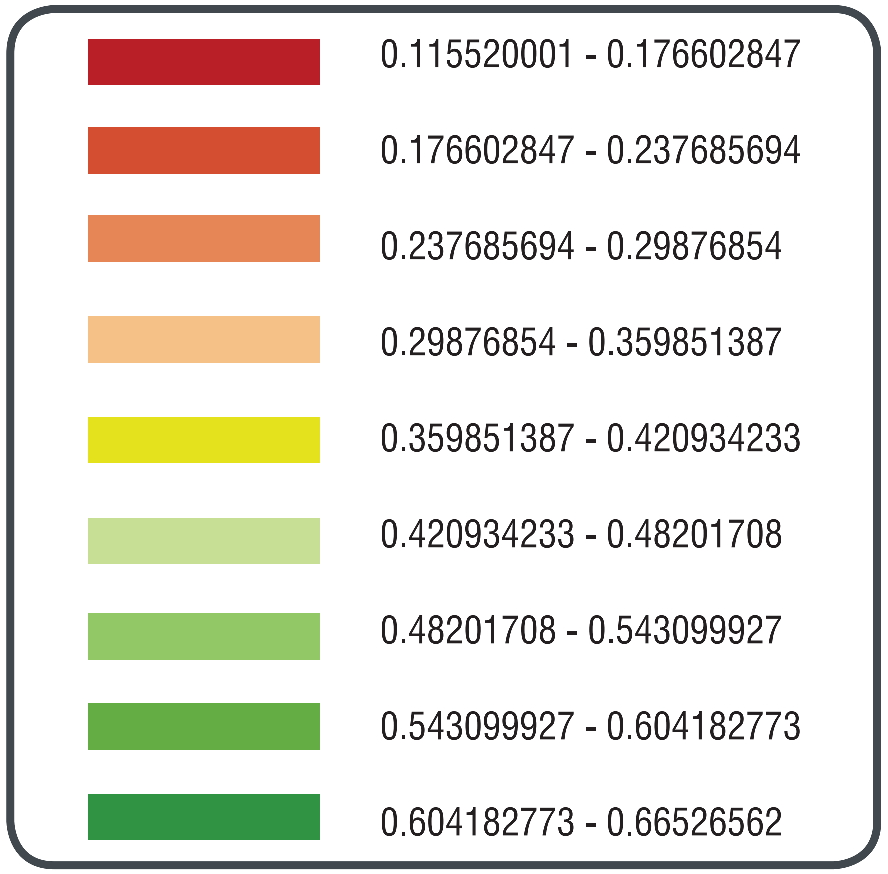
Accessibility

Date: 2019

Case Study: San Salvario



Map 38: Accessibility



E1-Sidewalk condition
E2-Number of footpaths
E3-Network integration in the urban fabric
E4-Proximity to 13 categories

Regarding accessibility, it can be seen that in the middle of San Salvario, there are generally more facilities, such as local markets, cinema, pharmacies and etc. In addition, sidewalk conditions and integration of streets with the whole city have effected on this map. By contrast, far from the middle of this district, the accessibility will be reduced.

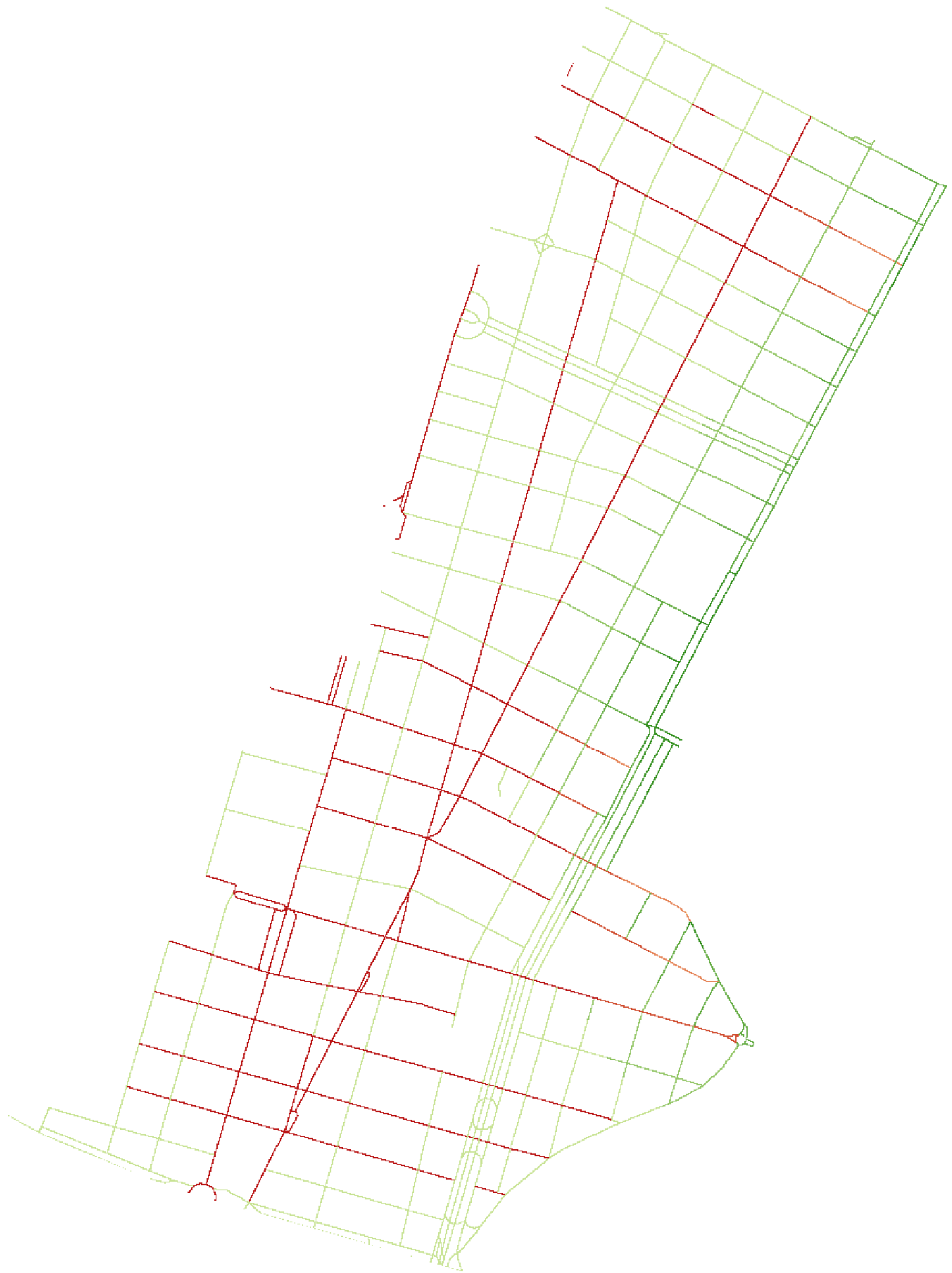
Result

F Index Suitability Map

Attractiveness and Aesthetics

Date: 2019

Case Study: San Salvario



Map 39: Attractiveness and aesthetics

	0.001911291 - 0.098458218
	0.098458218 - 0.195005145
	0.195005145 - 0.291552073
	0.291552073 - 0.388099
	0.388099 - 0.484645927
	0.484645927 - 0.581192854
	0.581192854 - 0.677739781
	0.677739781 - 0.774286708
	0.774286708 - 0.870833635

F1-Rows of trees
F2-Public open spaces (Plaza)

This suitability map shows the attractiveness and aesthetics in the neighborhood area. As it can be predicted, in the east side, which is close to the greenery spaces and park, this rate is higher. Another important factor for evaluating attractiveness was the availability of plaza in the streets. Therefore, the streets without plaza and greenery spaces have less attraction.

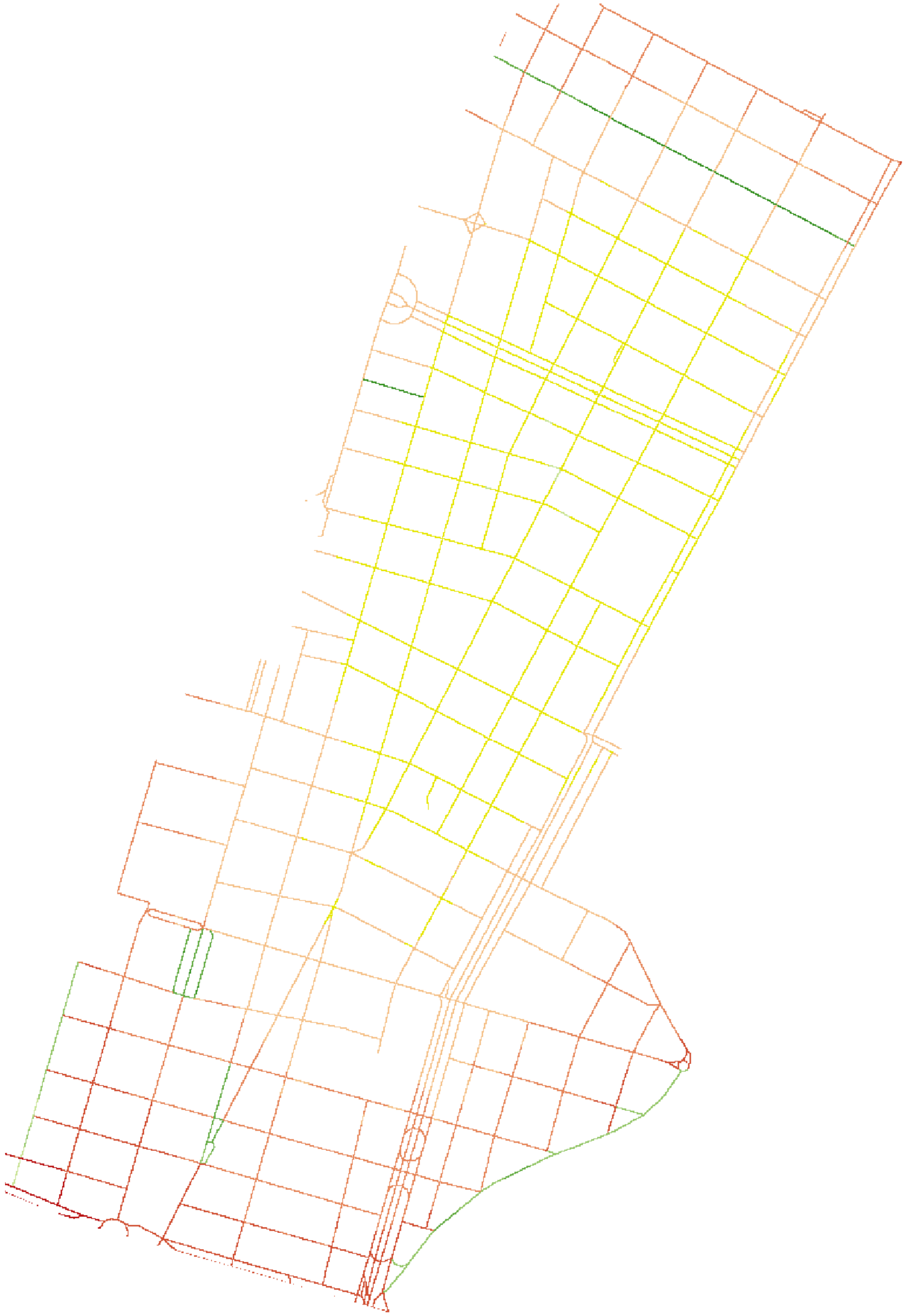
Result

G Index Suitability Map

Pedestrian Infrastructure

Date: 2019

Case Study: San Salvario



Map 40: Pedestrian infrastructure

- 0.007298163 - 0.058223243
- 0.058223243 - 0.109148323
- 0.109148323 - 0.160073404
- 0.160073404 - 0.210998484
- 0.210998484 - 0.261923564
- 0.261923564 - 0.312848644
- 0.312848644 - 0.363773725
- 0.363773725 - 0.414698805
- 0.414698805 - 0.465623885

G1-Pedestrian slope (Disability)
G2-Bicycle lanes
G3-Lighting
G4-Furniture

The suitability map is representing pedestrian infrastructure. As can be observed, in the middle of this district, it has a medium of facilities, in terms of lighting, furniture and bicycle areas. Moreover, when the distance from the center is increasing, generally, the rate of infrastructure will be decreasing.

Result

I Index Suitability Map

Land Use Mix

Date: 2019

Case Study: San Salvario

Map 41: Land use mix

I1-Mixed land use
I2-parks

This map illustrates the mixd land use which are the greenery areas and parks.

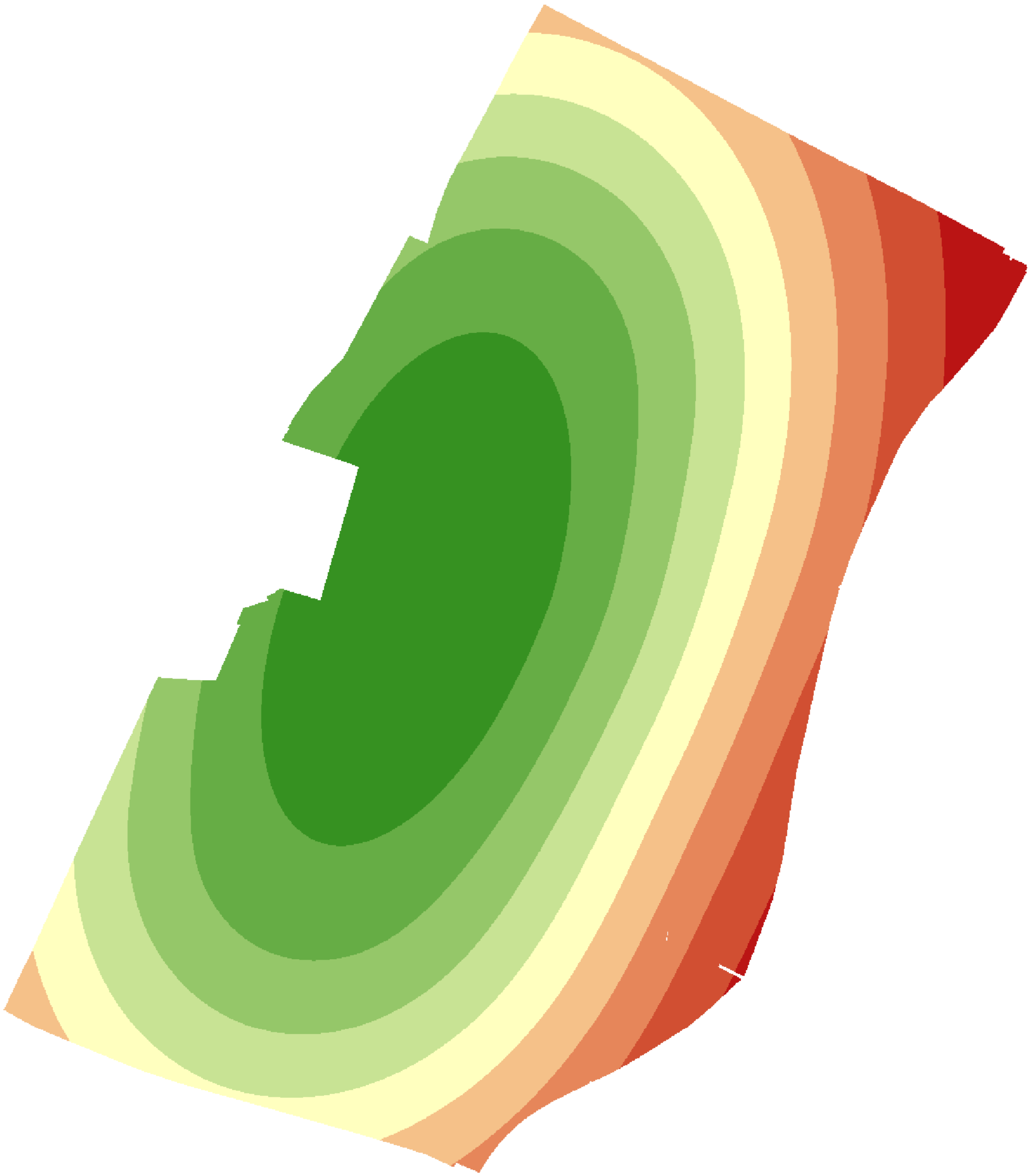
Result

J Index Suitability Map

Street Connectivity

Date: 2019

Case Study: San Salvario



Map 42: Street connectivity

0.002581837 - 0.101639193
0.101639193 - 0.200696549
0.200696549 - 0.299753906
0.299753906 - 0.398811262
0.398811262 - 0.497868618
0.497868618 - 0.596925975
0.596925975 - 0.695983331
0.695983331 - 0.795040687
0.795040687 - 0.894098043

J1-Continuity of walking path
J2-Intersection
J3-Block length
J4-Block width
J5-Public transportation
J6-Modal distribution

According to this suitability, it can be seen that, high rates of connectivity are related to the areas in which there are metro stops and more modal distribution. In the east side, near the architecture faculty of the Polytechnic university of Turin, the rates of connectivity is decreasing.

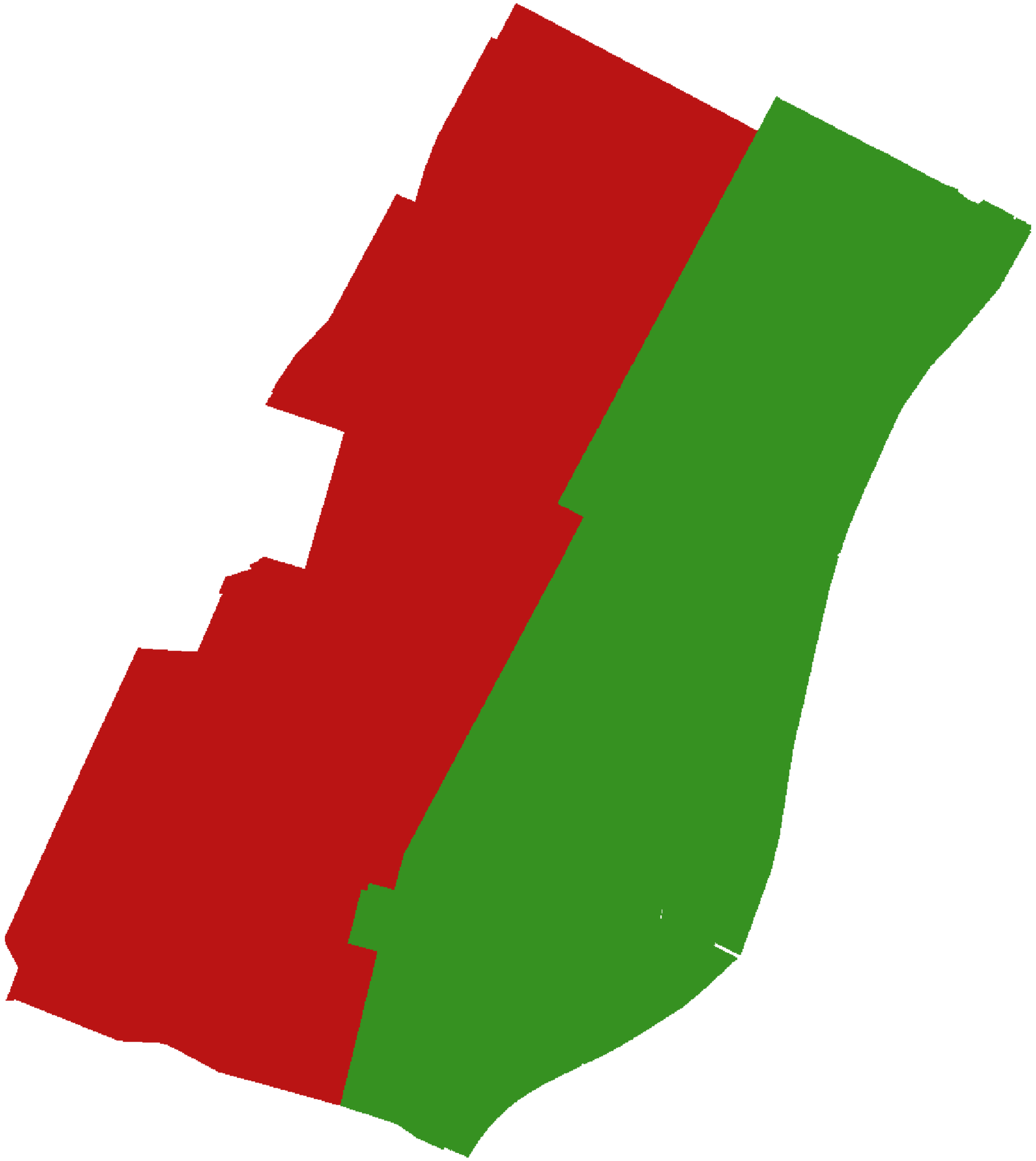
Result

K Index Suitability Map

Economy

Date: 2019

Case Study: San Salvario



	0 - 0.111111111
	0.111111111 - 0.222222222
	0.222222222 - 0.333333333
	0.333333333 - 0.444444444
	0.444444444 - 0.555555556
	0.555555556 - 0.666666667
	0.666666667 - 0.777777778
	0.777777778 - 0.888888889
	0.888888889 - 1

K1-Home Values

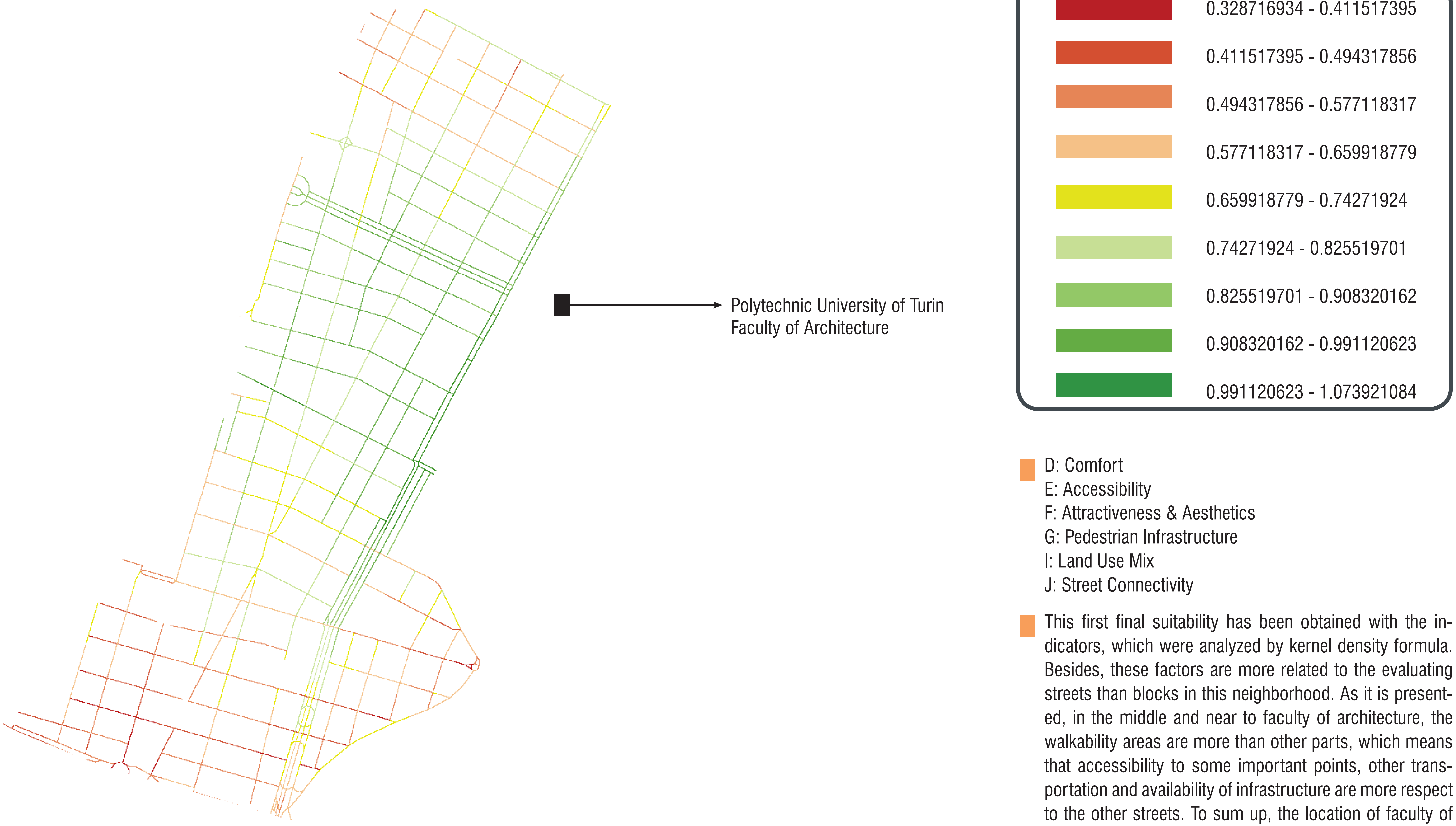
This map depicts the housing values. As can be indicated in this suitability analysis, the home values, which are closer to the park (in the eastern side), are higher. By contrast, in the western part, the home values are decreasing.

Map 43: Economy

Final Suitability map

Date: 2019

Case Study: San Salvario



Map 44: Final suitability map 1

D: Comfort
E: Accessibility
F: Attractiveness & Aesthetics
G: Pedestrian Infrastructure
I: Land Use Mix
J: Street Connectivity

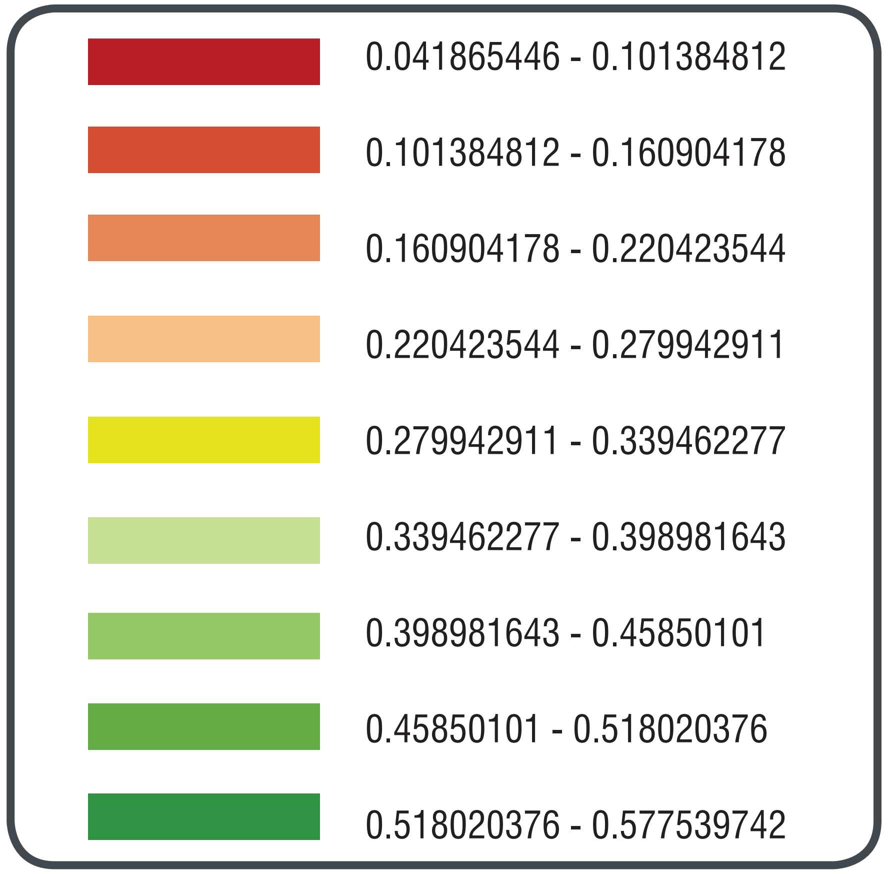
This first final suitability has been obtained with the indicators, which were analyzed by kernel density formula. Besides, these factors are more related to the evaluating streets than blocks in this neighborhood. As it is presented, in the middle and near to faculty of architecture, the walkability areas are more than other parts, which means that accessibility to some important points, other transportation and availability of infrastructure are more respect to the other streets. To sum up, the location of faculty of architecture is highly suitable in terms of walkability.

Final Suitability map

Date: 2019

Case Study: San Salvario

Map 45: Final suitability map 2



A: Demographic Characteristic
B: Density
C: Security
K: Economy

The map illustrates the final suitability map, which analyzed the blocks than streets. As it is shown, the blocks near to the city center and park, which also include faculty of architecture, have more rating of walkability. Whereas in the south parts the condition for the walkability are decreeing. To sum up, it is clear that in the north and east part of San Salvario where generally places are near to the greenery spaces and city center, the walkability ranges are higher.

4- Conclusions and Future Developments

Conclusion

Enhancing walkability in a neighborhood level is a preliminary step and critical part in creating the city livable and sustainable. Because mobility and integration of places with walkable areas and comfort are essential steps for raising sustainability. The objectives of this dissertation are divided into three parts:

- This thesis identified the most relevant indicators through systematic literature review, analyzing and comparisons between assessment tools.
- This research attempted to analyze each indicator in the neighborhood level quantitatively. Because the relevant indicators which have been obtained consist of both qualitative and quantitative characteristics.
- The case study has been selected in order to illustrate the methodology application. By this case study, which was San Salvario neighborhood in Turin, all of the indicators, have been assessed and visualized by ArcGIS software in order to analyze walkability.

As it was shown, there were the two final suitability maps. By these two maps, some recommendations are going to be provided for increasing walkability:

- Providing pedestrian areas with shaded elements and covering roof for walking in different climate conditions.
- Providing more trees and greenery specs at pedestrian walkways. (Except for the existing park in the west side and some main roods that have trees)
- Installation of infrastructure can encourage residents for walking (there are lack of furniture and facilities in many parts)
- Improving the sidewalk condition (as it was analyzed approximately 30 percent of streets have poor and very poor in terms of pathway assessment)
- Enhancing neighborhood safety will increase the walkability.
- Designing the neighborhood area by considering mix land use to provide the whole neighborhood's needs.

Limitation

However, there were some limitation and difficulties for this kind of walkability analysis. First of all, impact assessment of the indicators (31) were involved a lot of time and effort to gather information, due to the fact that this urban area consists of grids and analyzing each street was greatly significant for obtaining final results. Then, fining some information were not possible and hard to obtain (in this case study, 6 from 37 of indicators have not been calculated).

Future developments

This mixed-use methodology, which means analyzing walkability base on sustainability indicators, can be adapted in other neighborhood areas to assess the walkable conditions.
Moreover, some suggestions are propose for the future developments:
Since the walkable areas are undoubtedly related to pedestrian, it will be useful that in the further research, the people flow will be analyzed. Because apart from urban' features that until now have been assessed, the pedestrian movements are influential. Then, at the same time, it will be evaluated the people flow and built environments' characteristic to obtain precisely walkability in order to promote convenient conditions.
Another noticeable point is that, it will be also useful that for further developments, each of indicators will be assessed and then again calculated to see how much it will be affected on walkability. To clarify this issue, it will be highly helpful to provide different alternatives to observe and evaluate walkability. Thus, it will be selected the best solution by designers and stakeholders.

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