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Master Thesis

Designing Squares with Climate
An Assessment of Transit-Oriented Development (TOD) projects, United States

Supervisor
Prof. *Maurizio Tiepolo*

Candidate
Giovanni Foresto

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Abstract

Transit-Oriented Development is a planning pattern based on a transit station that includes high density and mixed-use environments that favor cycle and pedestrian pathways. The Transit-Oriented Development primary goal is to mitigate climate change by reducing private mobility and increasing public transports. This thesis's purpose is to discover whether and how the new public squares created within the Transit-Oriented Development provide mitigation and adaptation measures to face climate change. The thesis starts arguing the negative and unsustainable sprawl pattern that characterizes the United States suburbs and the related car-dependency, making the automobile usage one of the principal contributors to greenhouse gas emissions. It is within this context that the Transit-Oriented Development pattern represents a sustainable and alternative development to sprawl. The square created in front of the stations becomes the center of the development, which considers pedestrians in the first place. In the case studies analyzed, different climate needs and impacts emerge according to the Transit-Oriented Development geographical location. Although mitigation measures are sufficiently provided in each case study, allowing walkable pathways that link the public square and the station with the surrounding neighborhood, adaptation measures only partially take place, making the Transit-Oriented Development's public squares more inclined to create pedestrian-friendly environments, rather than climate adaptable. The research leads to understanding the gap between these two climate measures through identifying differences of scales, besides the objectives. In fact, having the Transit-Oriented Development pattern a regional approach, it is oriented to achieve mitigation measures, rather than adaptation, which requires a more detailed Urban Design process to be completely flexible according to the different climate change impacts.

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Dedication

a Lando, Ricki, Mamma e Papà
alla Banda e a Lukino
alla mia Raposa
ai miei amici e compagni di Università

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List of Acronyms and Abbreviations

BART	Bay Area Rapid Transit
CC	Climate Change
CNU	Congress of the New Urbanism
CLUHI	Canopy Layer Urban Heat Island
CO_2	Carbon dioxide
EPA	Environmental Protection Agency
EH	Extreme Heat
EHE	Extreme Heat Event
ET	evapotranspiration
FEMA	Federal Emergency Management Agency
FTA	Federal Transit Administration
GHG	Greenhouse Gases
H/W	height to width ratio
IDA	International Dark-Sky Association
IPCC	Intergovernmental Panel on Climate Change
KAB	Keep America Beautiful
KCC	Köppen Climate classification
KTC	Köppen-Trewartha classification
LED	Light Emitting Diode
MDGs	Millennium Development Goals
NCDC	National Climatic Data Center
NDMC	National Drought Mitigation Center
NOAA	National Oceanic and Atmospheric Administration
NRDC	Natural Resources Defense Council
NSC	National Safety Council
NUA	New Urban Agenda
PPS	Project for Public Spaces
SDGs	Sustainable Development Goals
SUHI	Surface Urban Heat Island
TCRP	Transit Cooperative Research Program
TND	Traditional Neighborhood Development
TOD	Transit-Oriented Development
UCSUSA	Union of Concerned Scientists United States of America
UNFCCC	United Nations Framework Convention on Climate Change
UHI	Urban Heat Island
ULI	Urban Land Institute
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States (of America)
WRI	World Resource Institute

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List of Figures and Tables

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Table 4.1 – Types of cool pavements according to solar reflectance and application
Source: Author's re-elaboration based on data taken from: "Heat Island: Understanding and Mitigating Heat in Urban Areas" (Gartland, 2008, p. 92-99)
Table 4.2 - Flood adaptation measures to flooding and examples
Source: Author's re-elaboration based on: (Silva & Costa, Flood Adaptation Measures Applicable in the Design of Urban Public Spaces: Proposal for a Conceptual Framework, 2016, p. 7-9)

Chapter 5

Figure 5.1 – KTC in the U.S.
Credit: Adam Peterson (22 September 2016)
Source: Wikipedia (https://en.wikipedia.org/wiki/Trewartha_climate_classification#/media/File:US_trewartha.svg)
Figure 5.2 - Map of Extreme Heat days by US county
Source: (National Resource Defense Council, s.d.)
Figure 5.3 - Map displays the number of weeks counties that have experienced D3 drought or greater
Credit: © Becky Bolinger
Source: (Bolinger, 2019)
Figure 5.4 - Map displays the number of weeks counties that have experienced D4 drought
Credit: © Becky Bolinger
Source: (Bolinger, 2019)

Wilshire Vermont (Los Angeles, California)

Figure 5.5
Source: Urban Land (https://urbanland.uli.org/development-business/remaking-greater-los-angeles-transit-oriented-region/)
Figure 5.6,5.8
Source: Realtor (https://www.realtor.com/realestateandhomes-detail/3183-Wilshire-Blvd_Los-Angeles_CA_90010_M21833-75972)
Figure 5.7
Source: AHBE (http://www.ahbe.com/portfolio/wilshire-vermont-station)
Figure 5.9
Source: Yelp (https://www.yelp.com/biz/wilshire-vermont-red-and-purple-line-station-los-angeles?start=20)
Figure 5.10
Source: Trulia (https://www.trulia.com/c/ca/los-angeles/wilshire-vermont-3183-wilshire-blvd-los-angeles-ca-90010--2077203061)

Fruitvale Village (Oakland, California)

Figure 5.11, 5.10, 5.13
Source: PGAdesign (https://pgadesign.com/projects/fruitvale-transit-village/)
Figure 5.14
Source: Hiveminer (https://hiveminer.com/Tags/architecture%2Cfruitvale)
Figure 5.15
Source: Author's production from Google Earth

Orenco Station (Hillsobro, Oregon)

Figure 5.16
Credit: © Buhacoff
Source: Flickr (https://www.flickr.com/photos/16709507@N02/26629045313/in/photolist-Gz7PqV-4tc7QJ-51oP8U-7QEtT-5zDt9u-i9stN2-5zzbpp-4aXo4G-nzZrgp-Nz1k2Z-2cfMqaj-Qcnmbs-F1EKB-Bsdrm-Bijs8p-9TjfJs-9Tjfhy-9Tgxd4-4t84LP-7JFnCf-9Tgt7v-kkaV3x-7JBrL4-7JBrGc-7JBrKr-7JFnJU-7JBrNp-7JFnJ7-7JBrCe-7JBrzM-7JBrDZ-7JFnQb-7JBrSV-9Tgs5z-9TgxM8-9Tjg29-9TjfqE-31ivzk-9Tgx86-9TgrWV-AfvhUS-9Tgsdc-9TjmRh-9Tgy3D-9Tgrgx-pm3uUD-9TjcN1-9Tjmbo-9TgsjX-9Tjkjy)
Figure 5.17, 5.18
Source: Author's production from Google Earth
Figure 5.19
Source: Congress for the New Urbanism (https://www.cnu.org/publicsquare/2018/05/02/connected-and-walkable-suburb)
Figure 5.20
Credit: © S. Morgan, 2016
Source:(https://commons.wikimedia.org/wiki/File:Orenco_Station_Plaza_and_Rowlock_Apartments_(2016).jpg)

Figure 5.21
Credit: © M.O. Stevens
Source: (https://commons.wikimedia.org/wiki/File:Orenco_Station_Plaza_Oak_tree_-_Hillsboro,_Oregon.jpg)

CityPlace (West Palm Beach, Florida)
Figure 5.22
Source: Casa Grandview (https://casagrandview.com/blog/tag/entertainment)
Figure 5.23
Source: West Palm Beach (WPB) Magazine (https://www.wpbmagazine.com/the-plaza-in-cityplace-west-palm-beach/)
Figure 5.24
Source: The Dish (https://thedish.blog.palmbeachdailynews.com/tag/taste-of-cityplace/)
Figure 5.25
Source: Author's production from Google Earth
Figure 5.26
Source: Mommy Nearest (https://www.mommynearest.com/edition/south-florida/article/15-best-things-to-do-in-west-palm-beach-with-kids)
Figure 5.27
Source: Waterfront Properties and Club Communities (https://www.waterfront-properties.com/blog/cityplace-getting-a-new-name.html)

Market Common (Arlington, Virginia)
Figure 5.28, 5.30
Source: Antunovich Associates (*https://www.antunovich.com/projects/mixed-use/the-market-common-clarendon*)
Figure 5.29
Credit: © Bozzuto Group
Source: Flickr (https://www.flickr.com/photos/bozzuto/4686327754/)
Figure 5.31, 5.32
Source: Jacobs/Ryan Associates (http://www.jacobsryan.com/New%20Pages%202013/513%20-%20Urban%20Design%20People%20Places%20-%20Market%20Common%20Clarendon.html)

Rockville Town Center (Rockville, Maryland)
Figure 5.33
Credit: © Dan Reed (27 September 2013)
Source: Flickr (https://www.flickr.com/photos/thecourtyard/11667046585/in/photolist-iLYEtB-dqLbGg-5bA3M5-8HgvMm-5bvKaD-5bA3FA-5bA3vd-5bvKLD-5bvKEB-5bvKtx-5bA34Y-5bvKiD-6yQimo-9CLWnb-arAvB3-dqLm3y-9CLWQy-QeEPnZ-5bA371-5bvKqT-5bA3Ab-9CJ23g-5bvK8g-5bvKm2-9CLX3C-5bvKgt-9CJ1TB-5bA3oY-roHVkt-5bvKyM-5bvKoD-6UyaEL-feuW8R-8HgvK7-2hhfAqE-2fDoE7-5tsw5J-cwpv1b-dqLbRc-2gxuiu-fEharD-dqLkWU-UzGuU3-fEhasX-dN1Kt5-MTuPZ-4VSQrh-5WnX5a-2hhfAS6-5tsvim)
Figure 5.34
Credit: © Simmons B. Buntin
Source: (Buntin, 2011)
Figure 5.35
Credit: © Dan Reed (26 May 2007)
Source: Flickr (https://www.flickr.com/photos/thecourtyard/519250042/in/photolist-MThWW-dG3fav-63P9DT-dG8Fgb-dG3gBF-dG3fmH-dG8Etw-B4atc-dG8F3w-dG3g2D-dG3gc4-dG3g6p-dG3fxi-dG8Fnj-dG3fMB-dG8EA7-dG8EYw-dG8FCd-dG8Epb-dG8EQq-dG8FJE-dG3gtB-dG3fhT-otuc7c-7Jd4rb-9CLWLd-dG3f7X-dG8F6m-dG3gyF-MTsQc-5bvKSD-dG3f2X-r7gSDD-2hNuRM-dG8F89-2hheCmE-iLYEtB-dqLbGg-5bA3M5-8HgvMm-5bvKaD-5bA3FA-5bA3vd-5bvKLD-5bvKEB-5bvKtx-5bA34Y-5bvKiD-6yQimo-9CLWnb/)
Figure 5.36
Credit: © Dan Reed (16 August 2012)
Source: Flickr (https://www.flickr.com/photos/thecourtyard/8156498023/in/photolist-dqLbGg-5bA3M5-8HgvMm-5bvKaD-5bA3FA-5bA3vd-5bvKLD-5bvKEB-5bvKtx-5bA34Y-5bvKiD-6yQimo-9CLWnb-arAvB3-dqLm3y-9CLWQy-QeEPnZ-5bA371-5bvKqT-5bA3Ab-9CJ23g-5bvK8g-5bvKm2-9CLX3C-5bvKgt-9CJ1TB-5bA3oY-roHVkt-5bvKyM-5bvKoD-6UyaEL-feuW8R-8HgvK7-2hhfAqE-2fDoE7-5tsw5J-cwpv1b-dqLbRc-2gxuiu-fEharD-dqLkWU-UzGuU3-fEhasX-dN1Kt5-MTuPZ-4VSQrh-5WnX5a-2hhfAS6-5tsvim-f3qaAM)
Figure 5.37
Credit: © Simmons B. Buntin
Source: Terrain (https://www.terrain.org/unsprawl/27/)

Pentagon Row (Arlington, Virginia)
Figure 5.38, 5.43
Source: Mahan Rykiel Associates Inc. (https://www.mahanrykiel.com/portfolio/pentagon-row/)
Figure 5.39
Source: Row (http://pentagonrow.com/?attachment_id=2694)
Figure 5.40
Source: Ridge House Condominiums (https://www.arlingtonridgehouse.com/ridge-house-arlington-virginia-pentagon-city-shopping-and-dining)
Figure 5.41
Source: MAA (https://www.maac.com/virginia/dc-metro/post-pentagon-row/)
Figure 5.42
Source: StayArlington (https://www.stayarlington.com/directory/pentagon-row/)

Richmond Village (Oakland, California)
Figure 5.44, 5.48
*Source: HDR Calthorpe (*https://www.calthorpe.com/richmond-transit-village*)*
Figure 5.45
*Source: Reimagine (*https://www.reimaginerpe.org/taxonomy/term/161*)*
Figure 5.46
Source: Richmond Confidential (https://richmondconfidential.org/2013/10/18/scenes-from-the-bart-strike/)
Figure 5.47
Source: BART (https://www.bart.gov/about/business/tod/completed)
Figure 5.49
Credit: © Pi.1415926535 (13 April 2018)
Source: Wikimedia Commons
(https://commons.wikimedia.org/wiki/File:Richmond_station_canopy_from_parking_garage_(3),_April_2018.jpg)

Santana Row (San Jose, California)
Figure 5.50
Credit: © Ryan Ritchie
Source: Los Angeles Times (https://www.latimes.com/travel/california/la-tr-d-san-jose-escape-20141102-story.html)
Figure 5.51
Credit: © Sergio Ruiz
Source: SPUR (https://www.spur.org/events/2017-02-02/santana-row-effect)
Figure 5.52
Source: Design for walkability SPUR (http://www.designforwalkability.com/casefive)
Figure 5.53
Source: SB Architects (http://www.sb-architects.com/project/santana-row/)
Figure 5.54
Source: San Jose (https://www.sanjose.org/neighborhoods/santana-row)
Figure 5.55
Source: San Jose (https://www.sanjose.org/listings/santana-row)

The Gateway (Salt Lake City, Utah)
Figure 5.56
Source: Building Salt Lake (https://www.buildingsaltlake.com/2018-big-year-gateway/the-gateway-olympic-fountain/)
Figure 5.57
Source: Pentax Forums (https://www.pentaxforums.com/gallery/photo-olympic-legacy-plaza-fountain-21268/&u=7629)
Figure 5.58, 5.59, 5.60
Source: Source: Author's production from Google Earth

Glossary

Adaptation

"The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects." (IPCC, Annex II: Glossary [Mach, K.J.; Planton, S.; von Stechow, C. (eds.)], 2014a, p. 118)

Climate change

"Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use." (IPCC, Annex II: Glossary [Mach, K.J.; Planton, S.; von Stechow, C. (eds.)], 2014a, p. 120)

Mitigation

"A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)." (IPCC, Annex II: Glossary [Mach, K.J.; Planton, S.; von Stechow, C. (eds.)], 2014a, p. 125)

Transit-Oriented Development

"A Transit-Oriented Development (TOD) is a mixed-use community within an average 2,000-foot walking distance of a transit stop and core commercial area. TODs mix residential, retail, office, open space, and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot, or car." (Calthorpe, The Next American Metropolis: Ecology, Community, and the American Dream, 1993, p. 56)

Urban Design

"Urban design is the design of towns and cities, streets and spaces. It is the collaborative and multi-disciplinary process of shaping the physical setting for life in cities, towns and villages; the art of making places; design in an urban context. Urban design involves the design of buildings, groups of buildings, spaces and landscapes, and the establishment of frameworks and processes that facilitate successful development." (Urban Design Group, s.d.)

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CONTENTS

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Introduction

We are all witnesses and conscious that climate change is on-going. Many are the forms in which such changes can occur, anomalous events can be found from global to local scales, threating the places where we live as never before. Warmer temperatures and climate alterations result in hotter heat waves, stronger flooding and storms, and longer-lasting drought, which are already taking place, hitting the planet tangibly and leaving indelible scars. The impacts on humans, the economic sector and the environment (both the natural and the build one) are huge. Cities around the world are being interfaced in the fight against climate change through the development of sustainable planning policies and strategies especially aiming to reduce GHG emissions. Among these strategies, the Transit-Oriented Development (TOD) proposes a planning pattern based on a transit station around which develops a neighborhood whose main objectives include reduce private mobility and increase density and mixed-use to favor public transport mainly by rail. This kind of intervention primary targets suburban zones, characterized by sprawl developments where weak infrastructural connections, minimum density, mono-use result in car-dependent environments and greater contributors to GHG emissions per capita than urban areas. The unsustainable sprawl development is the issue New Urbanists care the most. New Urbanism is a movement emerged at the end of the 20th century from the encounter between planning theories born from schools of thought in the United States of America. Experts like Calthorpe (1993, 2011), Duany (2002) and Plater-Zyberk (2000, 2003), Speck (2018) and many others, concentrate their ideas to face sprawl development through alternative solutions such as the Traditional Neighborhood Development (TND) and, indeed, the TOD.

To achieve its goals, one of the strategies provided by TOD is the creation of a vibrant square next to the transit station instead of the usual parking lots, making the public square the crucial node of the neighborhood. Therefore, the thesis focuses on the public square in U.S. TOD projects and on its design toward tackling climate change. Public spaces are of paramount importance for the community fortunes, and the square is the public space by definition. In order to tackle climate change, a set of sustainable solutions have been grouped within two broader containers and have been applied in the public square context: the mitigation measures and the adaptation measures. The first group aims to reduce GHG emission, thus, in the case of the public square, walkability is the mandatory aspect the square should offer and implement. The second group aims to increase the ability of public squares to adapt to (climate) changes. Both the measure types can be achieved through

Urban Design, a process encompassing and dealing with a broad range of sciences, from social to architectural ones. Urban designers such as Jacobs (1961) and Lynch (1960, 1942), started to create sustainable principles since the second half of the 20th century, setting the design pillars on which today's urban environments are based. Recently, with the increasing environmental problems, designers such as Carmona (2003, 2009), Lang (1994, 2005), Gehl (2010, 2011, 2013) and Moughtin (2003) offer urban design solutions to better accommodate the current urban needs, including the climate changes. Through Urban Design theories and principles, mitigation and adaptation measures can both create a more pedestrian-friendly environment while, at the same time, be able to shape the square and its surroundings in a flexible and efficient way. Therefore, Urban Design is regarded in this instance as the vehicle through which the public square can face and respond to climate change. Therefore, the thesis tries to answer the question: are the TOD's public squares properly designed to face climate change? Besides mitigation, are adaptation measures also considered within the public square design process? And, if yes, how?

To answer these questions, the thesis has been structured in three main parts. The *PART I – Today's challenge* introduces the thesis topic giving a general framework about the Urban Heat Island, flooding and drought events, the most impacting climate changes in the U.S. the New Urbanism ideas, grouped in the Charter of New Urbanism, are explained to bring in the TOD pattern, recognized by the current global Agendas addressed to sustainable developments. Subsequently, the *PART II - Square Design* focuses on the different strategies, applicable at the local scale, that help to tackle climate changes. Fourteen mitigation and fourteen adaptation measures have been extrapolated by mixing the Urban Design principles identified by Carmona in *Public Places Urban Spaces: The Dimensions of Urban Design* (2003), with the literature available on both walkability (Carmona, 2009; Gehl, 2010, 2011, 2013; Jacobs, 1961; Lang, 1994, 2005; Speck, 2018; White, 1980), to define mitigation measures, and on urban elements that minimize climate impacts (Gartland, 2008; Oke, 1997, 2017; Santamouris, 2001, 2004; Silva & Costa, 2016, 2018), to define adaptation measures. In *PART II*, the research's radius has been limited to the public square and its proximity, so both the measures do not consider the public square itself, but they have been slightly expanded in order to plan squares in coherence with their surroundings, rather than being isolated and detached from the urban context. Therefore, mitigation measures consider also the block size, whilst, the adaptation measures encompass also the buildings at the edge of the square, in terms of envelopes and orientation. The last *PART III - Case studies*, finally, regards ten case studies and represents the practical application of the principles and theories developed in the previous parts.

Each case study has been developed and analyzed according to the climate and geographical location because, even if the climate impacts identified in the first *PART I* (the Urban Heat Island effect, flooding and drought) can occur everywhere worldwide, especially the lasts two, they can impact differently according to the location. In fact, what climate change means, actually, is that it strengthens the impacts that would naturally occur, enlarging heatwaves and drought periods, and empowering storms. Some areas are more vulnerable to one or more hazards than others, according to the climate regions and to the elements at risk. Therefore, urban and suburban settlements should be prepared to properly respond to such events, and, at the same time, to accommodate them more softly. In order to understand if the TOD project areas are more or less subjected to the UHI effect and/or flooding and/or drought, each case study analysis has been developed through three steps.
First, the UHI effect is a though impact to measure to compute and assess and, although every Comprehensive Plan of the ten TOD project's cities has been consulted, the information resulted inhomogeneous and they were often lacking. Therefore, the UHI effect intensity has been extrapolated in relation to the Extreme Heat (EH) days per county. This was possible through the interactive map supplied by the NRDC (National Resource Defense Council, s.d.). Although the map does not refer to the real UHI effect values, the information provided by the number of days with EH is of significant importance due to the close link between UHI and temperatures. In fact, the number of days with EH will be more severe in dense urban areas than in the rural ones; thus, the location of the TOD project (T3/T4/T5) will be the discriminant factor to determine the UHI effect in each TOD project.
As suggested by the NRDC, the EH have been grouped into three class in order to define the level of intensity the different US counties are subjected to. Therefore, counties up to 9 days (included) are classed as low subjected to UHI and EH, those from 9 to 14 days as medium subjected and those over 14 days as highly subjected.
Second, to define the level of risk of flooding, it has been carried out a research through the online tool FEMA Flood Map Service Center (Federal Emergency Management Agency, 2019) to understand the flooding hazard of the TOD areas interested by the research. Three classes of risk have been identified according to the FEMA classification. Therefore, three classes have been extrapolated according to the level of risk: *Low risk*, *Moderate risk*, and *High risk* of flooding.
Third, it has been conducted the same operation to verify drought occurrence through the maps obtained using data from the U.S. Drought Monitor for the last two decades (1999-2019. Due to lacking information about long-period data, the only significant levels of drought available that have been considered are the two most grave: the D3 - Extreme Drought and the D4 - Exceptional Drought. As for the other climate impacts, also for the

evaluation of drought, the intensity has been considered by grouping the weeks of drought occurred in the last two decades into three ranges: from 0 to 50 weeks, from 50 to 150 weeks and the most severe conditions from 150 weeks ahead.

Subsequently, to verify if and how the twenty-eight climate measures (14 measures aiming at mitigation and 14 measures aiming at adaptation) take place in each case study, a "virtual survey" through the use of Google Maps Street view tool and Google Earth software has been performed, allowing the assessment of the TOD's public square from the climatic side point of view. The results are represented in different sheets, one for each case study, that summarize the virtual survey highlights.

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PART I

Today's Challenge

Introduction

The first chapter explains why the thesis focuses on the climate side of public elements in North American urban and suburban settlements. It starts to dig towards the public plaza and square, giving a general overview of climate changes in the U.S. through a brief summary of the recent climate conditions that will be useful to illustrate the contribution's weight that the U.S. gives to the overall global warming. Later, the chapter will try to make understand what are the reasons of such changes with an emphasis on the constantly increasing world population, a variable that should be controlled and well accommodated rather than limited (although it would help significantly). The chapter, then, focuses on one of the main causes of climate change: the phenomenon of sprawl and the related automobile dependency that make the suburban households larger Co_2 consumers compared to more city areas, as explained in the *Transit Cooperative Research Program* (TCRP) Report 93 (Feigon, et al., 2003). The document compares the emissions per square miles of three similar cities (Chicago, Los Angeles, and San Francisco) with their suburbs and the emissions per household of the same cities. The results show that the city areas produce more GHG emissions overall but, considering the production per household, the result overturns showing that "the transportation efficiencies of dense urban areas emerge clearly" (Feigon, et al., 2003, p. 21). Chapter 1 then turns towards the impacts generated by CC focusing on those affecting more urbanized areas: the Urban Heat Island (UHI) effect, floods, and droughts. To conclude, a brief overview of mitigation and adaptation measures are explained and proposed as the two most common approaches to battle CC, which will be further explained in *PART II*.

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1. Climate Change in the U.S.

Before start discussing public squares, it is appropriate to define the reasons why we are arguing about today's need to have such a well-planned city element. Today we are facing the biggest challenge humans have ever faced: global Climate Change (CC). If we look at CC from a negative perspective, we can say that we are feeding CC day by day just by living our ordinary lives. The Intergovernmental Panel on Climate Change (IPCC) is the United Nations (UN) organization that studies the global warming phenomenon by monitoring data and developing analysis about global CC. As reported in its Synthesis Report (2014), "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history" (IPCC, 2014b, p. 2). The Summary gives many warring information about climatic change conditions regarding the atmosphere and the sea levels that are "unprecedented over decades to millennia" (IPCC, 2014b, p. 2).

It is quite common knowledge that global warming is now ongoing, and its consequences are already taking place. It is difficult to foresee precise future predictions, but past forecasts from the IPCC and other climate organizations guessed, were worryingly right (Kirkegaard, 2018), so we should care for the current ones. Even if world is polluting since the Second Industrial Revolution (1870-1914) we have now reached a tipping point to preserve our planet for the next future generations and the IPCC (2014b) is keen to stress that "continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system" (IPCC, 2014b, p. 8). Thus, our objectives have to be shared and the maximum efforts are needed because "Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks" (IPCC, 2014b, p. 8).

Climate change has disturbing effects mainly on our biodiversity, natural and environmental systems and, consequently, also on us as human species. There are several effects in which CC manifests itself: heatwaves, floods and droughts, ocean acidification and many others leading to species migrations and their habitat adaptations. Humans must be included in this discussion. An example is given by observing the glaciers which are melting rapidly, therefore, sea-level rise proceeds aggressively towards coastal cities and people may be forced to migrate from their houses sooner than they think. Climate Change also impacts plants and upon the agriculture sector, influencing food and water storage threatening human's diet and health.

The celebrated movie *The Matrix* (1999), is plenty of references to CC and our present conditions. For examples, *Agent Smith* stated that:

> "Every mammal on this planet instinctively develops a natural equilibrium with the surrounding environment but you humans do not. You move to an area and you multiply and multiply until every natural resource is consumed and the only way you can survive is to spread to another area. There is another

> organism on this planet that follows the same pattern. Do you know what it is? A virus. Human beings are a disease, a cancer of this planet." (Wachowski, 1999)

This movie monologue clearly explains that CC is actually a paradox. Whoever would jeopardize its own future? It can be considered a terrible exaggeration, but I think the concept is truer than ever.

We must take into account that CC is strictly related to population growth. An increase in population means more space needed to accommodate them, more food to feed them, more garbage produced, and more resources are required to be consumed. In other words, the higher the population, the higher will be the overall human footprint, obviously. Today, the *World Population Review* believes that the total world population is around 7,75 billion, the 4.27% (or 329,953,409 people) of which lives in the U.S. resulting in the third most populated country (World Population Review , s.d.). The UN predicted that the world population "projected to reach 8.5 billion in 2030 and to increase further to 9.7 billion in 2050 and 11.2 billion by 2100" (United Nations, s.d.).

Today is commonly acknowledged that by limiting our own footprint living in a healthier and more sustainable way will be enough to solve CC. This is would be extremely helpful, but "unsustainable human population growth can overwhelm those efforts, leading us to conclude that we not only need smaller footprints, but fewer feet" (Center for Biological Diversity, s.d.).

There are several initiatives spread around the world about limiting procreation due to worrying population growth, from measures about women education and empowerment to family planning strategies. These actions can truly help to achieve goals towards a sustainable global population. But actually, considering also that the longevity rate is constantly increasing since the 1960s (The World Bank Data, s.d.), we should take into account that the population most likely will continue to surge. However, although our efforts are weak to in this sense, we can do put much more exertion on how to accommodate the current and the future population through adequate and reasonable urban planning.

1.1. Causes

This paragraph will explain why sprawl phenomenon is considered one of the main causes of the rising Co_2 emission values in the U.S., making North America one of the main contributors to global CC. How much we grow is important and it deserves our maximum attention, but the way in which we do so is sharply more fundamental. The IPCC and others organizations that deal with CC - like the World Resource Institute (WRI)[1] - tried to address the causes of such increasing global changes by pointing at the anthropogenic emission sources, largely produced through the industrial processes and the transports sector:

[1] https://www.wri.org/

"Globally, economic and population growth continued to be the most important drivers of increases in CO2 emissions from fossil fuel combustion" (IPCC, 2014b, p. 5).
According to the U.S. Union of Concerned Scientist (UCSUSA), China is the country that produces more carbon dioxide (Co_2) emissions worldwide (29% of the total emissions) (UCSUSA, s.d.), besides being the most populated one (with a population equals to 18,59% of the total)[2]. But if we wanted to understand who is the country that most contributed to our actual situation, it might be better to consider the cumulative Co_2 emissions. However, considering the developed countries (within the OECD list)[3], the supremacy directly shifts from the East side of the world to the West side with the U.S. taking the lead in the ranking largely[4]. Unless China is the most worrying current national power, according to Our World in Data from 1751 to 2017 the world has produced over 1,5 trillion Co_2, 25% of which by the U.S. alone (Ritchie & Roser, 2020). According to the Environmental Protection Agency (EPA) analysis, the graphs are shown in Figure 1.1 and 1.2 taken from the U.S. EPA's Inventory of U.S. Greenhouse Gases Emissions and Sinks:

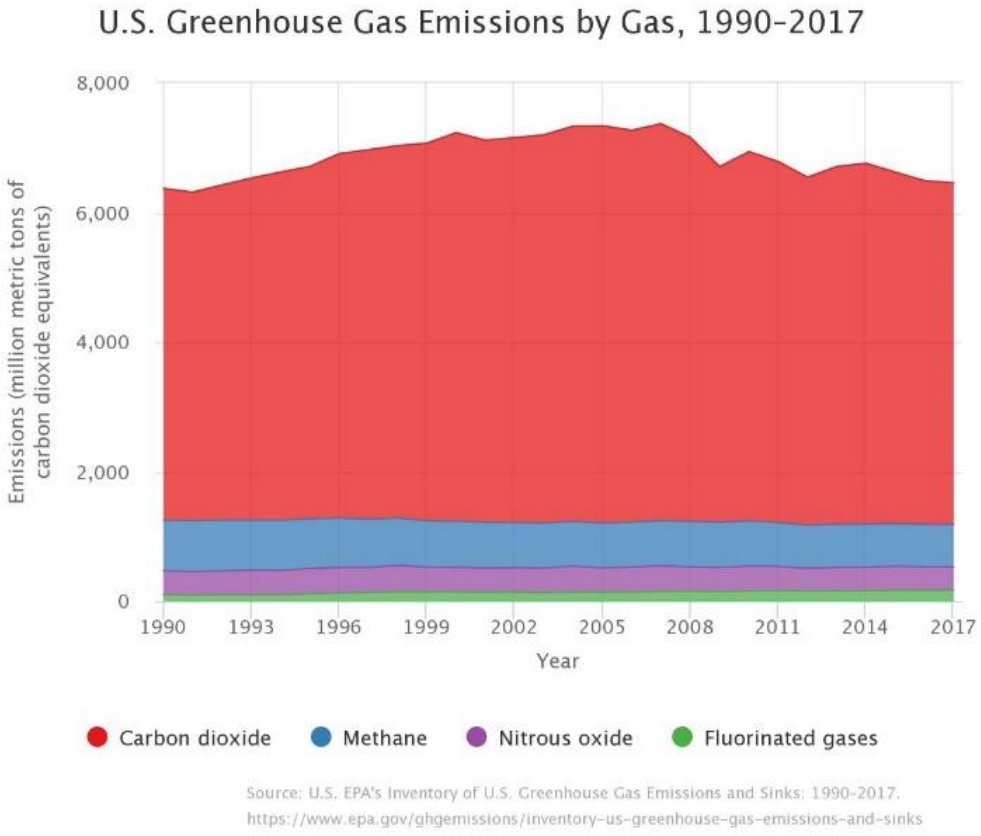

Figure 1.1 – U.S. GHG emissions by Economic Sector (1990-2017)
Source: U.S. EPA's Inventory of U.S. Greenhouse Gases Emissions and Sinks: 1990-2017 (https://cfpub.epa.gov/ghgdata/inventoryexplorer/#allsectors/allgas/econsect/all)

[2] China has a population equals to 1,436,427,647 or the 18,59% of the overall world population (December 2019). Retrieved from: http://worldpopulationreview.com/(2 December 2019)
[3]OECD (*Organisation for Economic Co-operation and Development*): https://www.oecd.org/about/document/list-oecd-member-countries.htm
[4] For further information visit: https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG

1990-2017 (U.S. Environmental Protection Agency, s.d.), clearly help us to understand where to point the finger when talking about CC. Whilst the graph in Figure 1.1 shows that nearly all amount of Green House Gases (GHG) produced in the U.S. is made of CO_2 (carbon dioxide), the graph in Figure 1.2 identifies the principal economic sector that produces CO_2 in the U.S.: the transportation sector.

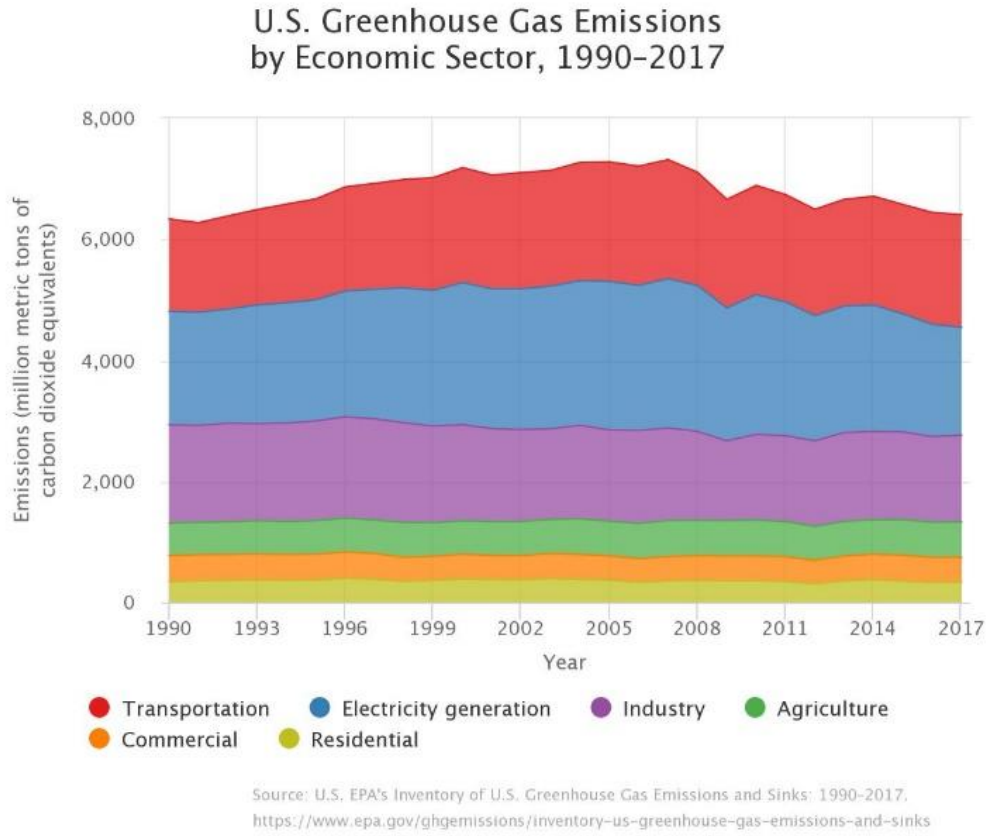

Figure 1.27 – U.S. GHG emissions by GAS (1990-2017)
Source: U.S. EPA's Inventory of U.S. Greenhouse Gases Emissions and Sinks: 1990-2017 (https://cfpub.epa.gov/ghgdata/inventoryexplorer/#allsectors/allgas/gas/all)

By digging down deeper into the topic, confirmations of what explained earlier are found. In fact, according to the data collected by *Our World in Data* in 2014, the motor vehicles ownership value (including automobiles, SUVs, trucks, vans, buses, commercial vehicles, and freight motor road vehicles) per 1000 inhabitants in the U.S. is the higher worldwide (Ritchie & Roser, 2020).

Although today the *United Nations Department of Economic and Social Affairs* (UN DESA) states that the "55% of the world's population lives in urban areas" and predicts "that is expected to increase to 68% by 2050" (UN DESA, 2018), according to the Pew Research Center Report more than half of the total U.S. population lives in suburbs (Parker, et al., 2018). Except for some very few cases, the majority of the suburbs are connected with its surroundings by roadways and, because of strong zoning, they are poorly served by primary needs and goods, therefore, as will be better explained later, they are forced to drive.

The twentieth century will be remembered for the two World Wars and for the events that deeply compromised and shaken the Western cities and societies in terms of environment

and urban morphology (Tagliaventi, 2002). As said before, no one would jeopardize its own life, being conscious of it by the way. But actually, this is what we do day by day because of improper behaviors and approaches to ordinary life issues dictated by consumption and car-dependency. If we add to this lazy and inappropriate way of living of human beings the blames of an inadequate urban zoning pattern and a diffuse organization of uses and spaces, it comes itself that people would still prefer driving to achieve consumption.

As underlined on the book *Growing Cooler: The Evidence on Urban Development and Climate Change* written by Ewing et al. (2008), the answer to the question "Why Americans are such car dependent?" (Ewing, Bartholomew, Winkelman, Walters, & Chen, 2008), is that because they "have little alternatives" (Ewing, Bartholomew, Winkelman, Walters, & Chen, 2008). After the Second World War, the development of cities in North America attacked the outer areas by building suburbs spread like wildfire, disconnected among them through the so-called phenomenon of sprawl. It is difficult to give a short and clear definition of sprawl, but when someone sees an American suburb of the late twentieth-century he will clearly understand what it means at a first glance (Figure 1.3). Sprawl is characterized by detached low-density houses built far away from workplaces, by schools unserved by public transports, by hard zoning allowing the creation of sectorial neighborhoods (like gigantic malls and industrial district) with attached huge car-parks tolerating the automobile as the only mean of transport.

Figure 1.3 - Typical suburban sprawl pattern in Herriman, Utah
Credit: © Michael Tuszynski
Source: Unspalsh (https://unsplash.com/photos/2osRMlJLdbU)

Surely it is not a so recent issue. Almost 60 years ago, the book *The Death and Life of Great American Cities* (1961) of the scholar and activist Jane Jacobs was published becoming today one of the most influential and pivotal masterpieces of the American planning culture. The author condemns the way of building and rebuilding and the planning methods of that time. In particular, her critics attack the worrying planning methods that divide the city uses and functions providing long distances to travel by private car and resulting in vehicle traffic congestion, unhealthy both for humans and also for our natural environment.
As briefly explained before, in urban developments population matters and, during the Postwar boom period was another fundamental aspect that encouraged sprawl in the U.S. By being only partially demographic affected by the War, and "experiencing a prodigious baby boom, the population jumped from 150 million people to over 200 million people in the first two full decades after the war" (Bruegmann, 2005, p. 42). As written in the book *Urban Social Geographies: An Introduction* by Knox and Pinch, the baby boom generation refers to those children born between 1946 and 1964, a period in which women got married earlier and had at least two children resulting in a "very large cohort of individuals, currently in their mid-40s to their early 60s, who have had, and will continue to have, tremendous impacts on the rest of the population" (Knox & Pinch, 2010, p. 10).
More recently, around 20 years ago, Duany, Plater-Zyberk, and Speck identified in their book *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream* that sprawl is characterized by five factors:

1- "Housing subdivisions, also called clusters and pods, made up only of residences" (Duany, Plater-Zyberk, & Speck, 2000, p. 5). To better understand, someone also calls them *villages*, *towns* or *neighborhoods*, mistaken because the neighborhood is made by activities and amenities that provide services to local residents, it does not only consist of residential houses (Duany, Plater-Zyberk, & Speck, 2000);
2- "Shopping centers, also called strip centers, shopping malls and big-box retail" (Duany, Plater-Zyberk, & Speck, 2000, p. 6), places made for shopping only. They shop every type of needs, from clothes to wood, from car to food changing in sizes. They are characterized by lack of residential units and by car dependency with very wide parking in between buildings (which does not stimulate one for a walk), the latter always built in a single-story building;
3- "Office parks and business parks. These are places only for work" (Duany, Plater-Zyberk, & Speck, 2000, p. 6). Basically, they are free-standing buildings isolated from any type of function and they are characterized by being placed in the middle, or next to, a parking area;
4- "Civic institutions and public buildings" (Duany, Plater-Zyberk, & Speck, 2000, p. 6), (e.g. libraries and schools) mostly placed in the middle of nowhere. As in the cases before, also these places are characterized by parking lots and lack of pedestrian accesses boosting the car as the only mode of transportation possible to reach them;

5- "Roadways" (Duany, Plater-Zyberk, & Speck, 2000, p. 7), which can be suitably seen as an incredible amount of pavemented land, especially if compared to the use that is actually made of them. Streets are necessary for connections and automobile movements can be allowed, but not by oversizing their widths otherwise the consequent effect is to incentive its usage.

To summarize, we observe that "The sprawl basis of American society is automobile dependence, absence of high social capital neighborhoods, and commodity housing" (Hirschhorn, 2004).
Considering the five components of sprawl together, we can deduce that what suffers from it the most is the environment (built and not) in which we live. Nowadays, the latter is seriously compromised by the effects of Climate Change. In the *C40 Blog,* it is stated that "whereas homes, businesses, and services are increasingly far apart in sprawling cities, sustainable neighborhoods function like ecosystems" (C40, 2017). This means that the neighborhood is made of a multitude of elements (e.g. street network, vegetation, people) that have to work in harmony to become sustainable, otherwise, sprawl and CC are obtained. According to C40, "as our neighborhoods get more compact and connected, we become more resilient" (C40, 2017). Then, in order to obtain sustainable cities, (sustainable) neighborhoods have to be considered first.
The first issue inhabitants consider public transport is whether public transports (be it the underground, light rail or buses) does work or not. To reach this objective, Duany, Plater-Zyberk, and Speck (2000) listed three rules a transit network must follow:

1- "Transit must be frequent and predictable.
2- Transit must follow a route that is direct and logical.
3- Transit stops must be safe, dry and dignified." (Duany, Plater-Zyberk, & Speck, 2000, p. 202, 203)

These three points above could be taken for granted and superfluous but actually, they represent the key elements to provide public transit opportunities for people and, possibly, shift them from car-dependency to commuting. Not many words should be spent on the quality of transit' stops, but actually, this is needed. In fact, a transit stop will be much more appealing if it offers "a transit experience both comfortable and civilized" (Duany, Plater-Zyberk, & Speck, 2000, p. 203) instead of waiting for the bus or train in an isolated stop under a dark bridge with no lights. Along with the present thesis, the most discussed way of transport is the one by rail in all its forms simply because it is faster and accessible to a larger amount of people, from light rail to underground-metro and elevated rails. Nevertheless, also bus transport is considered but as a secondary and complementary transport system service referring mainly to local movements.
By having different suburbs each one having different functions, one must move from one suburb to another in order to meet his ordinary activities and needs. Since public transports

and cyclo-pedestrian paths are rare options (even for quite short distances), people are forced to drive. Hence, the movements among the suburbs are possible by using private cars, usually occupied by one single person for each one, causing a very high level of traffic compared to the relatively high amount of people living and moving. Moreover, car-dependency is costly in economic, environmental, health and social terms. This is why zoning and suburban sprawl are no longer considered as good, sustainable growth. It is reasonable, then, to consider alternative options.

There is then the necessity to find a method that disincentives automobile usage and promote urban settlement on a human scale. This could be possible by switching people's behaviors and attitudes, emphasizing public life by donating more spaces to the public realm where they are lacking and making them more comfortable where they are already present.

1.1.1. Pedestrian, bicycle and transport systems

As explained by Cervero, a professor at the University of California, Berkeley, the most common way of transport to get to a transit stop is the automobile, especially in the suburbs (Cervero, 2001). Due to this fact, every rail transit stop is surrounded by huge car-parking making them "the dominant "land uses" within a half-mile of most suburban rail stations in the United States" (Cervero, 2001, p. 1, 2).

To get as many automobiles off the road as possible, there should be an efficient and accessible public transport system supporting the high demand of passengers that would be wonderfully blown from the car inside to the train carriage or bus seat. Keeping in mind that limited and controlled use of the automobile is allowed only when other more sustainable options are not available, the pedestrian and bicycle network should be wide-spread and well-distributed around the neighborhood and connected with different efficient transport systems, both on rails and roads. However, there are a lot of other factors influencing people's choices. In an interesting article written by Saneinejad, Roorda, and Kennedy (2012), for example, it is underlined the important aspect that weather has on pedestrians and cyclists according to the distances they should cover on foot or by bicycle (Saneinejada, Roorda, & Kennedy, 2012). As explained before, in American suburbs the most commonly used way of transport is the automobile due to long distances, zoning and lack of efficient public transports. The solution proposed by Cervero is the "transit village" that focuses on the valid and sustainable model that prioritizes pedestrian and bicycle patterns to reach transit stations as a way to disincentivize automobile usage. Linking this topic to the public square issue, Professor Cervero stresses the importance of this urban element stating that plazas are the core of public life during ordinary but fundamental weekly days and also during weekends when more entertainment activities can be held within the plaza (Cervero, 1996). However, "What is important is that the transit station functions as a window, or gateway, to the rest of the region and is physically tied to and associated with the village's major gathering place" (Cervero, 1996, p. 105, 106) as public

squares are. In the last decade of the 20th century this idea of "transit village" has taken hold and it is been developed in-depth by many experts coming from California to Florida under the so-called New Urbanism movement that will be better explained in the next Chapter 2.

To summarize, both walking and bicycling contribute to increasing transit passengers, but in a slightly different way. In fact, whilst people walking can cover short distances (between 400 to 800 meters), bicyclists can cycle further distances. Therefore, walkable paths would serve more local population and bicycle lanes, by enlarging the range of action, which could also serve further population (Pucher & Buehler, 2010). In other terms, "Bicycling supports public transport by extending the catchment area of transit stops far beyond walking range and at much lower cost than neighborhood feeder buses and park-and-ride facilities for cars" (Pucher & Buehler, 2009, p. 79). Moreover, Pucher and Bueler (2009) exalt bicyclists stating that "Transit services also can provide convenient alternatives when cyclists encounter bad weather, difficult topography, gaps in the bikeway network, and mechanical failures" (Pucher & Buehler, 2009, p. 80) underling that there are many other factors that can condition transit choices.

However, there is an infinite number of benefits from improving access for pedestrians and bicyclists in this transit-based strategy of planning. The *Federal Transit Administration* (FTA) prepared a *Manual on Pedestrian and Bicycle Connections to Transit* (McNeil, et al., 2017) where some benefits of bicycling and walking to and from a transit station are listed as follows:

- "Transit depends on safe and pedestrian access" (McNeil, et al., 2017, p. 8)
  As previously explained, safety and easy access to transit station are binding conditions to guarantee a sufficient transit flow;
- "Help improve equity" (McNeil, et al., 2017, p. 8)
  It may be an underestimated factor, but transit is more affordable than driving because of the cost of fuel and car ownership is something that not everyone can afford. Thus, the transit system also allows to lower social disparities;
- "Extend the reach of transit" (McNeil, et al., 2017, p. 8)
  Creating more pedestrian and cycle pathways that directly connect further areas with the transit station would incredibly enlarge the range of action of a given station;
- "Support more multimodal trips and more specific options" (McNeil, et al., 2017, p. 9). Make more accessible a transit stop does not only imply its appealing issue but the way it is linked with another way of transports making the multimodal aspect of a certain station a key element on determining the commuter's choice (Brons, Givoni, & Rietveld, 2009);
- "Serve as a redundancy in cases of transit outages" (McNeil, et al., 2017, p. 9).

Linked with the previous benefit, the fact of having a multimodal and interchange character, allow a transit station to be more versatile in case of unexpected problems;

- "Improve health and well-being" (McNeil, et al., 2017, p. 9)
  It is commonly acknowledged that doing physical activities like walking and bicycling can help to maintain a healthy mind in a healthy body, even for short distances.

1.2. Effects

The major impacts of CC are already in action and they are hitting worldwide. There are different types of events through which climate change impacts on humans and our built and natural environment. Surely climate change has negative and warring impacts, there are so many ways in which CC strikes and affect our behaviors and environments that it is difficult to draft a clear and simple list of impacts. First of all, to facilitate the understanding, a net distinction between direct and indirect impacts must be done. The formers are those that directly affect the place where they occur – thus they are spatially limited– and they are the direct cause of global warming. An example could be the acidification of seas and oceans due to more acid rainfalls. In other words, they happen because of climate change. Furthermore, as reported on the website of the *Union of Concerned Scientists of United States of America* (UCSUSA, s.d.), direct impacts are also a matter of social inequality. As an example, they state that "hotter temperatures and droughts will make corn, wheat, and other staple crop supplies less stable, leading to price spikes and foot shortages. The roughly 800 million people currently living in extreme poverty will be most affected" (UCSUSA, s.d.). These kinds of impacts are the indirect ones, those that affect indirectly other populations or countries – thus they cannot spatially limited– through the share and the exchange of certain resources hit by the direct ones (Benzie, 2014). As the IPCC states, (direct) "Impacts can have beneficial or adverse outcomes for livelihoods, health and well-being, ecosystems and species, services, infrastructures, and economic, social and cultural assets" (IPCC, 2018, p. 26). However, for the purposes of this thesis, only the direct impacts of CC will be taken into account.

The direct effects of climate change depend on the place where they occur, so they obviously differ from country to country, region to region and city to city. According to their location and the relative climatic region, every country, region, and city will be impacted by CC differently. Given the complexity and mutability of CC impacts, and given the purpose of the thesis, the scope is narrowed down by considering the impacts that CC has on our built environment.
As said before, CC impacts cities differently according to their location and climatic region. However, the seriousness of CC impacts depends on their strength and perseverance, but also on their target. That is for example if a hurricane changes its course before hitting a

coastal city, the impact of the hurricane itself would be much softer than if it had not changed direction destroying the city and hundreds of lives. This leads us to a fundamental distinction between natural hazard, vulnerability, and risk explained through the formula proposed by Varnes (1984, p. 10):

$$"R_t = (E) * (R_s) = (E) * (H * V)"$$

Where:

- "Natural hazard (H) means the probability of occurrence within a specific period of time and within a given area of potentially damaging phenomenon.
- Vulnerability (V) means the degree of loss to a given element or set of elements at risk (see below) resulting from the occurrence of a natural phenomenon of a given magnitude. It is expressed on a scale from 0 (no damage) to 1 (total loss).
- Specific risk (R_s) means the expected degree of loss due to a particular natural phenomenon. It may be expressed by the product of H times V.
- Elements at risk (E) means the population, properties, economic activities, including services, etc., at risk in a given area.
- Total risk (R_t) means the expected number of lives lost, person injured, damage to property, or disruption of economic activity due to a particular natural phenomenon, and is therefore the product of specific risk (R_s) and element risk (E)" (Varnes, 1984, p. 10)

The direct impacts of CC are later explained, aiming to get a general framework about the possible most common effects produced in different U.S. urban areas.

1.2.1. The UHI effect

The UHI (sketched in Figure 1.4) is an effect of CC that affect cities and their populations worldwide. According to Landsberg (1981), "The most obvious climatic manifestation of urbanization is the trend toward higher air temperatures. This is also the theme most frequently discusses in the literature since its discovery by Luke Howard" (Landsberg, 1981, p. 83) at the beginning of the 19th century (Oke, 1982). The Urban Heat Island (UHI) effect is the difference in air temperature between city areas compared to its rural areas. Professor at the University of British Columbia, Vancouver, Oke dedicated his studies and researches to urban climates and he provided important efforts on understanding the UHI effect. He

noticed that "air temperatures are often higher in a city than in its surrounding countryside" (Oke, 1982, p. 2).

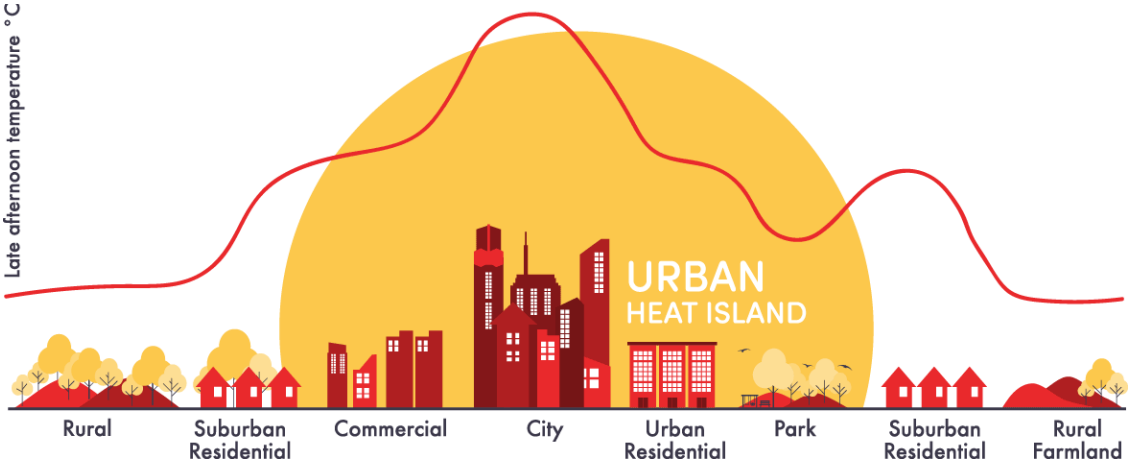

Figure 1.4 – Urban Heat Island (UHI) sketch
Source: Cool Parramatta (http://coolparramatta.com.au/about_us)

Therefore, the UHI effect is more perceptible in cities where there is a large number of densely concentrated buildings and people's activities, thus, UHI mostly occurs in medium to large cities, where its effects are more tangible and severe. In fact, the UHI effect "is widely recognized as a heat accumulation phenomenon, which is the most obvious characteristic of urban climate caused by urban construction and human being activities" (Yang, Qian, Song, & Zheng, 2016, p. 11). A typical consequence of the UHI effect is the presence of hotter temperatures in cities during nighttime. This happens because "Man-made surfaces store the solar energy that strikes during the day and rerelease it into the atmosphere at night." (Desonie, 2008, p. 35). The climatologist Landsberg that hotter temperatures during nighttime happen because the UHI "is a reflection of the totality of microclimatic changes brought about by man-made alterations of the urban surface" (Landsberg, 1981, p. 84). It is clear that tampering the natural Earth's soil by covering the land with non-natural elements (e.g. buildings), these will act differently from normal land coverage. Keeping it simple, the key point is to provide good and sustainable ways to apply to such land changes.

There are several ways in which UHI can be avoided or at least limited, that focuses on the characteristics of the cited man-made alterations. However, it is necessary to identify which are the causes of the UHI effect (Table 1.2) and why there are such higher temperatures within the city's boundaries rather than in rural areas.

Table 1.2 - The UHI causes and effects

Main causes	Effects
Poor vegetation	Reduces evaporation

Elevated presence of man-made surfaces (pavements and roofs)	Reduces evaporation
High values of thermal conductivity and heat capacity of urban materials	Increases heat storage
Low solar reflectance (low albedo) of dark-colored urban materials	Increases net radiation
Improper urban geometry	Reduces convection
Increased levels of air pollution	Increases net radiation
Increased energy used	Increase anthropogenic heat

Source: Author's re-elaboration based on *"Table 2.1 Urban and suburban characteristics important to heat island formation and their effect on the energy balance of the Earth's surface" (Gartland, Heat Islands: Understanding and Mitigating Heat in Urban Areas, 2008, p. 16).*

1. Reduced evaporation

   "*Evaporation* is energy transmitted away from the Earth's surface by water vapour" (Gartland, 2008, p. 16). Considering that the Earth's land surfaces have tampered with both natural (e.g. vegetation) and non-natural (e.g. canopies) elements, evaporation depends on the ability to evaporate of these surfaces. As will be later explained (Chapter 3 and 4) vegetation is plenty of beneficial resources that help to tackle CC. According to the master thesis of Slingerland (2012) "There are two ways in which vegetation can contribute to the mitigation of the UHI. The first is by providing shade, the second way is by evaporation" (Slingerland, 2012, p. 6), better known as evapotranspiration (ET). The latter is "complicated process plants use to keep cool" (Gartland, Heat Islands: Understanding and Mitigating Heat in Urban Areas, 2008, p. 16) deriving from the combination of two processes: evaporation and transpiration, which is "the loss of water vapour through their leaves" (Chavarria & dos Santos, 2012, p. 106).
2. Increased heat storage

   Besides vegetation and its natural processes, the Earth's surface can be covered also by non-natural surfaces. In this case, these surfaces accumulate heat according to two material properties: "thermal conductivity and heat capacity" (Gartland, Heat Islands: Understanding and Mitigating Heat in Urban Areas, 2008, p. 18). Whilst with high values of thermal conductivity and heat capacity, the heat is easily stored within the surfaces and longer-lasting, with low values of the material properties the heat is kept and they are shorter-lasting within the surface's material resulting in lower temperature (Gartland, 2008).
3. Increased net radiation

   According to Gartland (2008), the net radiation is made of "four different radiation processes that occur at the Earth's surface:

> Net radiation = (Incoming solar – Reflected solar + Atmospheric radiation – Surface radiation)" (Gartland, 2008, p. 16)

Where:

- The "Incoming solar represents the amount of energy radiating from the sun" (Gartland, 2008, p. 17) depending on several factors like the weather, with clear or cloudy sky, and/or the period of the day, the incoming solar radiation has lower values in the morning and evening compared to noon (Gartland, 2008);

- The "Reflected solar radiation is the amount of solar energy that bounces off a surface, based on the solar reflectance of the material. Surfaces with high solar reflectance, such as bright white roofing materials, reflect most of the solar radiation that falls on them, whereas dark surfaces such as asphalt pavement absorb most of the solar radiation" (Gartland, 2008, p. 17). The reflected solar radiation is commonly known as albedo. The term "albedo" (Figure 1.5) comes from the Latin (albēdo, "brightness", albus, "white") and, according to Philander, "The more the amount of light reflected back, the brighter the color of the object. A lesser amount of light is reflected back from darker objects" (Philander, 2008, p. 24). Thus, in this context, materials are characterized by their colors that can reflect incoming solar radiation with values ranging from 0 (with withe color) to 100 (black color) (Philander, 2008). In urbanized areas like cities and surrounding suburbs, most of the urban areas are covered by man-made surfaces of different materials considering that surfaces do not only include pavements but also building roofs, building

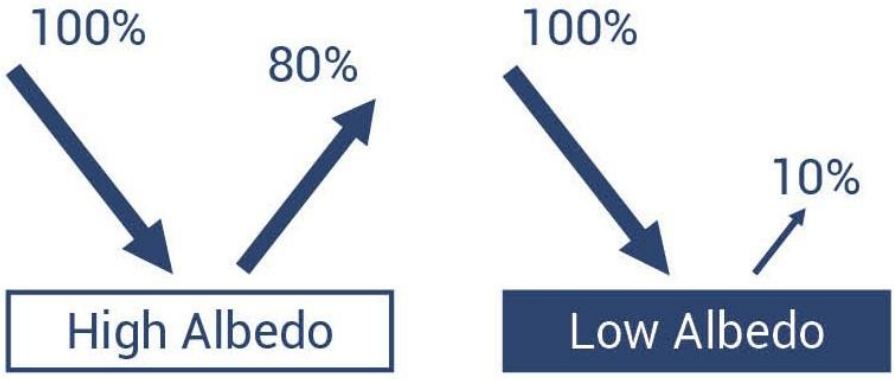

Figure 1.5 - Different reflected solar radiation depending on the surface's albedo
Source: Author's elaboration

façades and the whole built environment in general. In fact, as stated by Mohajerani, Bakaric, and Jeffrey-Bailey in urbanized areas are mostly covered by roofs and pavements (Mohajerani, Bakaric, & Jeffrey-Bailey, 2017) which absorb heat from incoming solar radiation. Therefore, the material's colors of those surfaces are fundamental in order to reflect the maximum of solar radiation striking on them and avoid the UHI effect;

- The "Atmospheric radiation is heat emitted by particles in the atmosphere, such as water vapour droplets, clouds, pollution and dust" (Gartland, 2008, p. 17);

- The "Surface radiation is heat radiated from a surface itself" (Gartland, Heat Islands: Understanding and Mitigating Heat in Urban Areas, 2008, p. 17). Hence, surface radiation is strictly conditioned by the surface's temperature making hotter surfaces higher radiation emitters (Gartland, 2008).

4. Reduced convection
   According to Gartland (2008) "*Convection* is energy that is transferred from a solid surface to a fluid (i.e. a liquid or gas), in this case from the Earth's surface to the air above it" (Gartland, 2008, p. 16). Hence, convection is strictly related to wind flows and to wind characteristics resulting in high or low convection according to the intensity of wind flows which is one of the most important features of UHI effect, characterized by stale warm air and an absence of air exchange (Oke 1982, Gartland, 2008). As explained later (Chapter 4), the building, play "an important role in the transport and removal of pollutants" (Priyadarsini, 2009, p. 263) because, according to urban geometry (that is, building's orientations N-S, W-E, NW-SE, NE-SW, forms in terms of heights and location from one building to another), wind flows be stimulated to and directed aiming to air exchange rather than obstructing natural wind flows.

5. Increased anthropogenic heat
   According to Gartland (2008), the last cause that generates the UHI effect is the anthropogenic heat which "is generated by human activity and comes from many sources, such as buildings, industrial processes, cars and even people themselves" (Gartland, 2008, p. 22). Hence, anthropogenic heat depends on several different variables like population number, the efficiency of public transports and the climate regions resulting in diverse anthropogenic heat for every region.

In an interesting study made by Stone, Hess, and Frumkin (2010) on a comparison between compact cities and large metropolitan regions over a given period (1956-205), have been examined and demonstrated that Extreme Heat Events (EHEs) are most common in sprawl metropolitan regions than in compact cities (Stone, Hess, & Frumkin, 2010). In their research, they found that in addition to the negative features of sprawl previously listed, lack of vegetation is a crucial driver to UHI (Oke, 1982). In this case, vegetation has to be

considered not as sporadic trees planted in small numbers but rather as parks and wide green open spaces. The authors conclude stating that over the 10 years analyzed, "the rate of deforestation in the most sprawling metropolitan regions is more than double the rate in the most compact metropolitan regions" (Stone, Hess, & Frumkin, 2010, p. 1427). The research made by these authors has been useful to understand that UHI occurs also, and in some cases even harder, in sprawling areas than in more compact urban areas and, therefore, sprawl suburbs also need strategies to tackle UHI.

1.2.2. Flooding

Floods are natural disasters meaning that it is intrinsic in climate nature and that is natural to happen. Besides the climate regions, upon which depend on the frequency of rainfalls and their intensity, floods can occur in every U.S. county randomly. In fact, "Floods are the most common (and among the most deadly) natural disasters" (Denchak, 2019) and, according to Brilly and Polic (2005), floods are the "most studied" (Brilly & Polic, 2005, p. 345) natural events since the "90 percent of weather-related disasters in the U.S. involve some type of flooding" (Cannon, Gotham, Lauve-Moon, & Powers, 2019, p. 3). The *Federal Emergency Management Agency* (FEMA) defines flooding as "A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area" (FEMA, s.d.). Staying with this definition, it has to be pointed out that the normal land area only refers to the climatologist status. In fact, land areas are urbanized in cities and in suburbs, covered by impervious man-made surfaces. Because of the reasons just cited, floods can hit and affect both people and the environment (both the built and the natural ones) having huge impacts on our societies. According to Merz et al. (2010), there are two types of floods damages: the direct damages that are those generated by impacts on humans belongings, and the indirect damages which are the consequence of the direct ones on humans livelihoods, which can last for a longer period (Merz, Kreibich, Schwarze, & Thieken, 2010). According to the *Natural Resources Defense Council* (NRDC), there are four different types of floods (Denchak, 2019):

1. River flooding
   River floods require the presence of a river because they occur when "a river overspills its banks; that is, when its flow can no longer be contained within its channel" (Shaw, 2019).

2. Coastal flooding
   This type of flooding affects those cities overlooking the sea and are, therefore, linked to the sea level rise (e.g. Boston and San Francisco). People living in such cities, which are real attractors due to the benefits generated by the close proximity to the sea (Dassanayake, Burzel, & Oumeraci, 2012), are vulnerable to storm

events because of lacking any kind of obstacles in between (Hsu, Shih, Li, & Lin, 2017). As reported by the U.S. EPA (2016), coastal flooding in the U.S. occur mostly in the East Coast and, comparing the two decades 2010-2015 and 1950-1959, coastal flooding has worryingly increased (U.S. Environmental Protection Agency, 2016). As Dassanayake, Burzel, and Oumeraci (2012) affirm, this is why the "development of methodologies for the estimation of coastal flood risk has become an urgent need for the identification and implementation of proper coastal protection measures" (Dassanayake, Burzel, & Oumeraci, 2012, p. 241).

3. Flash floods

   Flash floods occur when very intense rainfalls hit a dry surface lasting for a relatively short period of time (also few hours of strong and constant rainfall could be enough to obtain a flood) (Goudie, 2004). According to Gruntfest and Handmer (2001), they are characterized by little lead period, ferociousness, expectancy in terms of location and period and they generally occur at a small scale (Gruntfest & Handmer, 2001). Moreover, flash floods are distinguished from the other types of flooding by a high level of uncertainty; thus, covering areas with proper materials and adaptation structures (e.g. water reservoirs) can help to alleviate the flooding strongness and avoid severe damages. Unfortunately, due to their unexpected nature and "because they are rare, the motivation to invest time and resources into such activities is low." (Montz & Gruntfest, 2002, p. 16).

4. Urban flooding

   The previous types of floods can occur almost everywhere, and the severity of the damages are related to the specific locations. When they occur in urban areas, which are generally characterized by impervious surfaces such as streets, parking lots and roofs, the phenomenon called "runoff" takes place (Denchak, 2019). Urban runoff is the total amount of rain, usually fallen in a short period of time, that could not manage to infiltrate on urban surfaces due to their imperviousness (Rafieian, Khaleghi, Malekani, & Mahmoodi, 2014). Thus, urban flooding strictly depends on the land uses and their respective degree of imperviousness. Natural soils themselves have a maximum capacity of water storage according to their pervious characteristics, once the rainfall gets over that given threshold, the water starts flowing above ground. Considering that all kind of man-made surfaces are less pervious than the natural ones, cities can be considered as "flood attractive" and, due to the diffuse land consumption and its paved ground, sprawl is among all one of the main causes of urban flooding leading to the affirmation that sprawl is a development strategy to forget.

To conclude, floods are the most common natural disaster in the U.S. because they depend on the interrelation of a multitude of factors and they can be generated as a consequence

of other natural disasters, such as storms and hurricanes (e. g. the Hurricane Katrina in 2005 with more than 1800 victims)[5]. Urbanized areas are vulnerable due to an extremely high percentage of soil imperviousness, particularly the inner-city areas. However, urban sprawl must be considered. Although urban density decreases further and further away from the inner-city areas, the same does not happen for the perviousness. The main contributors to floods in suburban areas are abundant asphalt roads, impervious roofs and wide public parking around malls and around private houses that do not allow water to be infiltrated causing violent surface runoff.

1.2.3. Drought

If the two previous impacts concern about an excess resulting from a collision between natural power and anthropic influences, this third kind of impact is related, instead, to a lack of natural primary need for human beings: the water. In fact, not only humans need water, but it is necessary for the whole planet to continue to work (Madaan, s.d.). According to Nagarajan (2009), drought "is the period when rainfall is less than normal for several weeks, months or years, the flow of streams and rivers declines and water increases. If dry weather persists and water-supply problem develops, the dry period can become a drought" (Nagarajan, 2009, p. 3). Moreover, drought can occur in every type of climatic regime in every part of the world, this is the reason why it is so difficult to give a unique and comprehensive definition of drought. Nevertheless, it is easy to understand that droughts in Sub-Saharan Africa differ from the North American ones because of a multitude of factors. According to Trimble (2008), droughts are different because of three factors:

- Intensity, mainly related to the rainfall itself in terms of power and brutality of damages caused;
- Duration, usually a minimum of one to a couple of months is necessary to be considered a drought but it can last for much longer periods (even years);
- Spatial characteristics, which can expand or restrict according to seasons and regions but, in general, every change in intensity occur slowly and progressively.

As in the case of floods, also droughts can be caused, or at least influenced, by urban areas imperviousness. In fact, as noted by Szalińska, Otop and Tokarczyk, lacking water in urban areas can be strictly linked with an elevated rate of "impervious area that increases the surface runoff and reduces water storage in soils" (Szalińska, Otop, & Tokarczyk, 2018, p. 2). Thus, in areas prone to droughts a well-managed system that combines both water scarcity and rainfall should be considered in order to lower drought periods.

[5] https://eu.usatoday.com/story/news/weather/2019/07/17/worst-floods-in-american-history/39692839/

Similar to the other CC effects, also droughts can affect cities and societies in different ways through direct or indirect impacts. The formers are generally environmental causes, the latter are a consequence of the direct impacts. According to the *National Drought Mitigation Center* (NDMC), drought impacts can usually affect three different sectors:

- Economic impacts
  "Are those impacts of drought that cost people (or businesses) money" (NDMC , s.d.). Some examples could be related to a farmer and the monetary value of his agriculture crops, destroyed by a drought;

- Environmental impacts
  "Plants and animals depend on water, just like people" (NDMC , s.d.). Probably, environmental impacts are the easiest a drought can affect because it drastically changes their habitats and living conditions. Some examples could be related to the drinking water scarcity for animals that would alter their capacity to face survival problems;

- Social impacts
  They are probably the weakest ones but have to be considered anyway. The social impacts of droughts are those affecting "people's health and safety" (NDMC , s.d.), for example, respiratory problems due to polluted air caused by lack of rainfalls.

Concluding, it is difficult to define droughts due to their several and different variables that take place. According to Wilhite and Glantz (1985), droughts depend not only on the three factors (intensity, duration, and spatial scale) identified by Trimble (2008), "but also on the demands made by human activities and by the vegetation on a region's water supplies. Drought's characteristics along with its far-reaching impacts make its effects on society, economy, and environment difficult, though not impossible, to identify and quantify" (Wilhite & Glantz, 1985, p. 3).

1.3. Measures

As explained earlier in the Chapter, the climate is changing mainly due to GHG emissions produced by human activities. In fact, as reported by the IPCC, "Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate" (IPCC, 2018, p. 2). Therefore, humans are at the core issue. We are producing, consuming and wasting as never before. If we are the main cause of this tremendous change, we should also be the ones able to control it and try to stop or, at least, limiting it. There are two main large

strategy policies that contain actions inside to tackle climate change: mitigation and adaptation actions. In the research fields, they are usually considered separate. They have nearly the same objective, that is tackle CC, but the ways in which they try to reach it is slightly different. Nevertheless, is better to consider them as mutually necessary rather than different and disconnected.

1.3.1. Mitigation

According to Duguma and Minang (2014), mitigation policies aim to reduce and contain GHG emissions and increase GHG sinks (Duguma & Minang, 2014). Hardy (2003) stated that "If we could reduce CO2 emissions at the source, we could eliminate much of the greenhouse warming potential, but this is easier said than done" (Hardy, 2003, p. 187). Considering the mitigation actions, they are strictly related with technologies and technical sciences devoted to limit and control GHG emissions (Zhao, et al., 2018), which are improving year by year and they will continue to do so even in the next future, especially in the energy efficiency sector (Desonie, 2008). A key element in mitigation policies is, therefore, the effort on the development of technologies to reduce GHG. According to Desonie (2008), in order to reach the objectives fixed by the IPCC and to guarantee at least the same healthy future for the next generations, the world society should switch to other more sustainable energy sources avoiding those producing GHG emissions if we want to guarantee a (Desonie, 2008).
Today is plenty of helpful and sustainable technologies that deal with climate change and GHG reduction and they are constantly evolving, ranging from solar panels and windmills to hydropower. Without belittling those sustainable technologies, they are not what this thesis wants to focus on. However, as will be later explained in Chapter 3, advanced technologies are not the only solution to mitigate CC. Actually, there is one strategy that is 100% sustainable (even more sustainable than the ones just cited), that has only positive benefits because it is healthy, environmentally sustainable, it boosts the economy by being free at the same time and that, therefore, has a magnificent impact on CC. This measure is called walkability and will be detailed and explained later (in Chapter 3).

1.3.2. Adaptation

If mitigation measures help to reduce GHG emissions that generate CC, adaptation "is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007, p. 6). Going deep into the topic, adaptation measures are those that are needed to accommodate new conditions generated by some changes (climatic in this case). Whilst mitigation actions involve people and cities at a larger scale, "Adaptation can be a specific action, such as a farmer switching from one crop variety to another that is better suited to anticipated conditions" (Leary, et al., 2008, p. 6).

The general background on which adaptation measures are based on is that limiting GHG emission is mandatory for us and for future generations especially, but even if we stop generating any kind of GHGs in a very short period of time, the world and its inhabitants will continue to suffer from CC for a longer period. In fact, while applying mitigations strategies and changing our consumption behaviors, everyone worldwide can decide to "respond to environmental changes after they happen, or they can anticipate and prepare for the changes" (Desonie, 2008, p. 156) thanks to adaptation measures.

As interestingly pointed out by Laukkonen et al. (2009), "mitigation aims to avoid the unmanageable and adaptation aims to manage the unavoidable" (Laukkonen, et al., 2009, p. 288). In other words, they are both useful and necessary if we want to reach the thresholds fixed by the IPCC. McKibbin and Wilcoxen (2004) provided a perfect example to understand that both mitigation and adaptation measures are needed. They compare the difference between choosing mitigation or adaptation actions with the "decision to wear seat belts versus installing anti-lock breaks on a car. The anti-lock breaks help to reduce the likelihood of an accident (mitigation) whereas the seat belts help to prevent catastrophe if there is an accident (adaptation)" (McKibbin & Wilcoxen, 2004, p. 1). Even if mitigation and adaptation are both essential to tackle CC, they actually have some characteristics in common and others in contrast. As underlined by Zhao et al. (2018), the main difference between the two measures is concerning the scale of action. The best way to act towards mitigation would be through policies with global range. That is, for example, prohibiting car-driving within a certain radius from the city center, while encouraging and building efficiency public transport systems to connects the suburbs and applying it worldwide (Zhao, et al., 2018). In contrast, adaptation measures should act more locally and regionally to obtain larger benefits as clearly illustrated in Figure 1.6.

Concluding, both mitigation and adaptation measures have to be considered today. They share the same objective but they operate at different scales in time and in dimension areas (Tol, 2005); thus, their benefits are different because "adaptation benefits are local and mitigation benefits are global" (Locatelli, 2011). In the next *Part II* (Chapter 3 and 4) of the thesis, it will be explained how these two approach options try to tackle climate change in a very limited area: the square. The latter is considered as the central element upon which the public realm is rooted.

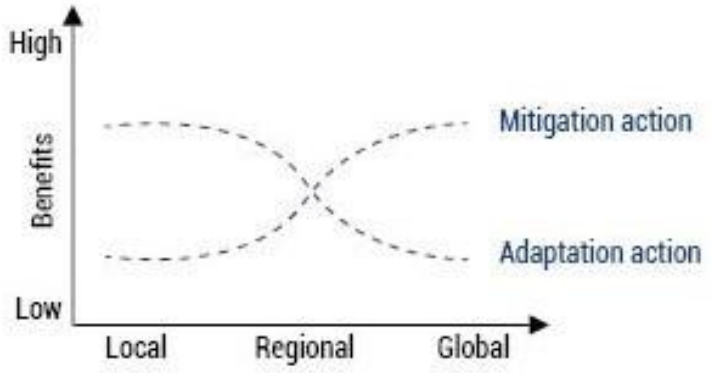

Figure 1.6 – Comparison between mitigation and adaptation scale benefits
Source: Author's elaboration based on: *(Wilbanks, Leiby, Perlack, Ensminger, & Wright, 2007)*

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2. Planning theories and actions

According to what discussed in the previous Chapter 1, the most immediate and obvious idea to tackle CC would be stopping to drive. But this is not so easy, at least partially. Moreover, in order to stay underneath the IPPC threshold[6] which would allow avoiding catastrophic consequences, complete car-removal is not mandatory, but a slightly high decrease would be enough.

In order to face the dilated sprawl in the American suburbs, at the end of the 1980s a new cultural and architectural movement started to be considered as the possible solution. The New Urbanism was conceived by some experts in urban planning and architecture (among which: Peter Calthorpe, Andres Duany, Elizabeth Plater-Zyberk, Robert Davis and Peter Katz) in the belief of a pedestrian and bicycle-friendly, mixed-use, dense neighborhood in a precisely defined net of blocks, streets, and squares.

New Urbanism has its roots in the Postmodernism movement, it has to be considered then the successor of Modernism. According to Lucka (2018), considering Modernism in the urban planning and architecture spheres, it has generated "two 'products': downtowns in Le Corbusier's style, and sprawling suburban areas" (Lucka, 2018, p. 18). It is in this context that New Urbanists start working and developing their ideas, as this Chapter will try to explain.

2.1. The New Urbanism and the Congress of the New Urbanism

As previously said, the ideals against which New Urbanism is been founded on start with critiques against sprawl. Sprawl has been said that has also some positive aspects (for example, privacy and owning a plot of land) but it definitely brings harmful and irretrievable consequences (Lucka, 2018). Moreover, Lucka (2018) analysis the positive and negative aspects of New Urbanism and found that, besides the evident land consumption and the related environmental problems, suburban sprawl "leads to the spatial segregation of inhabitants, usually based on race and income, and therefore generates concentration of poverty" (Lucka, 2018, p. 19). Even if the thesis does not want to focus on social and segregation aspects of sprawl, this is surely an important aspect to keep in mind.

Many professional figures were interested in getting their hands in such a problem, from architects to sociologists to many others, given the large serious amount of negative externalities sprawl emits. However, regarding urban planning, experts were coming from every corner of the United States, mixing influences of the East and the West Coasts. The main current movements of that time were the Eastern Neotraditional Planning and the Western Transit Oriented Development (TOD), which were spatially opposite, but they shared common ideas and principles.

[6] The IPCC Reports refer to risks that may occur with global warming at temperature 1,5C° and 2C°; with risks substantially lower at 1,5C° than at 2C° (https://www.ipcc.ch/)

What emerged from the first "meeting" in 1991 is a set of principles better known as the Ahwahnee Principles, the name of which derives from the "hotel in Yosemite National Park in California where the meeting took place" (Howard, 2005, p. 31). Held in Alexandria, Virginia, the second meeting can be considered as the birth of the New Urbanism as a kind of reform movement. Experts in urban planning and architecture (among which: Peter Calthorpe, Andres Duany, Elizabeth Plater-Zyberk, Robert Davis and Peter Katz) created a non-profit organization called the *Congress of the New Urbanism* (CNU) in the belief of a pedestrian and bicycle-friendly, mixed-use, dense neighborhood in a precisely defined net of blocks, streets and squares (Howard, 2005). In 1996, a list of twenty-seven principles institutionalized the guiding ideals of the developing movement in what is today known as the Charter of New Urbanism (see Appendix I). So, comparing comes itself: as the *Charter of Athens*[7] (1938) stands for the CIAM, the Charter of New Urbanism (1996) stands for the CNU. It could sound wired and unreasonable, but actually, as underlined by Howard (Howard, 2005) the two movements and their relative outcomes have some features in common. To start, both the documents emerged from the respective Congresses critique their current situations proposing themselves as reformist movements that will ensure better future conditions. But a great dichotomy characterizes the two Charters. The main difference between the two lies in the fact that the CIAM in 1933 wanted to break away from the traditional settlement of the city by pulling the land uses away from themselves while, more recently, the CNU aims to recover the traditional neighborhood and cluster as much uses as possible together (Howard, 2005).

The Charter of New Urbanism contains twenty-seven principles to define sustainable planning guidelines organized in three spatial planning scales, each one holding nine principles. The three scales are strictly linked one another starting from the smallest (the block) which, if well managed, would give the possibility to obtain the middle scale (the neighborhood) that, in turn, could lead to the largest one (the region) if planned according to the principles. The latter is available in *Appendix I* and they are briefly explained as follows:

- The region (with Metropolis, city, and town), where policies and strategies like those for "economic development, pollution control, open-space preservation, housing" (Leccese & McCormick, 1999, p. 13) have to match in order to obtain a region made of villages and suburbs well connected among them and to the principal city in terms of transportation services (including bus rapid transit and buses on dedicated lanes, besides all types of rail transports) (Calthorpe, 2011);

- the neighborhood (with district and corridor), considered by the Charter as the "heart of New Urbanism" (Leccese & McCormick, 1999, p. 71) and focuses on mixed-use instead of zoning, density instead of spread, diversity instead of

[7] The document resulted from the IV *Congres Internationaux d'Architecture Moderne* (CIAM) in 1933, promoted by the architect Le Corbusier.

uniformity aiming to social life activation in great public spaces. This middle-scale identified by the Charter is based on the two pillars of New Urbanism: the Traditional Neighborhood Development (TND) and the Transit-Oriented Development (TOD), later explained;

- the block (with street and building), is the smallest scale and focuses on detailing the neighborhood scale. That is, the neighborhood scale foresees diversity in its spatial scale patter, thus this smallest scale should work on façades, for example. In practice, this scale focuses on urban design strategies aiming to connect the built environment with the community (Leccese & McCormick, 1999).

Respecting these explanations, it emerges that, for the scope of the thesis (squares and plazas), only the neighborhood and especially the block scale will be detailed but having the regional city background in mind.

2.2. The Pillars of New Urbanism

As said before, New Urbanism comes from the embrace of two schools of thought, the first one captained by the architect and urban planner Peter Calthorpe based on the idea of Transit Oriented Development placed in the West Coast under the technical and cultural background of the Berkeley University. The second one, similarly, focuses on the Neotraditional Planning led by Andres Duany and Elizabeth Plater-Zyberk (DPZ) on the other side of the U.S. in Miami, Florida.
So far, we have discussed principles, concepts and guidelines of New Urbanism from the theoretical point of view, but new urbanism has advanced pragmatic measures, methods and urban patterns over time to apply in new developments. The following pages will explain the practical features of the two urban movements developed in the 1980s that have given rise to the New Urbanism.

2.2.1. Traditional Neighborhood Development

As described in the Charter of the New Urbanism (*see Appendix I*) the neighborhood is considered as "the heart of the New Urbanism" (Leccese & McCormick, 1999) and has to be considered as a basic "building block" (Duany, Plater-Zyberk, & Co., 2003, p. 3.2). The architects DPZ "promoted a return to the principles of traditional urbanism and the design of cities that fosters a sense of community" (Howard, 2005, p. 31). The return to the concept of the traditional neighborhood meant by the New Urbanists swims against the sprawl phenomenon. The neighborhood is considered by New Urbanists as "a compact walkable urban pattern whose environment provides a balanced range of activities: dwelling, working, shopping, and recreational and educational uses" (Duany, Plater-Zyberk, & Co., 2003, p. 3.1). Even though the institutional identification of New Urbanism

dates from the 1990s, the architects Duany and Plater-Zyberk in the 1980s started to develop their ideas which will become the basis of New Urbanism. In those years, they projected SeaSide[8] (Figure 2.1), a community neighborhood in Fort Walton Beach, Florida.

Figure 2.1 - Aerial view of SeaSide neighborhood
Source: DPZ & Co. website (https://www.dpz.com/Projects/7903#)

The neighborhood today is a kind of pedestrian-friendly resort and it is considered one of the most iconic TND projects. The New Urbanist *Traditional Neighborhood Development* (TND) derives from the *Neighborohhod Unit* concept that Clarence Perry designed for the first Regional Plan of New York in 1929 (Howard, 2005). Duany Plater-Zyberk & Co. found inspiration from Perry's idea, and decided to modify some elements as they state (Figure 2.2 and 2.3):

- "Neighborohhod Unit: A diagram and description from the First Regional Plan of New York (1929) which conceptualizes the neighborhood as the fundamental element of planning.
- Traditional Neighborhood Development: A diagram that reconciles current urbanization models with the traditional Neighborhood Unit" (Duany, Plater-Zyberk, & Co., 2003, p. 3.1).

[8] SeaSide neighborhood is the set of *The Truman Show* movie (1998). The fact emphasizes the idyllic character of the Traditional Neighborhood Development character.

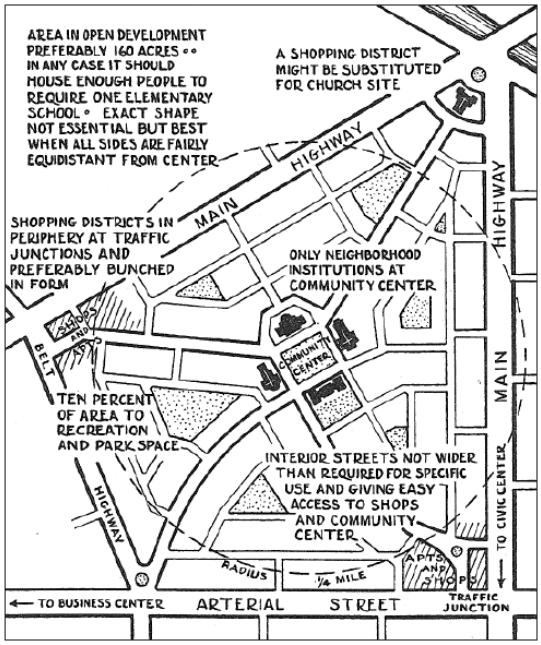

Figure 2.2 - Neighborhood Unit according to Perry's first Regional Plan of New York in 1929
Source: (Leccese & McCormick, 1999, p. 76)

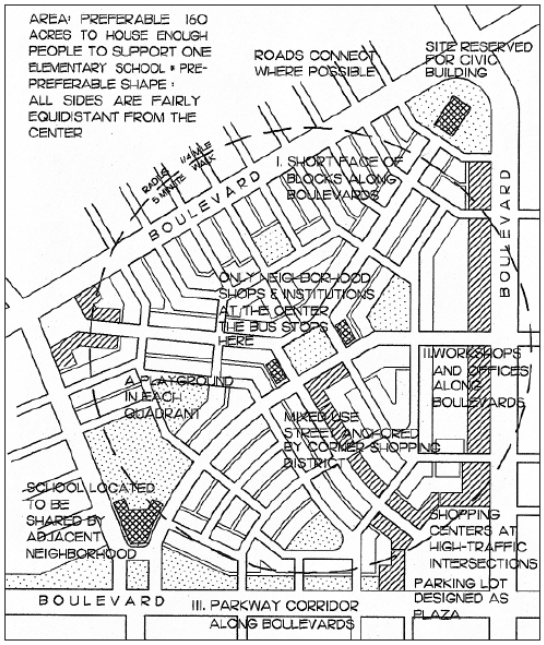

Figure 2.3 - Dunay Plater-Zyberk's diagram of an Urban Neighborhood
Source: (Leccese & McCormick, 1999, p. 76)

The TND emphasizes the importance of pedestrian patterns by delineating standard measures to apply within the neighborhood. Thus, the TND expects to be designed within

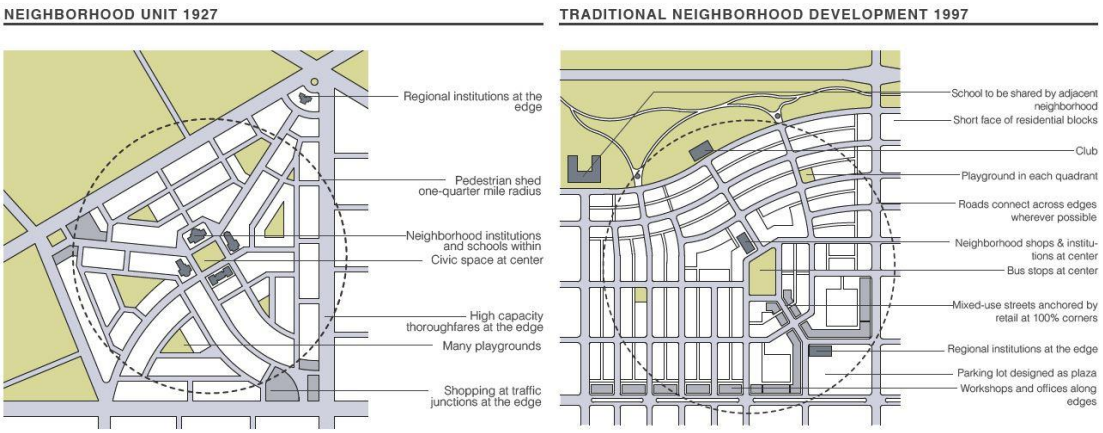

Figure 2.4 - Changes from Perry's Neighborhood Unit (1927) to Dunay Plater-Zyberk's TND (1997)
Source: (Duany, Plater-Zyberk, & Co., The Lexicon of New Urbanism, 2003, p. 3.1)

a walking distance of around 5 to 10 minutes from the core, which corresponds to a radius of around ¼ mile from the center. What change between the two schemes proposed by Perry and DPZ is better illustrated in Figure 2.4 retrieved from the Lexicon of the New Urbanism (2003). The image shows that first, the DPZ's scheme of TND is more detailed, specifying that the school should be placed at the edge of the neighborhood in order to be shared with the surrounding neighborhoods' inhabitants and also changes in parking lots and on thoroughfares types are made regarding their orientation, location and shape having impacts on the traffic patterns (Duany, Plater-Zyberk, & Co., 2003).

To define the spatial contexts in which human settlements develop, Duany Plater-Zyberk & Co. drafted a *Urban to Rural Transect* (Figure 2.4) in order to differentiate developments with different mixed-uses, densities and other urban measures according to their location resulting in a definition of "human and natural habitats" (Duany, Plater-Zyberk, & Co., 2003, p. 1.4).

As illustrated in Figure 2.5 retrieved from the *Lexicon* by DPZ (2003, p. 1.4), the *Transect* is sub-divided into six zones: Natural, Rural, Suburban, General Urban, Urban Center, and Urban Core becoming denser and more mixed going from the natural areas to the urban ones, plus a Special District (SD) referred to industrial districts. However, according to Duany and Talen (2002), the *Transect* should be considered as an approach to sustainable urban planning "coherent in design, and composed of an array of livable, humane environments satisfying a range of human needs" (Duany & Talen, Transect Planning, 2002, p. 245).

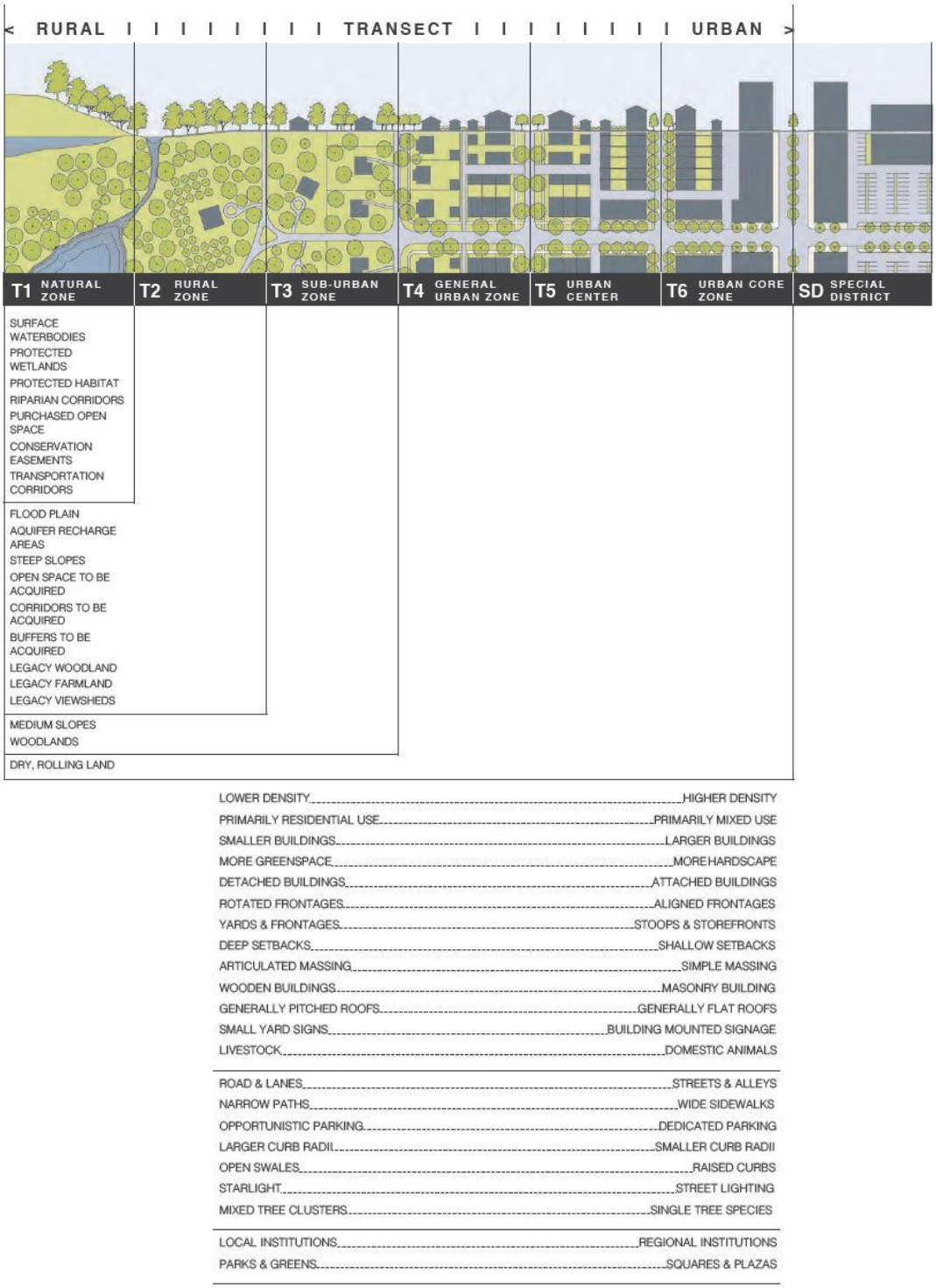

Figure 2.5 - The Urban to Rural Transect
Source: (Duany, Plater-Zyberk, & Co., The Lexicon of New Urbanism, 2003, p. 1.4)

2.2.2. Transit-Oriented Development

Meanwhile, in the West Coast at the University of Berkeley, California, Peter Calthorpe was designing an idea of development called *Transit-Oriented Development* (TOD) with many aspects and goals in common with the TND previously explained. TODs, differently from its similar, are strongly centered on transit stations around which develop the whole neighborhood guided by the New Urbanism principles. Hence, a TOD neighborhood prefers mixed-use instead of zoning, walking pattern instead of vehicular flow (although the automobile is allowed within certain measures) and it favors the public realm on the private one. As already noted, TOD can be applied to different scales of planning, from the regional one, by strengthening the rail network and concentrating sustainable urban settlements around its stations, to more specific neighborhood Plans by the redevelopment of existing areas or by the development of completely new projects.
In his most famous book *The Next American metropolis* (1993), Calthorpe gives theoretical aspects, definitions and practical measures around which TODs are based. By definition, TOD "is a mixed-use community within an average of 2000-foot walking distance of a transit stop and core commercial area" (Calthorpe, The Next American Metropolis: Ecology, Community and the American Dream, 1993, p. 56) illustrated in Figure 2.6.

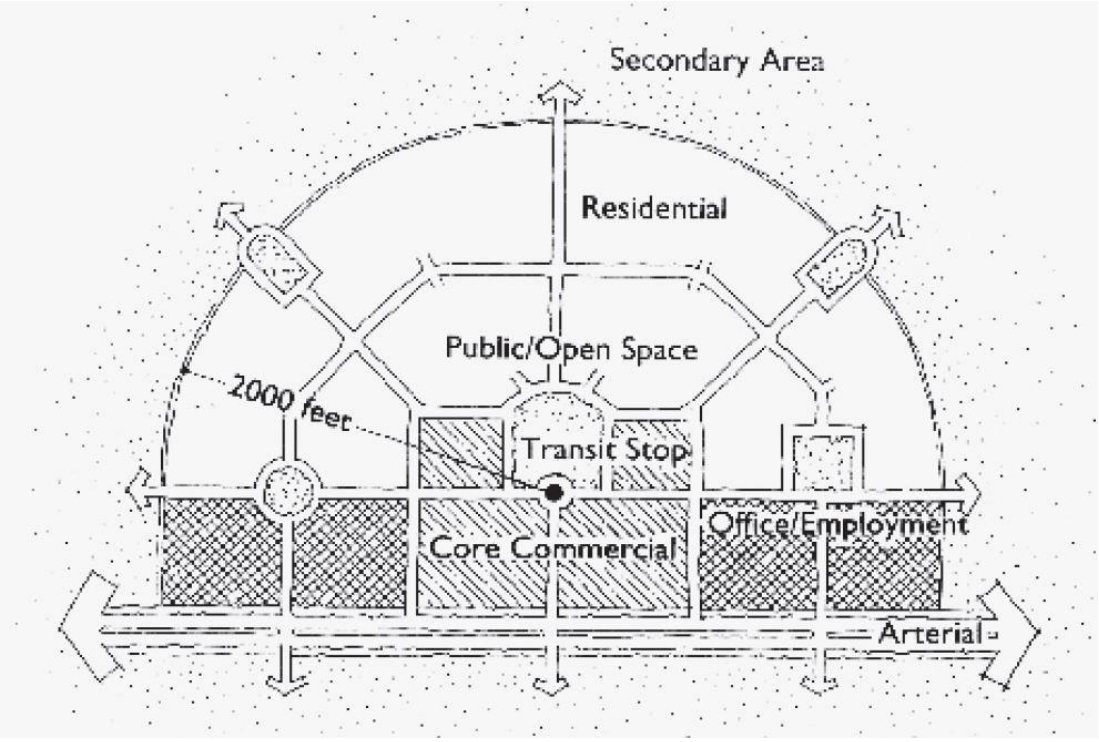

Figure 2.6 - The Transit-Oriented Development (TOD) scheme according to Peter Calthorpe
Source: (Calthorpe, The Next American Metropolis: Ecology, Community and the American Dream, 1993, p. 56)

What is central for all the similar development forms of New Urbanism, is that all the elements (commercial activities, offices, residences and open public spaces) must be covered by walkable pattern. The standard neighborhood design is obtained considering that Calthorpe identifies a 2000-foot (around ½ mile) walking distance (around 10

minutes) as comfortable for pedestrians. By designing a radius of such length around the transit station, within the area resulting from the drafted circumference should be placed first the commercial area next to the transit stop, then the open public spaces and the offices and on the outwards the residential units. Obviously, not all the TODs can perfectly respect the measure and organization of spaces as indicated in the figure proposed by Calthorpe. Thus, the sketch must be considered as indicative, allowing soft changes according to the context morphology in which the TOD is placed. Calthorpe identifies the most important in his type of development not mixing uses ora density but, rather, walkability is the essential factor TODs must consider. In fact, he states that if people commuting "can easily run errands and coordinate trips on the way to or from a station, they are more likely to use transit" (Calthorpe, 2011, p. 21) as happened for Fruitvale Village, Oakland (California), which projected a pedestrian plaza/corridor next to a BART station revitalizing the neighborhood, previously a rough area (Figure 2.7).

Figure 2.7 - Aerial view of Fruitvale Village TOD project in Oakland, California
Source: Metropolitan Research Center, University of Utah (http://mrc.cap.utah.edu/trip-and-parking-generation-at-transit-oriented-developments-phases-i-ii/)

A similarity between the two types of development TND and TOD is that both differentiates mixed-uses, density and parking lots according to the distance from the urban core, as illustrated in the *Urban to Rural Transect* (Duany, Plater-Zyberk, & Co., 2003). But according to Calthorpe, there also differences. He indicates that whilst a TOD must include the transit station within the development area, the TND could be "located on a local or feeder bus line within 10 minutes transit travel time (no more than 3 miles) from a truck line transit stop" (Calthorpe, 1993, p. 57). Also according to Dunay & Plater-Zyberk, there is a lot in common between TOD and TND, but their differences can be found "primarily in the conception of the pedestrian shed: the location of its centroid, and its extent. These

differences manifest secondary consequences regarding the density of the required model and the social quality of the center" (Duany, Plater-Zyberk, & Co., 2003, p. 3.2). Comparing Figures 2.8 and 2.9, there is such a lot in common with the TND of Duany and Plater-Zyberk and the TOD pioneered by Calthorpe that we can hazard saying that a TOD is a TND exclusively centered on a transit station. In fact, whilst beginner TODs require solely rail transit stop within its development, the TND, because of its greater freedom about location, could be served by bus transports only.

As shown in Figure 2.8, the location of the centroids in the TND pattern can be different from the transit stop and is allowed to have more than one of them resulting in a large pedestrian catchment. This pedestrian priority organization leads to relatively short walking distances from the center enhancing bus transit to be efficient (Duany, Plater-Zyberk, & Co., 2003). Moreover, another advantage of TND is that the main roads are expected on the edges with related commercial activities, avoiding then massive traffic transiting through the neighborhood and having the possibility to share commercial benefits with inhabitants coming also from other close neighborhoods (Duany, Plater-Zyberk, & Co., 2003). As a negative consequence of this spatial organization, there is the possible lack of commercial power: because the centers do not fit together with the rail transit stop, the commercial spaces could serve only the inhabitants without exploiting mass transit on the rail network (Duany, Plater-Zyberk, & Co., 2003).

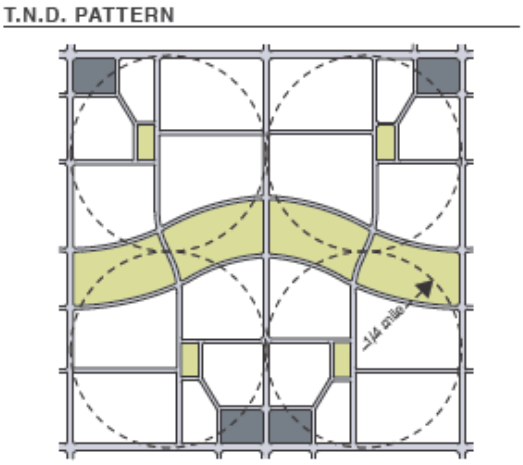

Figure 2.8 - TND pattern according to Duany Plater-Zyberk & Co.
Source: (Duany, Plater-Zyberk, & Co., The Lexicon of New Urbanism, 2003, p. 3.2)

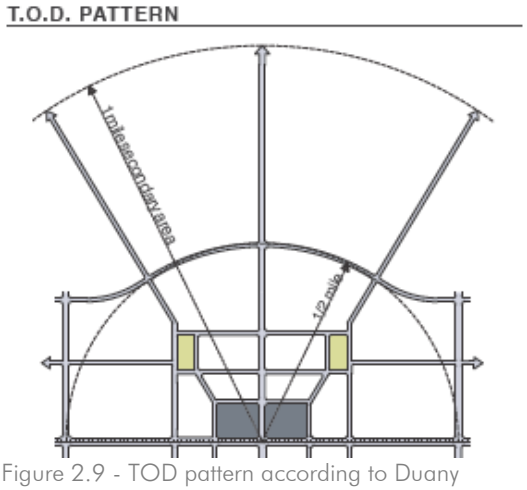

Figure 2.9 - TOD pattern according to Duany Plater-Zyberk & Co.
Source: (Duany, Plater-Zyberk, & Co., The Lexicon of New Urbanism, 2003, p. 3.2)

As shown in Figure 2.9, TOD is developed starting from a rail stop, which is "the most efficient form of transit" (Duany, Plater-Zyberk, & Co., 2003, p. 3.2) but also the most expansive one, needing then high-density population to be sustained. Contrary to the TND, the TOD takes clear advantages from the commercial point of view by locating its centroid on the rail station. At the same time, the TOD pattern may be run into a lack of commercial benefits in the outward neighborhood

areas. A challenge proposed by TOD is about the traffic flow around the transit node because, on the one hand, it could provide very high accessibility to the station and to commercial and institutional uses around it but, if not optimally managed, the vehicular traffic could compromise the whole neighborhood (Duany, Plater-Zyberk, & Co., 2003).

TOD patterns have emerged to face suburban sprawl developing around the transit stations higher density, mixed-use, and pedestrian-friendly environments. Nevertheless, TOD can be planned also for urban areas where blocks present vacant lands that could be fulfilled with the same development principles foreseen for those in the suburbs. In this sense, the thesis is still focusing on the main New Urbanism's targe area, also called "T3 - suburban zone" by Duany, Plater-Zyberk, & Co. (The Lexicon of New Urbanism, 2003), but it will also consider the zones "T4 – general urban zone" and T5 – urban center", especially in the case studies' analysis.

2.3. Connecting TOD with today's global Agendas

As seen in chapter 1, there are different ways in which climate change can be controlled and limited. Due to rapid urbanization, GHG emissions and impacts on our lives, in recent years the CC topic has reached its peak of attention. Nevertheless, it is since 1995[9] that the UN held yearly Conferences of the Parties (COP) in order to set future objectives and verify signs of progress and/or regressions on topics dealing with CC. With the TOD model, in the 1990s New Urbanists partially anticipated what the UN proposed in 2015 and 2016 through the production of two documents. Expiring in 2030, the first document is *Transforming our world: the 2030 Agenda for Sustainable Development* including 17 *Sustainable Development Goals* (SDGs) made of 169 targets that aim to complete, update and improve the 8 *Millennium Development Goals* (MDGs) active for the period 2000-2015. The second is T*he New Urban Agenda* (NUA) adopted at the UN Conference on Housing and Sustainable Urban Development (Habitat III) in 2016. These two agreements are strictly related, but while the SDGs deal with sustainability in its broader terms, taking care of sustainable humanity and ending poverty besides a sustainable planet, the NUA focuses on human settlements referred to sustainable urban developments. Although this relevant and useful difference, the two Agendas are strictly related since they share the same aim. In order to understand how New Urbanism predicted the current problems and conditions, is required integration between the two Agendas considering that NUA act as a bridge for the SDGs in urban environments.

Among all, the most pertinent goal to urban development is the SDG11: Sustainable Cities & Communities which aims to "Make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2015, p. 21) and it is structured as follows:

[9] The first COP meeting was held in Berlin in March 1995 (https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop)

"11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels

> 11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials" (United Nations, 2015, p. 21)

The SDG11 fixes targets in order to face the rapid and unregulated urbanization in both developed and developing countries generating un-proper suburban sprawl and slums, respectively. To do so, "investment in public transport, creating green public spaces, and improving urban planning and management in participatory and inclusive ways" (UNDP) is necessary to create sustainable development and adapt cities to CC.
The concepts illustrated in the SDG11 targets are matched in some points of the NUA which is structured in 175 points divided into 3 main chapters: the "shared vision", the "principles and commitments" and the "call for actions" (United Nations Habitat III, 2016). The latter is the biggest chapter "identifying how cities should work to be sustainable" (Okraszewska, et al., 2019, p. 6). Referring to the TOD model, the NUA's main concepts described in the document "have been grouped into three main pillars of sustainable development: social, economic and environmental." (Okraszewska, et al., 2019, p. 6). Although TOD does not treat the topic specifically, it is acknowledged that it can be considered a sustainable urban development thanks to the emphasis on limiting car-dependency and combatting sprawl (Okraszewska, et al., 2019). Thus, the environmental one seems to be the most coherent with the climatic objectives of TOD. The importance of TOD model to tackle CC is specified in the NUA in point 114 (b) where TOD is cited and highlighted: "Equitable "transit-oriented development" that minimizes the displacement, in particular, of the poor, and features affordable, mixed-income housing and a mix of jobs and services" (United Nations Habitat III, 2016, p. 29).

To conclude, this *PART I* highlighted that today we are facing the big and complex challenge of CC which cornered human society. Cities and urban settlements in general play a crucial in determining the fortunes of future generations. In this sense, urban planners and architects should act in encouraging sustainable types of development based on pedestrian environments and favoring the use of public transport while discouraging driving, a diffuse practice incentivized in American suburban sprawl. Fortunately, strategies arose from a New Urbanism, a revolutionary urban planning movement born from the encounter between two American schools of thought, which principles and ideas are today met in the UN goals and Agendas. New Urbanists develop theories and urban models like TOD and TND which are applicable at almost every kind of scale, from the regional to the local one, resulting in a very versatile model pertinent worldwide. Nevertheless, it does have a downside. That is, by being so feasible, it could not respond to CC properly because the same pattern should fix in different climatic areas, which are characterized by completely different behaviors in terms of impacts. Therefore, to introduce *PART II*, other, more local, strategies are needed, and they are found under the concept of Urban Design. New

Urbanists mention these aspects in the *Block* section of the *Charter*, but only in a premonition way without specifying important aspects which will be underlined in *PART II*.

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PART II

Plaza Design: How a Square can tackle CC

Introduction

As underlined in the masterpiece *The Architecture of Community* (Krier, Thadani, & Hetzel, 2009), the public squares embedded in the street networks and the public buildings have to be considered not as layers disconnected but as one single system that dialogues every day with the community that lives in the same system (Figure 3.1).

> "All traditional architecture clearly distinguishes between public symbolic institutional buildings, on the one hand, and utilitarian private buildings, on the other. The former expresses the qualities of things public, of res publica – dignity, solemnity, and grandeur; the latter, the private activities of housing, commerce, and industry in the *res privata* and the *res economica*. If factories have the facades of cathedrals and houses resemble royal palaces, if museums look like assembly lines and churches like industrial warehouses, a basic value of the body politic is threatened, the very nature of its public realm is in peril. But what is the nature and hierarchy of architectural objects?" (Krier, Thadani, & Hetzel, 2009, p. 29)

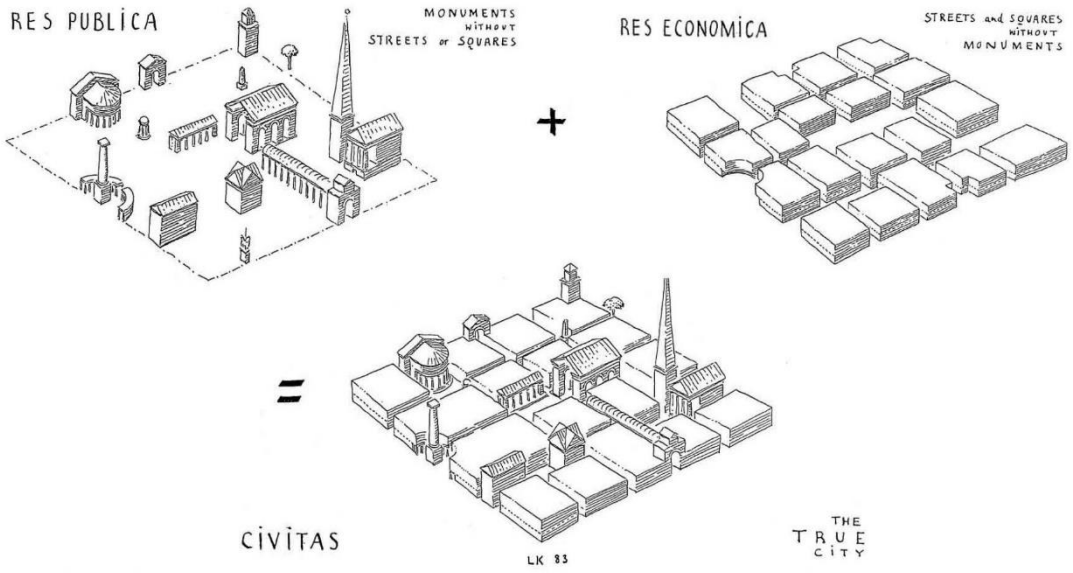

Figure 3.1 - Léon Krier's 1983 diagram on the city knitting together public and private buildings
Source: CNU Public Square (Steuteville, 2017)

PART II starts with a brief introduction to what is Urban Design and why it plays such an important role within the developing processes of urban and suburban TODs. Chapters 3 and 4 will deal with the thesis core topic: the plaza design. Public squares are a part of what is called the public realm. According to Moughtin (2003), the public realm refers to "streets, boulevards, squares and public parks together with the building façades that define them" (Moughtin, 2003, p. 2). The first fundamental requisite for every kind of plaza in every part of the world is the ability to host people and offer them a comfortable, safe and pleasant place to be. But, according to the climate changes and the relative impacts in urban and suburban areas explained in the previous Chapters, public squares, considered as central elements of urban settlements, should also behave properly in facing CC. Bearing in mind New Urbanists' theories and principles, this second part basically tries to assembly methods and strategies to tackle CC with both mitigation and adaptation measures applicable in public squares and its next surroundings through urban design. As underlined by the CNU, "New Urbanism is focused on design, which is critical to the function of communities" (Congress for the New Urbanism, s.d.). According to New Urbanists, urban design is the way through which the community can recognize a sense of belonging of a certain place, through which can be stimulated to actively participate in the social life of the neighborhood but also through which the most important objective – walk(-)ability – can be achieved. According to Hebbert (2003), New Urbanists have always been attracted by Urban Design, in particular "when urban growth and renewal were managed through design strategies that used conventional systems of streets and spaces, shaped through techniques of alignment, active frontage, parcellation, height control and public land scaping" (Hebbert, 2003, p. 200). Since the times of the Greek *agorà*, the public square has been the place where the community could meet other people, hang out and share lives harmoniously. Since that period, many things have changed but the public square, if designed properly, still represents the vital core of urban and suburban settlements. New Urbanists theories dedicate efforts to reducing car-dependency and act towards the achievement of a pedestrian-friendly environment. To do so, as already explained, the TOD model is based around a transit station while TND allows a larger automobile usage and, for this reason, TOD is the model chosen to which the next Chapters will refer to. In this context, therefore, urban design is considered as the vehicle through which walkability can be achieved and, given its public transit nature and pedestrian-friendly character, the promotion and attainment of walkability rules are considered as mitigation actions.

However, as largely explained in Chapter 1, mitigating climate changes, which is undoubtedly a pressing need, could be long-lasting and exhausting. To "alleviate" the (hopefully not) long waiting for GHG emission reduction, adaptation actions represent a healthy and sustainable way to answer to CC. Although New Urbanist theories do not dedicate efforts on how to adapt to such changes, they share many aspects with the urban design intended as:

> "the collaborative and multi-disciplinary process of shaping the physical setting for life in cities, towns and villages; the art of making places; design in an urban context. Urban design involves the design of buildings, groups of buildings, spaces and landscapes, and the establishment of frameworks and processes that facilitate successful development" (Urban Design Group, s.d.).

Given this definition, Urban Design touches many different disciplines, from planners and architects to sociologists and ecologists, at all small scales but, in this thesis, only its sustainable and environmental side will be dealt with. Carmona is a Professor at the Bartlett School of Planning, London, UK, focusing on Urban Design. He argues that all the different actions act in an urban settlement should be coordinated because, even if they are placed at very small scale (e.g. urban furniture), "their aggregation results in major effects on the overall natural systems of the neighbourhood, town, city, region" (Carmona, Heath, Oc, & Tiesdell, 2003, p. 40). Likewise happens for adaptation measures, because even if the real contribution of a lonely square could seem slight, a neighborhood could be made of more than one plaza, a city is made of more than one neighborhood and so forth until the entire build environment worldwide. Therefore, urban design is a process that should be applied also in public square, it is a process that every professional figure dealing with the built environment, planners and urban designers in particular, should apply for every development. With the growing warming cities and environments, then, urban design is the strategy that best accommodates CC adaptations. Although in Chapter 1 has been argued that technology advances play an important role in combatting CC (Desonie, 2008), and it is still confirmed, Lang, Professor of Architecture at the University of New South Wales in Sydney, Australia, contrary, states that environmental threats are not solvable by advanced and energetical efficient technologies only (Lang, 1994). *PART II* will try to explain how.

Once understood that urban design can come in several forms and scales, it is necessary to state that this *PART II* focuses on squares only, which exist in what Lang defines the "terrestrial niches" aiming to "improving its quality so that it functions better as a self-sustaining system that, in return, enriches human experiences" (Lang, 2005, p. 21). According to Carmona (2009), Urban Design is based on nine principles:

1. Stewardship, referred to the easy management of the urban environmental qualities: "clean and tidy, green, unpolluted, secure, safe, accessible, socially inclusive and fulfilling, economically vital and viable, physically attractive" (Carmona & de Magalhaes, 2009, p. 526);
2. Resource efficiency, referred to all those forms of technologies that involve sustainable energy (from solar panel to the surface materials) but, in particular, this

principle refers to the strategic design of spaces which allow resource savings (e.g. natural lighting and ventilation);

3. Diversity and choice, referred to the creation of attractive places that stimulate people to choose walking (or bicycling) instead of driving being diverse, mixed and easily accessible;
4. Human needs, referred to as indispensable to achieve environmental needs because, as happens in the case of CC, human's health and comfort are strictly dependent on environmental impacts (Carmona, 2009);
5. Resilience, referred to the ability to adapt to present and, especially, to future changes. In fact, in the case of public spaces, resilience is meant as the ability to adapt to the numerous and diverse functions public spaces – like squares – can host;
6. Pollution reduction, referred to the location and orientation (and others) of buildings, public spaces and neighborhoods can affect the whole environment by reducing resources needs and GHG emissions;
7. Concentration, referred to the compactness and density of urban settlements. The principle is based on the preference of a fine-grained disposition trying to compact not only buildings but also vehicular road, thus, removing precious space from the drivable environment and donating it to the public realm;
8. Distinctiveness, referred to the interesting value of the public realm that characterizes the built environment, in accordance to the aesthetical characters of the settlement in order to be distinct and in coherence with the surroundings at the same time;
9. Biotic support, referred to fundamental ecological efforts that plants, vegetation, landscape, and urban green system have on the built environment.

These nine principles are valid for all the spatial scales: "the building, urban space, quarter and settlement-wide scales" (Carmona, 2009) but, for the purpose of the thesis, only the building, space and quarters scales are considered as explained in Table 2 (Carmona, 2009). The Table shows how the different principles of urban design can interact according to the different spatial scales, resulting in a sort of list of guidelines to apply in urban and suburban spaces. These guidelines are the starting point from which to start to develop sustainable urban design places. In the case of Table 2, in fact, Carmona (2009) delineates just some keywords that should be considered while planning the built environment but, since every place differs from another first because of its geographical location, we should consider that each place be designed according to the sustainable design principles, but they should be declined according to the climatic conditions of a certain place.

Table 3.1 - Sustainable design principles by spatial scale

	Buildings	Spaces	Quarters
Stewardship	Responding to and enhancing context Design for easy maintenance	Responding to and enhancing context Managing the public realm Allowing personalisation of public space Traffic calming	Design for revitalisation Developing a long term vision Investing necessary resources
Resource efficiency	Using passive (and active) solar gain technologies Design for energy retention Reduce embodied energy - local materials and low energy materials Use recycled and renewable materials Design for natural light and ventilation	Layouts to allow sun penetration Spaces that reduce vehicle speeds and restrict vehicle circulation Design spaces that reduce wind speeds and enhance microclimate Using local, natural materials Capture and recycle water	Reduced parking standards Urban block depths that allow sun and natural light penetration and which encourage natural ventilation Using combined heat and power systems Local access to public transport
Diversity and Choice	Provide opportunity to mix uses within buildings Mix building types, ages and tenures Build accessible, lifetime homes and buildings	Mix uses along streets and in blocks Design for walking and cycling Combat privatisation of the public realm Remove barriers to local accessibility	Mix uses within quarters Design a fine grained street and space network (micro scale) Support diversity in neighbourhood character Localise facilities and services
Human Needs	Support innovation and artistic expression in design Design to a human scale Design visually interesting buildings	Provide high quality, legible, public spaces Combat crime through space design and management Enhance safely by reducing pedestrian/vehicle conflict Design for social contact and for safe children's play	Design visually interesting networks of space Enhance legibility through landmark and space disposition Socially mix communities Support social capital
Resilience	Build extendible buildings Build adaptable buildings Build to last Use resilient materials	Design robust spaces, usable for many functions Design spaces able to accommodate above and below ground infrastructure requirements Design of serviceable space	Design to allow fine grained changes of use across districts Robust urban block layouts

Pollution Reduction	Reuse and recycle waste water Insulate for reduced noise transmission - vertically and horizontally On-site foul water treatment using SUDs	Reduce hard surfaces and run-off Design in recycling facilities Design well ventilated space to prevent pollution build-up Give public transport priority	Match projected co2 emissions with tree planting Plant trees to reduce pollution Tackle light pollution
Concentration	Design compact building forms to reduce heat loss i.e. terraces Bring derelict buildings back into use Consider high buildings where appropriate	Reduce space given over to roads Reduce space given over to parking Increase vitality through activity concentration	Intensify around transport intersections Raise density standards and avoid low density building Build at densities able to support a viable range of uses, transport and facilities Respect privacy and security needs
Distinctiveness	Consider surrounding architectural character when designing Enhance locally distinctive building settings Retain important buildings and heritage	Reflect urban form, townscape and site character in design Retain distinctive site features Design for sense of place - local distinctiveness Retain important building groups and spaces	Reflect morphological patterns and history - incremental or planned Identify and reflect significant public associations Consider quarter uses and qualities
Biotic Support	Provide opportunities for greening buildings Consider buildings as habitats	Design in robust soft landscaping Plant and renew street trees Encourage greening and display of private gardens	Provide minimum public open space standards Provide private open space Create new or enhancing existing habitats Respect natural features

Source: Author's re-elaboration based on: (Carmona, Sustainable Urban Design: Definitions and Delivery, 2009)

According to these principles, urban design is, therefore, useful to provide a proper and sustainable environment for those using the public realm, since they provide comfort by organizing buildings that shape public spaces and, consequently, neighborhoods.

Proceeding toward the core topic of the thesis, since these three urban scales identified are the basis of the Urban Design process, they are able to influence, and at the same time, they are being influenced by the CC impacts, according to the nine sustainable Urban Design principles listed before. Therefore, the occurrence of the UHI effect, flooding, and droughts and the intensity degree with they occur, are being influenced and, at the same

time influence the building, space and quarter scales. Consequently, they are involved in the Urban Design process playing a crucial role in tackling CC. The following draft tries to embrace specific design strategies and actions arising from the principles of Urban Design, with particular regard for the public square. In this way, they have been subdivided according to their principal climatic target:

- Mitigation goal: reduce GHG emission by reducing car-driving and increasing pedestrian-friendly spaces;
- Adaptation goal: increase the ability to adjust to climate changes by making public spaces less vulnerable to CC impacts.

Some measures identified in Figures 3.2 and 3.3, can have more than one single functionality and be useful in achieving both the targets. Taking water bodies as an example (e.g. fountains), their attractivity value is commonly spread worldwide since childhoods, therefore, placing a fountain in the middle of a square could be a beneficial strategy to increase walkability. Probably of less common knowledge is the positive effect water bodies have on reducing high temperatures caused by the UHI effect thanks to their technical properties.
In the following Chapters are detailed all the measures that should be designed in order to achieve sustainable public squares in terms of CC.

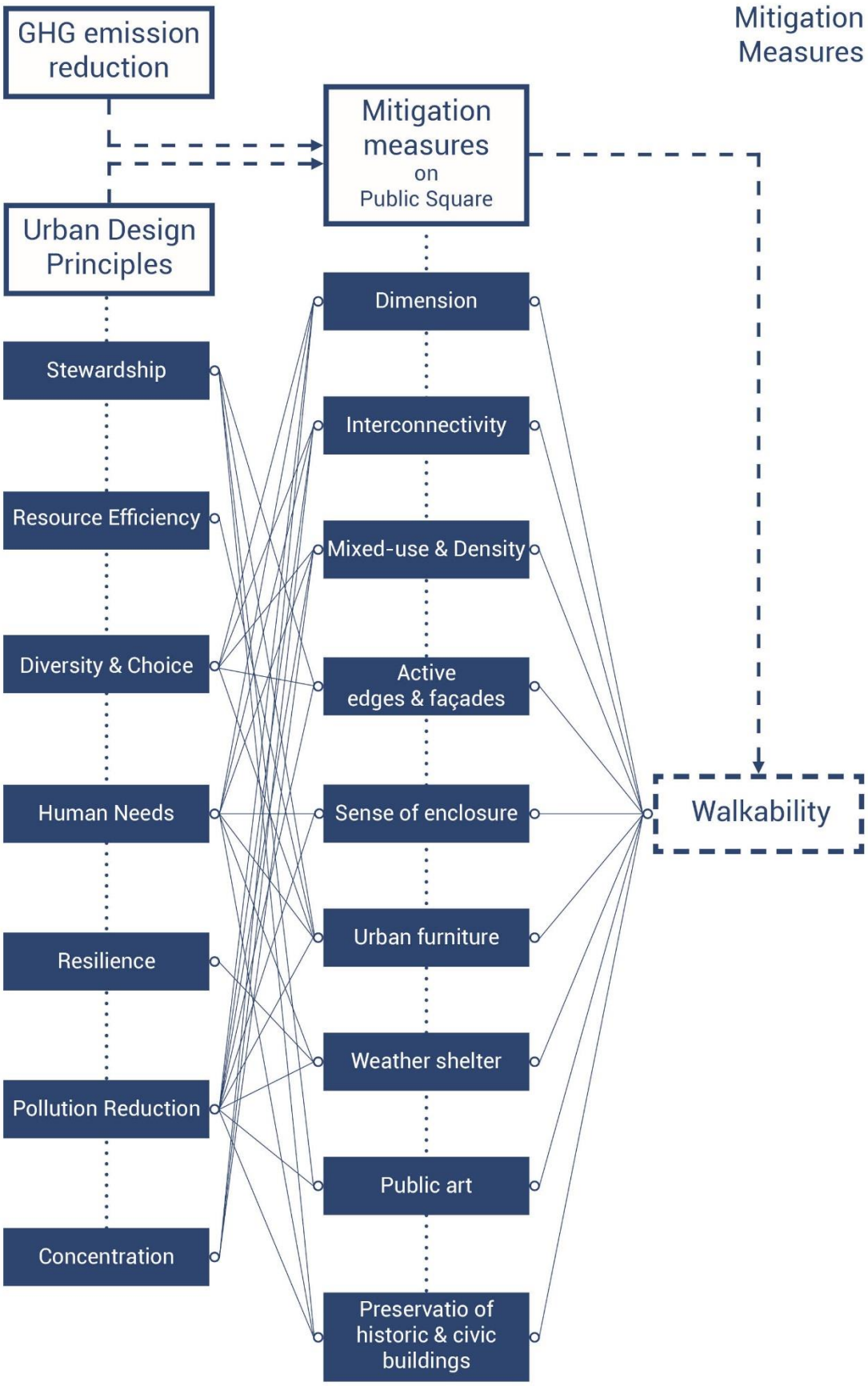

Figure 3.2 - Urban Design Principles and Mitigation measures
Source: Author's elaboration

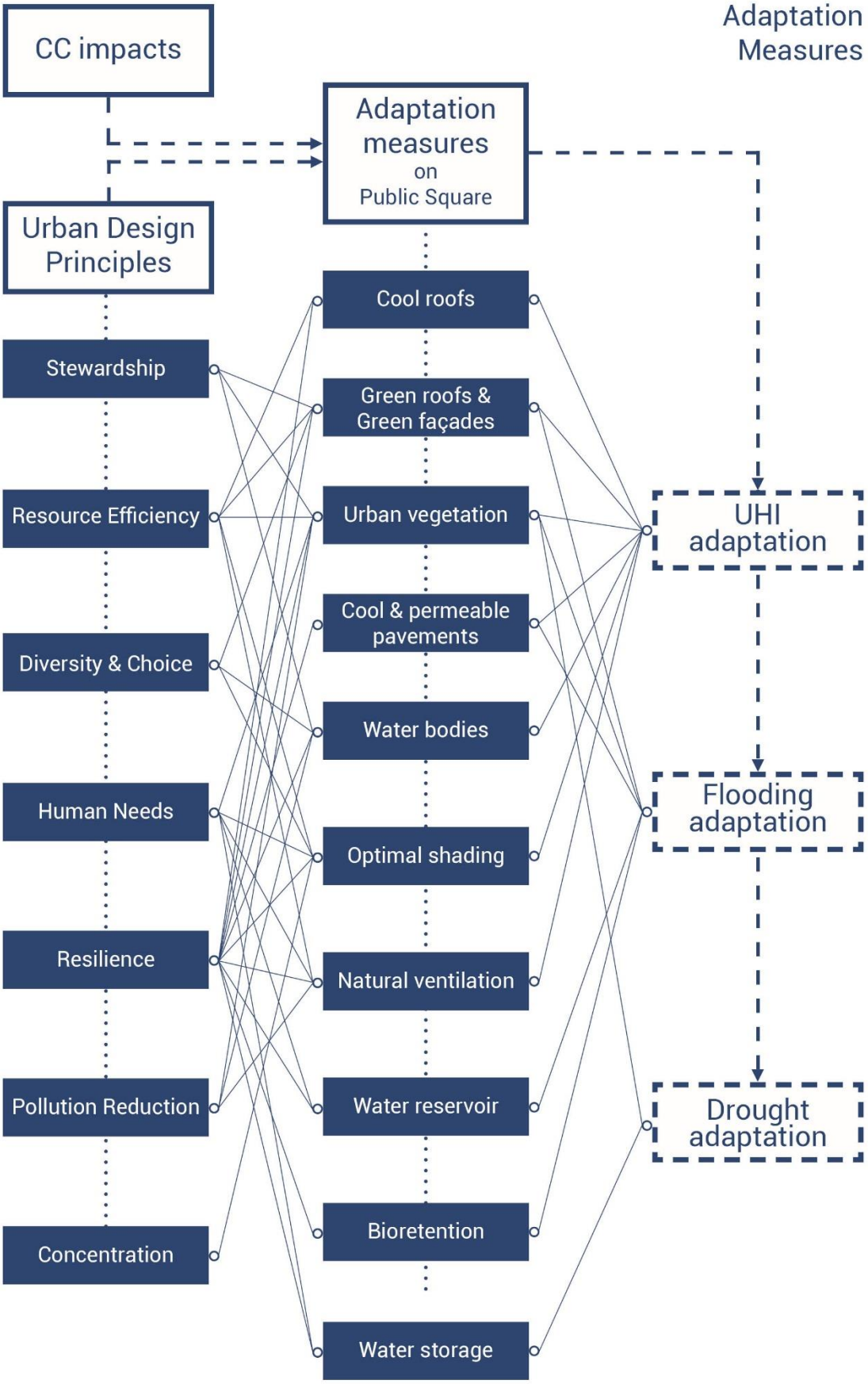

Figure 3.3 - Urban Design Principles and Adaptation measures
Source: Author's elaboration

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3. Mitigation measures

As explained in Chapter 1, mitigation measures aim to limit GHG emissions to avoid further warmer temperatures. Considering the plaza or square as a single element of the public sphere, it is not easy to think about it as a useful component to reduce GHG emissions but, according to New Urbanists, an increase in the number and quality level of public spaces and their higher expression - the square – could represent a good starting point.

The main aim of plazas is to be attractive and as accessible as possible, in other words, it focuses on its walkability. Before starting to explain what are the urban design elements that make a plaza appealing, we must say that a successful plaza depends not only on the plaza itself but, firstly, on its surrounding context. Whilst the previous Chapter 2 illustrated the benefits and characteristics of TOD, this one is working more on the pedestrian-oriented side of cities. This because of several reasons, not least the unregulated use of the automobile even for very short distances, causing heavy road traffic and changing irreversibly our climate conditions. Hence, by placing pedestrians on the top of the peaky order to be safeguarded, New Urbanists face one of today's biggest hitch in American cities. In a study made by *NationMaster* (Nation Master, 2014), after the Republic of San Marino and Monaco, the U.S. is the country with the highest number of automobiles (797) per 1000 capita; that means almost 1 for each American citizen. These numbers make stand out the ideals of the New Urbanists.

There are several ways to try to solve this problem. In some cities traffic is not allowed on the road on Sundays, in others driving is not possible between a certain period of time and still, in other cases, some areas, frequently located in the inner ones, are completely forbidden to motor vehicles. The latter option seems to be the easiest and efficient. Actually, it is efficient, but not necessarily the easiest to be obtained.

3.1. Walkability

The Danish architect Gehl has dedicated his professional life to improving cities by donating more spaces to pedestrians and cyclists and orienting them to the public realm. He states that "Walking is first and foremost a type of transportation, a way to get around, but it also provides an informal and uncomplicated possibility for being present in the public environment" (Gehl, 2011, p. 133). The way in which public space is perceived is subjective and change from person to person according to their preferences, habits, and lifestyles, of course. A public space can have different functions and can serve a multitude of purposes through different approaches: walking, sitting and standing (Gehl, 2011). In this Chapter, the first approach leads the other two because while standing and sitting involves a stationary usage, walking, as will be later explained, is a motor function with higher potential reduction impacts on GHG emissions.

3.1.1. Walkability benefits

In this paragraph are explained the multiple benefits of investing in walkability. For the purposes of this thesis, what matters the most are the impacts that walkability has on CC but, as it will be explained, it is not only a matter of CC itself but there are many indirectly correlated important elements that contribute to improving a community lifestyle. In fact, walkable patterns and pedestrian-oriented developments can affect:

1. Wealth benefits

   The already cited Speck, in his new book *Walkable city rules: 101 steps to making better places* (Speck, 2018) states that walking costs are not expensive, especially if compared to car and public transports (Figure 3.4).

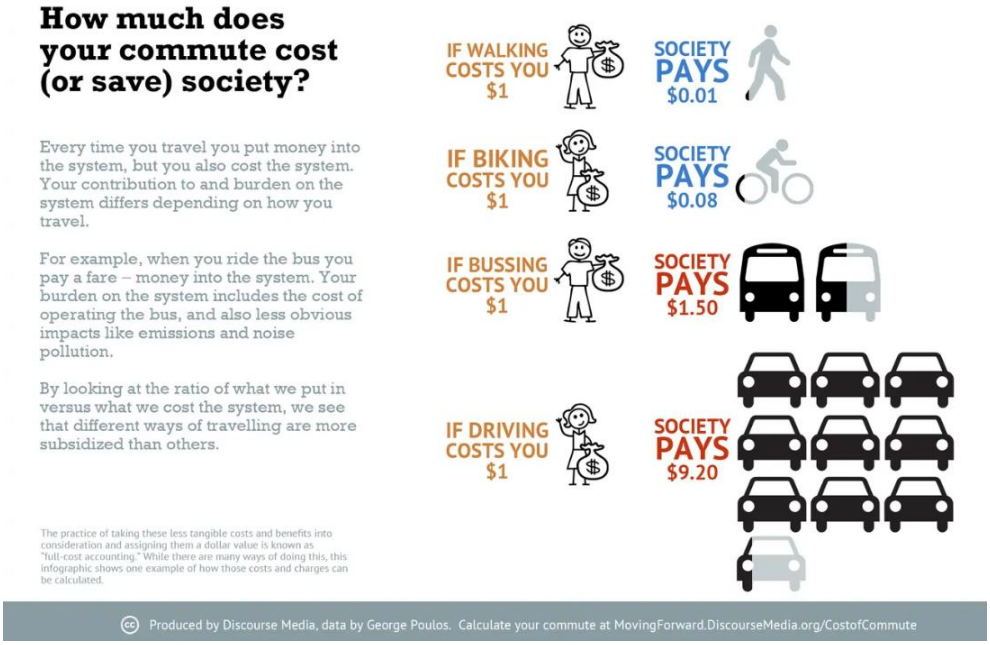

Figure 3.4 - Commuting cost comparison between walking, biking, bussing and driving
Source: (Speck, 2018, p. 3)

Besides the obvious but true money-saving, according to research made by Shrikant, operating towards walkability within cities "also attracts diverse populations and creates jobs" (Shrikant, 2018). Furthermore, Shrikant found that "people also tend to spend more money in walkable cities, stimulating the local economy" (Shrikant, 2018). However, it should be considered that even if pedestrian-oriented developments bring enormous benefits itself, in order to completely exploit its advantages, a city should be prepared to host pedestrian flow. That is, every form of urban planning that stimulate pedestrian flows like safe sidewalks and attractive spots should be applied and, in terms of wealth, commercial and retail activities (cafès, restaurant, etc.) along the pedestrian corridors or public squares tempt pedestrians to take a walk;

2. Climate Change benefits

   In an article published on *The Guardian* website, Milman states the biggest source of GHG emissions are not houses and electricity but transports, including "cars, trucks, planes, trains and shipping" (Milman, 2018). At the city, district and neighborhood level it is, therefore, necessary to discourage the use of private vehicles as much as possible in favor of walking, bicycling and public transports, rather than private. As underlined by Speck, "the first thing one learns in city-planning school is that how we move determines how we live" (Speck, 2018, p. 7), thus, basing cities and suburbs towards pedestrian-oriented developments should be a primary necessity. Hence, by siphoning off impermeable and polluted land from vehicles transit, more precious pedestrian areas would be created resulting in better climate conditions;

3. Health benefits

   A walkable city can lead to saving lives. It is not news that climate change has very dangerous impacts on human health and on our natural environment. Climate change is produced by different sources but whilst most of the smog was previously produced by the factory and industrial sector, today car emissions represent the most significant ones (Lutz & Fernandez, 2010, p. 172). According to Caiazzo et al., "in 2010 there were around 160.000 premature deaths in the U.S. due to PM2.5 exposure and around 4300 deaths related to ozone exposure" (Caiazzo, Ashok, Waitz, Yim, & Barrett, 2013, p. 198). It is evident that in order to obtain cleaner air, more vehicles should be taken off the streets, and donating them to pedestrians would be a great deal. Another important aspect of the health problem is obesity. According to the *World Population Review* (Most Obese Countries Population, 2019), the United States is one of the countries with a higher percentage of overweight people in the world (36,2% of the total population)[10], obesity must be considered a real health problem for Americans. Obesity is strictly linked with the sprawl phenomenon. Its nature, in fact, by requiring the use of the automobile as almost the only way of transports to cover all the distances, make people deciding to take the car and turning them into lazy – and fat – human beings. As a result, if a city is walkable, it is less likely that the population will be overweight and, of course, fewer diseases would be caused by obesity (not to mention the countless psychological benefits associated with physical activity). As reported by the *National Safety Council* (NSC), fatal car accidents in 2018 in the U.S. caused at least 40000 deaths for the third consecutive year (40.231 deaths in 2017 and 40.327 deaths in 2016), and about 4,5 million people were seriously injured (National Safety Council, s.d.). Since fatal accidents are mostly caused by vehicle traffic, less vehicle traffic means less fatal accidents and, once again, a

[10] http://worldpopulationreview.com/countries/most-obese-countries/

walkable city could provide nice health benefits to citizens avoiding unexpected deaths.

3.2. How to reach walkability

After having explained – very briefly - all the positive impacts a city can benefit from the insertion and/or the implementation and the enrichment of walkable patterns, now it is important to define how to reach walkability. What are the elements that stimulate a person to go-by-foot and not go-by-car? If we think of closing to motor traffic a previously busy road randomly without thinking on details, then we might obtain an even worst result. No, it would be not enough. As Duany, Plater-Zyberk, and Speck describe in their masterpiece *Suburban Nation: the rise of sprawl and the decline of the American dream* (2000), the devil is the details. Reminding that the focus is about how a public square can intervene in tackling CC, the following pages of the Chapter are dedicated to the mitigation measures that merge onto the wider, complex and sustainable Urban Design Process.

3.2.1. Square dimensions

The dimension of a square can vary depending on a multitude of factors: will the square be created within an already existing settlement of buildings or it will be a new public space inserted in a wider new project? What its function will be? Under which zoning regulation, laws, urban standards, will be developed? Many others are the aspects and considerations to take into account in order to outline square dimensions. Some scholars dealing with urban planning and public space, in particular, tried to do so in the past resulting in a series of ideas, principles, and approaches to public space. As already said, the concept of public square date back to the Greek's *agorà* and, since that period, many studies on the design of public space have been carried out, especially from the European point of view.

Camillo Sitte in 1889 published a pioneering book called *Der Städtebau nach seinen künstlerischen Grundsätzen* ("City Planning According to Artistic Principles" or "The Art of Building Cities") on urban planning with particular regards on public spaces of that period, especially in Germany and Italy. In his masterpiece, Sitte stated that the square dimensions are strictly related to the road network that encompasses it. Street widths, as squares', can change according to the city and the location. Street measures are crucial to the valorization of the public square and they can measure around fifteen to twenty-height meters to, as happens in many European (e.g. Champs Elysèes in Paris) cities can reach up to more than hundreds of meter widths. However, Sitte argues that 58 x 142 meters is the medium dimensions in the biggest squares in ancient European cities (Sitte, 1981).

Kevin Lynch in his book *Site Planning* (1962), defines that "the most successful enclosed square of the past have not exceeded 450 feet" (Lynch, 1962, p. 60) which is around 137 meters.

The Danish architect Gehl in Cities for People (2010) argues that a typical dimension for public square should not exceed a hundred meter per side, resulting in a maximum square area of one hectare.
However, all the opinions given by such important and influencing authors are obviously related to European city structure and rich cultural heritage. Within the American context, pretty far from the previous ones, the more recent ideas of TODs express different square sizes. According to due Duany, Sorlien and Wright, in the manual *The SmartCode Version 9.2* (2003) they define precise dimensions an open space should contain, according to the type of public space. So far it has been discussed without making any differentiation between the terms "square" and "plaza" but, as argued by Duany, Sorlien and Wright, they differ both in function and dimension:

- "Square: An Open Space available for unstructured recreation and Civic purposes" (Duany, Sorlien, & Wright, The SmartCode, 2003, p. 41). According to Duany et al. (2003) the square (Figure 3.5) should measure between 0,2 and 2 hectares (Duany, Sorlien, & Wright, The SmartCode, 2003).

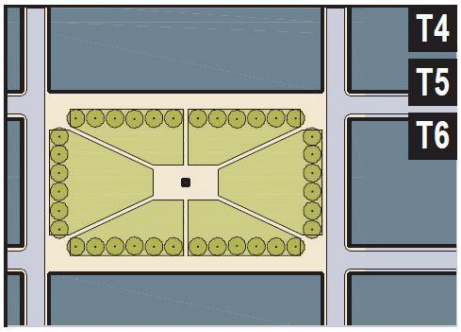

Figure 3.5 - Ideal New Urbanist square
Source: (Duany, Sorlien, & Wright, The SmartCode, 2003, p. 41)

- "Plaza: An Open Space available for Civic purposes and Commercial activities" (Duany, Sorlien, & Wright, The SmartCode, 2003, p. 41). Thus, a plaza (Figure 3.6) could function as an informal public space obtained from street intersections, ranging from 0,2 to 0,8 hectares. (Duany, Sorlien, & Wright, The SmartCode, 2003).

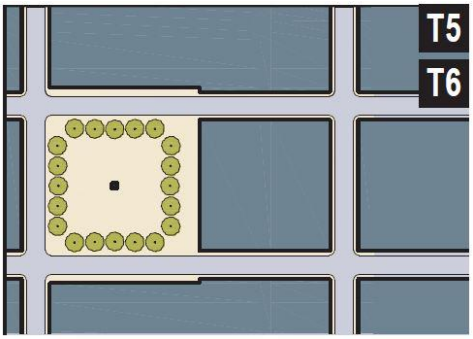

Figure 3.6 - Ideal New Urbanist plaza
Source: (Duany, Sorlien, & Wright, The SmartCode, 2003, p. 41)

3.2.2. Mixed-use and density

Today is fairly believed that high density with numerous diverse activities is the right receipt to build lively and pedestrian-oriented cities. We can state that, in order to have livable communities, cities should offer a diverse range of activities, services, and amenities within certain walkable distances. A numerous variety of uses contained in a single building allow people to have a (social and public) life at almost every moment of the day without needing

their private automobiles. That is, by having the main primary needs within walking distances, the use of the automobile as a choice would disappear because of convenience reasons. The easier to reach is any destination, the more people will be encouraged to use it and reach it by walk. This could be possible by mixing land uses and uses within the same building, in order to develop an efficient and convenient system vertical rather than horizontal-oriented (Figure 3.7). To develop a properly mixed-use building, retail and commercial activities should be placed on the ground floor, visible and accessible from everyone. Unless the bar, restaurant or grocery occupy also the first floor, from the first floor upward the spaces are occupied by offices or residential units. If buildings are well uses-mixed, a normal worker can have a beer or go to the gym after work and children can have an ice-cream or go to the playground after school. In her masterpiece *The Death and Life of Great American Cities*, Jacobs criticizes the current planning method of American cities characterized by diffuse sprawl. In her masterpiece, she recognizes the essential primary need for building structured towards a mixed-uses approach identifying it as the *1st condition* for cities:

> "the district, and indeed as many of its internal parts as possible, must serve more than one primary function; preferably more than two. These must ensure the presence of people who go outdoors on different schedules and are in the place for different purposes, but who are able to use many facilities in common" (Jacobs, 1961, p. 152).

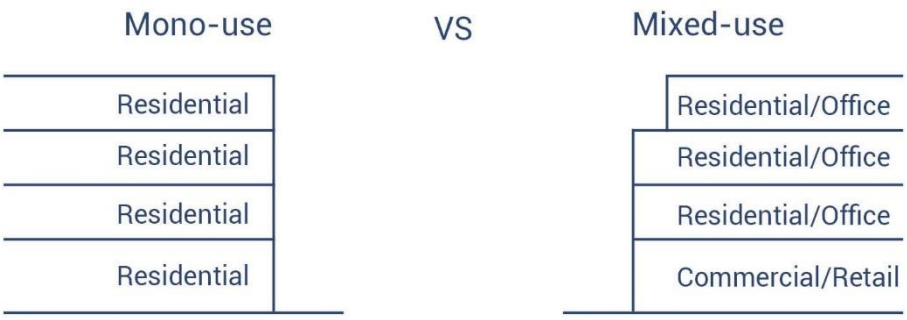

Figure 3.7 - Comparison between homogenous and mixed building
Source: Author's elaboration

Another topic related to mixed-use and diversity is building density. The latter, if well planned with diversity, allow to contrast the spread development of the majority of new American suburbs. But whilst diversity should be implemented as far as possible, the same thinking cannot be applied with buildings because, as explained later, density involves also and especially the space existing on the ground floor. Thus, as recommended by Calthorpe

(1993), high density should be set in the inner commercial area in order to allow (vertical developed) more space for commercial and retail activities, creating a vibrant pedestrian environment from which both people and retailers are able to benefit. Therefore, density is strictly related to the building's location, generally having higher and denser buildings in inner areas that lower as moving away from the neighborhood core. However, attention in elevating buildings should be paid in order to do not obtain the opposite result, that is public space literally obscured by a too-tall building. In this sense, as expressed by Gehl's book *Cities for People* (2010), "what the lively city really needs is a combination of good inviting city space and a certain critical mass of people who want to use it" (Gehl, 2010, p. 68). In the book, he argues that in some cities, recent buildings are too high and too dense to allow passengers an enjoyable walking through them because they do not allow natural sunlight to illuminate and warm up public spaces. Reasonably, this is more concerning inner-city areas characterized by their CBDs and lack of physical space; but it must be also taken into account when projecting a new suburban public plaza because public spaces measures may be different, but certainly not the way people perceive them.

3.2.3. Compactness and interconnectivity

As previously said, what allows a public square or plaza to have success is its attractiveness depending on its surrounding context. Basically, a square is an open space made up of buildings limiting the area on the perimeter; even if we know that is much more than that. Therefore, a public plaza is strictly affected by the elements of which is surrounded by, one for all the blocks. The location, size, and morphology of the latter have the central and, at the same time, dangerous power of defining the road network. This point is fundamental for square function since the road network is its accessible axes. Thus, the wider are the surrounding roads, the more the people will feel unsafe to use and cross them.

What actually makes people decide of moving on foot is the possibility to reach the destination easily. Studies have demonstrated that the maximum distance a people are willing to walk – "the pedestrian shed" - is between five and ten minutes, or between ¼ a mile (400 meters) and ½ a mile (800 meters), before deciding to drive. Calthorpe (1993, p. 56), considers a "*comfortable walking distance*" the area covered within a 2000-foot radius (about 10 minutes walking) from the transit station. This takes us to another important element defined by the block's physical characteristics, which is the length of their perimeter sides. In other words, the length pedestrians should walk before changing direction. Nevertheless, there are several factors that must be considered when talking about "pedestrian shed" that could affect the choice of walking. Those are for example the scope of walking and the related urgency to reach a certain destination, the different options of moving nearby (for instance, bicycle and public transport stops), the topography, the climate conditions, and other physical features.

Speck dedicates two rules in his book *Walkable city rules: 101 steps to making better places* (2018):

- "Rule 36 – Understand Network Function", where the author encourages to design "porous road network" to exploit its convenience properties (e.g. flexibility in changing destination and pattern's choice), instead of the "dendritic (branching)" system typical of the tentacular sprawl organization (Speck, 2018, p. 87) n. This would ameliorate the block as a whole because it would be more attractive in terms of pedestrian frequency and it would be able to host little vehicle traffic in inner streets. Moreover, by removing it from the more congested arterial roads, regarding inner streets it would mean not such severe changes but, contrary, for the arterial thoroughfare having surrounding neighborhoods that attract traffic within them, it would mean a lot (Speck, 2018).
- "Rule 37 – Keep Blocks Small", where the author encourages to build keep blocks within of certain measures and size, ranging from "1000-foot maximum perimeter in cities and 2000-feet in suburbs" (Speck, 2018, p. 89) to guarantee safety, comfort and to make them more interesting to walk through. As in the previous Rule 36, the emphasis is put upon the necessity to have blocks of a limited extent to allow the flexibility and possibility to choose.

As illustrated in Figure 3.8, the smaller the blocks, the higher will be the possibility to change directions leading to interconnectivity. Interconnectivity is obtained by setting neighborhoods with small blocks, as Jacobs states "Most blocks must be short; that is, streets and opportunities to turn corners be frequent". (Jacobs, 1961, p. 178)

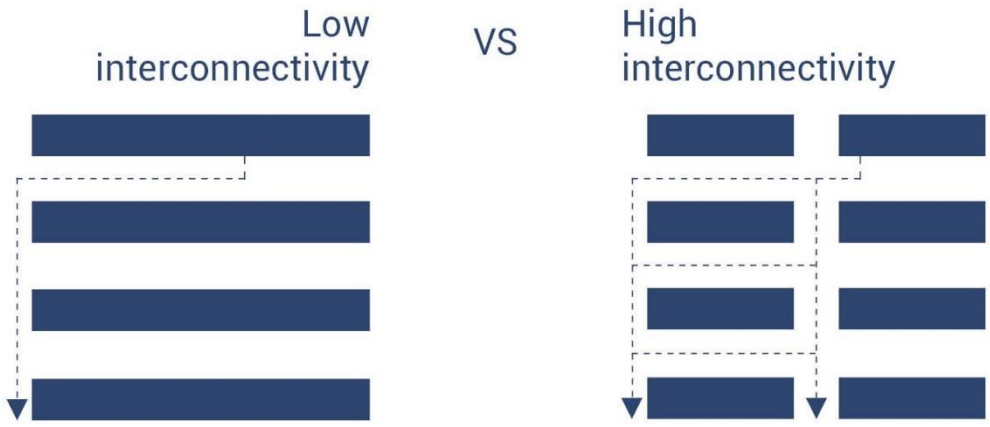

Figure 3.8 - Comparison between low and high block interconnectivity
Source: Author's elaboration

3.2.4. The building's exterior side

As pointed out by Calthorpe, "The pedestrian life of a building is at its entry" (Calthorpe, 1993, p. 80). In order to achieve walkability, particular attention must be paid to the exterior side of the buildings and their perimeters. These physical elements actually consist of why people are enticed to walk in open spaces: to live their "outdoor experience". There

are two types that characterize a building by the passenger's views: the edges and the façades.

The first floor of any building is its most important element, not only for its structural function and its location at the base. Defined "plinths" (Figure 3.9) in *The City At Eye Level*, they are the "most crucial part of the city at eye level" (Karssenberg & Laven, 2016, p. 14). Gehl, J. called them "soft edges", meaning the foundations "where you enter and leave buildings, where indoor and outdoor life can interact. This is where city meet building" (Gehl, 2010, p. 75). According to the author, edges help to shape urban squares and other public spaces by giving them an identity that offers interest and memory of certain places instead of others surrounded by flat and blank walls (Gehl, 2010). By being located at the ground floor next to sidewalks, edges represent the "exchange zone" (Gehl, 2010, p. 75) through which activities embedded in buildings dialogue with the external public environment. The entries can be considered as a synonym of edges. As expressed by Calthorpe (1993), all the entrances of commercial buildings should be oriented towards the public space to guarantee a sort of dialogue between the (exterior) public spaces, made of (possibly) pedestrian streets and squares and the (interior) buildings (Calthorpe, The Next American Metropolis: Ecology, Community, and the American Dream, 1993).
The first goal of edges is to do not annoy their front passengers but, on the contrary, to entice them (Figure 3.10). People usually, get bored when they repeat something to exhaustion. In urban design, this can happen when walking along with a monotonous building (a garage or a mall) characterized by for example a blank wall with no windows or entries. In this case, the strategy to get people interested is to limit repetitions because "more than a few dozen feet of the same façade treatment gets boring" (Speck, 2018, p. 212). This is why it is so important when designing walkability to always keep in mind that is better to have an open and active façade than a closed and passive one.

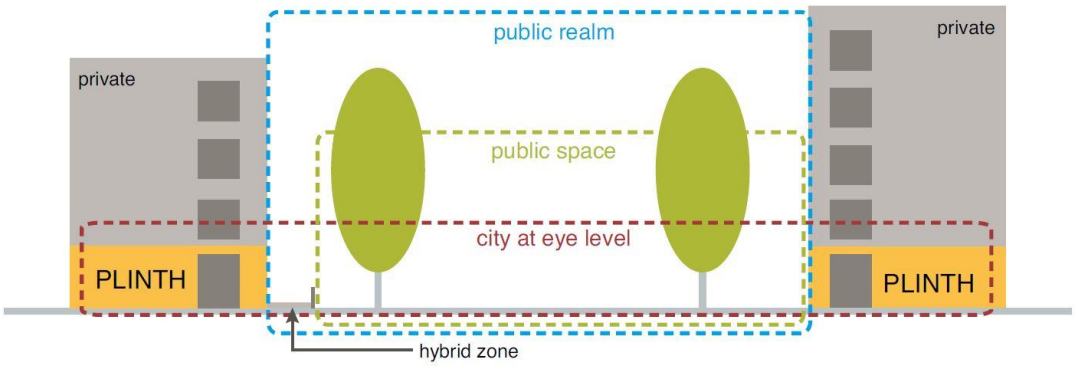

Figure 3.9 - The "plinths"
Source: (Karssenberg & Laven, 2016, p. 15)

In this context come in handy the concept of the demise line[11] to model the rhythmic form of the building side that creates the effect of having architecturally and aesthetically different buildings one next to the other. In this case, the devotion to fine details make the difference, hence, it is mandatory to develop building's rhythm by choosing aesthetically appealing

Figure 3.10 - Active edge connecting the building and the public space in Gent, Belgium
Credit: © Joris Visser
Source: Unsplash (https://unsplash.com/photos/CecCDfKJtzk)

[11] "A demise line is an artificial vertical boundary that breaks a façade conceptually into several smaller units" (Speck, 2018, p. 214).

design elements like windows, visible showcases, appropriate materials and other items to enrich the buildings facing the public realm (but this context will be better explained later). The aesthetical aspect necessarily leads to the development of the façades. The perimeter's shape of a certain plaza or the rhythm of a certain street strongly influences the people's desire to have an outdoor experience. To stimulate people in walking rather than driving, the buildings' edges should be active both in terms of opening and closing time of the ground floor activities (obviously, more open diverse activities attract more people looking for diverse scopes), but also in terms of rhythm, "provided by buildings having vertical rather than horizontal articulation" (Speck, 2018, p. 210). The façades of buildings should offer a variety of elements of different colors and materials without burdening distances and making pedestrians interested in walking along streets and squares. Many are the aspects that influence the fortunes about a successful or failed attractiveness of first floors. The most physical ones have been previously described, ranging from active façades and vibrant walls to attractive colors and materials. But they are not the only ones. It can seem obvious, but if there are not many people walking by buildings' plinths, there will not be many people interacting with them, and walkability fails at its roots. To operate in this sense, a strategy has been developed to ensure successful plinths considering three mandatory layers: the building, the street, the context. It is important to consider these three layers as a whole, constantly dialoguing. As Karssenberg and Laven argue (2016), it does not matter if there is one single fantastic building but standing alone and surrounded by degraded areas, there would be no changes to obtain walkability in this way. Rather, it would be better to create a system within all the parts and elements (plinths included) are interacting and operating towards the same scope of walkability (Karssenberg & Laven, 2016). This is why efforts should be committed not on the square space itself, which is surely fundamental, but also on its surrounding environment. Edges and façades can also have a covering function when considering structured parking. There are several methods to hide a visibly unpleasant huge parking (Figure 3.11). From an urban design perspective, they can literally hide and disguise the parking structure and letting its exterior's side facing a pedestrian street with active façades instead of empty and blank walls (Speck, 2018, p. 219).

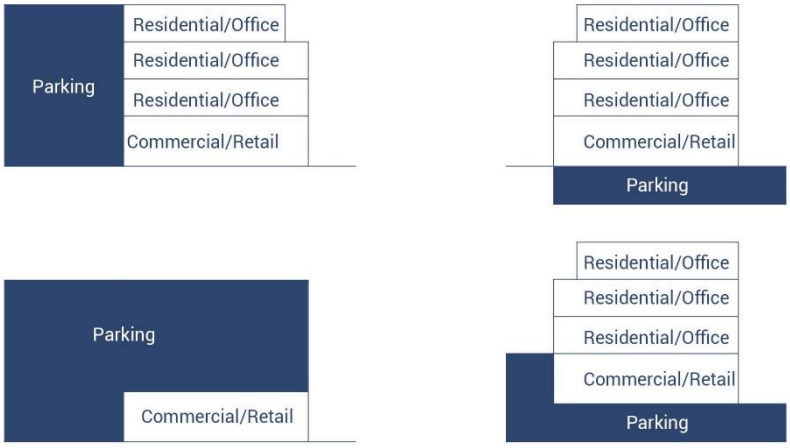

Figure 3.11 - Methods to incorporate parking to buildings
Source: Author's elaboration

3.2.5. Sense of enclosure

It is fundamental for pedestrians to perceive a comfortable feeling while walking and resting in public spaces. This is what is obtained through an adequate sense of enclosure. The latter is given by a proportioned use of the public space, which is the ratio between the buildings' height that surround the square, plaza or street and the width of the public space itself. The height to width ratio is "the proportion of spatial enclosure related to the physiology of the human eye" (Duany, Plater-Zyberk, & Co., 2003, p. 7.2).

Similarly to the dimensions of a square, there are no standard and universal measures regarding the relationship between the height and width (H/W) since the design of public space is strictly dependent on its surrounding context, as already mentioned. However, in *The Lexicon of the New Urbanism* Duany, Plater-Zyberk & Co. sketched some examples to give an idea of the most appropriate H/W ratio. As illustrated in Figure 3.12, the H/W ratio can depend on the context but also on the function the public space would have. The relation indicated in the Figure, of course, does not has to perfectly respected and can change according to different locations but Duany and Plater-Zyberk have set different ratios to different public spaces.

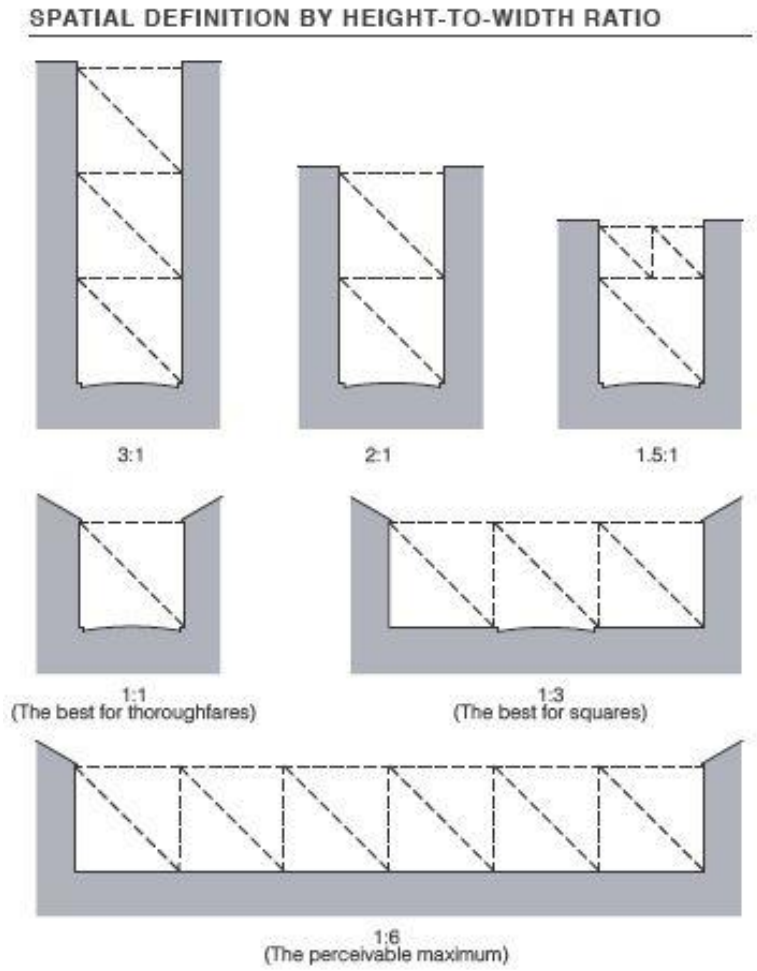

Figure 3.12 - Height to Width ratio (H/W) in urban public spaces
Source: (Duany, Plater-Zyberk, & Co., The Lexicon of New Urbanism, 2003, p. 7.2)

Duany, Plater_zyberk & Co. consider that an approximately 1:1 ratio is ideal for thoroughfares, that could be used for the commercial corridor, for examples. Regarding public squares, a 1:3 ratio is considered the best choice, giving a perfect sense of enclosure with a maximum 1:6 ratio, assumed as the maximum in order to perceive the sense of enclosure. The sense of enclosure depends on the H/W ratio counting on the fact that at a higher value of H/W correspond higher value of the sense of enclosure (Figure 3.13). If the existing buildings that surround the square are not tall enough, other vertical elements could be added back to increase the sense of enclosure.

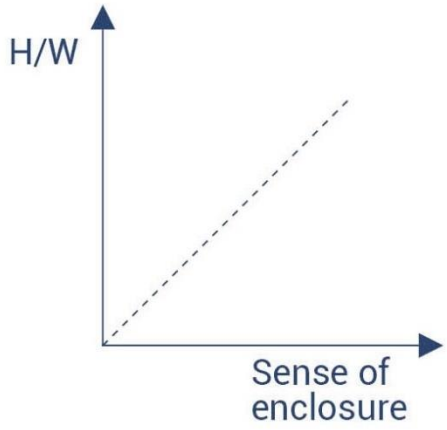

Figure 3.13 - Spatial relation between H/W ratio and sense of enclosure
Source: Author's elaboration

3.2.6. Urban furniture

Urban furniture is not only made by benches, but it is a fundamental branch of the wider Urban Design process which makes the public square a more comfortable and enjoyable place furnishing it of elements that can be considered of secondary importance, but that actually makes the difference. In other words, urban furniture "can improve the quality of life for the inhabitants of a city" (Tosca, 2018). The following pages are going to explain where, how and why urban furniture components in public spaces – especially squares and plazas – contribute to reaching walkability. It is not enough to shake urban furniture elements like dice and hoping that they will work appropriately. The risk is to fall down and degenerates in the so-called "defensive planning", "defensive urban architecture", "excluding architecture", "disciplinary architecture", "hostile architecture", and even "evil architecture" (de Fine Licht, 2017, p. 27). These synonyms refer to those urban elements that repulse people rather than welcome them. Even if it could sound wired, there are many cases in which, for example, ledges are designed uncomfortable on purpose, letting people leaning against them but forbidding a comfortable solution. But let's concentrate on the urban furniture elements that help to stimulate, protect and enhance walkability.

Seats and benches

In order to determine the degree of success or failure of a certain square or plaza, there are many variable aspects to take into account but, here, the evaluation will be based on how much the public space is frequented by pedestrians in order to encourage walkability. According to Gehl & Svarre, useful aspects to contemplate are, therefore, how many people attend the social life within the square and how much time they spend in it (How To Study Public Life, 2013). The first variable (how many) is strictly related to the square's function and to the number and quality of the activities and services settled in the square (in turn dependent on the edges and façades characteristics previously described) and is necessary to understand and measure "how many people are moving (pedestrian flow) and how many people are staying (stationary activity)" (Gehl & Svarre, 2013, p. 13). The stationary activity usually occupies the exterior layer of the public space next to building frontages and helps us to better recognize the second variable (how much). According to Gehl (2013), there are two types of stationary activity: standing and sitting. The latter implies a fundamental public space element: the sitting places explained as follows.

There is an infinite multitude of typologies regarding sitting places, varying from their materials to their design. However, aiming to walkability, what we can do is to study where and how to locate sitting places. The latter, as already explained, belong to a wider container – known as urban furniture – in which are included all the physical elements that fill the urban public environment, within which seats and benches play a primary role.
It is largely acknowledged that public space needs a relatively great number of sitting places to give the possibility to benefit from their comfort by a relatively great amount of people. Nevertheless, their location is particularly important in defining public spaces in order to allow meeting, waiting and socializing, comfortable practices (Yücel, 2013). With particular regard to public squares, sitting places should be integrated within the existing environment already placed in outdoor spaces, "so that when seats are not in use they do not create a sense of isolation or emptiness" (Yücel, 2013). Assuming that benches and sitting places are needed where there is the lively and continuous pedestrian flow when thinking about their location is important to have in mind that when people are seeking to seats, they prefer to watch what happen on their surrounding environment and they prefer to have their back protected (Gehl, 2011). As Gehl states (2011), single sitting places like benches should not be located alone and detached from the other elements that made up the square but, rather, it is preferred to place them "along facades and spatial boundaries" (Gehl, 2011, p. 157). To remark the location importance, that every bench should be better placed in a closed and protected space rather than wide-open space to stimulate "intimacy and security and, as a rule, a good microclimate as well" (Gehl, 2011, p. 159).
The Project for Public Spaces is a non-profit organization devoted to the creation and support of public spaces aiming to generate a community environment. In an article posted on their website (2008), they draw up a list of good practices creating a sort of guidelines to follow in order to perceive their objective: create community. The guidelines go in-depth

with sitting places details, and specify that they should: "be set back at least 24 inches from the pedestrian walkway", they should be placed next to other urban furniture elements and other street amenities, "placed at a 90 to 120 degree angle, which is good both for conversations and for sitting alone" because of people's intimacy, "not be lined up in a row because this makes it difficult for a group to have a conversation", they should be "movable" because fixed benches do not allow people do arrange them as they need, and they should provide spaces for disabled people (Project for Public Spaces, 2008). The guidelines just described are surely useful to have an overview of the sitting places' importance. But, as already said, many variables occur when dealing with public spaces. In fact, benches can differ in many aspects: seat width, length, heights, materials, with or without armrests, with backs or backless, design, etc. but the two most important aspects to consider about sitting places are their physical comfort and their psychological comfort, both necessary to obtain a useful and appreciated sitting area. In turn, the psychological aspect has a double meaning: it is related to the choice of seats because of privacy issues, but one can also choose where to sit down because of a certain level of privacy, this involves the security facet that will strongly affect people's decisions. Besides this, it must be considered also another fundamental feature for urban design that aims to better accommodate its users, that is the thermal comfort (which will be explained in the next Chapter 4), related not just to seating areas but to all the components of urban furniture. For the purpose of the thesis, two conceptual typologies of seats emerge:

1. The explicit and formal
   This category refers to those sitting places inevitable in a busy public space, defined by Gehl as "primary seating" (Gehl, 2011, p. 159). In fact, as illustrated in Figure 3.14, they are the most common benches findable in most public spaces (like squares and parks) and they are explicitly recognized as places where to sit on.

Figure 3.14 - Explicit and formal benches
Credit: © Viktor Talashuk
Source: Unsplash (https://unsplash.com/photos/kZESeBsuwt4)

Benches of this group are located and designed for people seeking a medium-high level of privacy, meaning for those who want to chill out and rest alone or to those looking for a quiet place where to read a book, for example. Considering, for example, those benches facing a spectacular view. In this case, benches function as a place where to rest and enjoy the panorama and they are not surely aiming to create social contacts (even if it could happen, of course). But this was just an example. As underlined by the PPS (2008) and by Yücel (2013), in order to avoid the problem of intimacy due to direct eye contact with strangers, benches should be placed between 90 and 120 degree from each other, allowing "both socialization and sitting alone" (Yücel, 2013, p. 628).

2. The integral and informal sitting places

   Conversely, these kinds of seats mainly regard steps and low walls (Figure 3.15). These sitting places differ from the previous one first of all because of their "clientele". The typology of these sitting places can be obtained by other elements already present in the square like steps from the elevated building, low walls from fountains and flowerbeds, and from building ledges. Low walls and steps are usable and enjoyable by young and people that have the ability to sit down and get up easily, in this case, for certain groups of people, "the general situation plays a more important part than the seat does" (Gehl, 2011, p. 159). Consequently, for the elderly and disabled persons, this kind of seats are not available and, therefore, they are more oriented towards a primary (explicit and formal) seating. However, many people use and benefit from them, they allow socialization and they can be gained from the presence of other urban furniture elements (for instance, flowerbeds, fountains, and stairways) which can be exploited with a double useful function.

Figure 3.15 - Implicit and informal sitting places in Bologna, IT
Credit: © Maria Bobrova
Source: Unsplash (https://unsplash.com/photos/EdpbTj3Br-Y)

To summarize, when planning seating areas in public spaces, a brief analysis of the location, orientation and physical comfort in relation to the public space usage should be done in order to obtain a public space full of empty benches or seating areas. The best solution is to try to provide a balanced mix of both formal and informal places so that people will have a wide range of sitting typologies. A large range of sitting opportunities can be achieved by squeezing "the sittability of inherent features. This means making ledges so they are sittable, or making other flat surfaces do double duty as table tops or seats" (White, 1980, p. 28).

Public realm signage

Reminding what public realm is, Lang in *Urban Design: A Typology of Procedures and Products* (2005), considers it "those places to which everybody has access to, although this access may be controlled at times. It consists of both outdoor and indoor spaces" (Lang, 2005, p. 7). Therefore, the public realm is present in any city and suburb, wherever the private and public sphere interact. Thus, it "can play a vital role in influencing socio-behavioural as well as articulating relations in experiencing and identifying urban identities of the environments" (Cheshmehzangi, 2012, p. 313). Talking about urban furniture in the public realm, considered for a busy plaza or square, what can be more influencing than indications? This is what public realm signage stands for, it helps people to walk in the direction they are looking for. It is the way through which a certain place communicates with its users. Obviously is not useful for locals and people living nearby, but for those who visit a certain square for certain reasons, it is extremely useful. Moreover, public signage is particularly helpful when located within a square next to train stations or bus stop to indicate useful information (for instance, bus or train schedule) for those who come afar. In the *Public Realm Design Guidelines of South Australia* is remarked that the pedestrian signage "improve accessibility, orientation and connectivity of spaces and functions" (Local Government Association of South Australia, 2014, p. 20). Thanks to indications, one can be more stimulated to move also in a new place by transit or by foot, counting on public realm signage.

Besides its directional function which allows people to find their ways, signage has another important function, that is giving information about the place and its surroundings (e.g. its history).

Public lighting

Sunlight is probably the most important natural element that public space must have for its users because it allows people to fully enjoy the public spaces. As happens in other contexts, humans tend to realize the importance of something only when they cannot benefit from it anymore, so it also happens about light (Augustesen, et al., 2006, p. 8). However, sunlight is not always available. Especially in northern cities where dark hours come early particularly during winter seasons, is necessary to allow people to spend ordinary daily life

and benefit from public spaces also without natural light. Nevertheless, "there is a big difference between "'more light' and 'better light'" (Peña-García, Hurtado, & Aguilar-Luzón, 2015, p. 142-143). A good public lighting system is indispensable for public spaces' quality and walkability for two main reasons:

1. Safety

   If people do not feel safe outdoor during nighttime, they will not use public spaces in certain periods. Well-projected public illumination will reduce people's fear of crime. Generally, is acknowledged that lighting can warn people of possible wrongdoers in public spaces by increasing visibility but lighting alone may not be enough. According to Welsh (2007), this is because the positive impacts carried out by improvements in public lighting can vary according to several variables (for example, the area dimension and design) and because they "are likely to be greater if the existing lighting is poor and if the improvement in lighting is considerable" (Welsh & Farrington, 2007). Therefore, if the aim of lighting is to guarantee the safety of a certain place, the lighting system should be implemented and reinforced by a supporting video surveillance system that works together. For example, lighting that focuses on a withdraw machine may be not enough for people's fears during nighttime but, with a video security camera pointing on the same spot it would notably increase its security environment, and vice versa;

2. Appealing

   Lighting systems, if properly managed, can make a difference in the quality of urban public spaces. They can create a charming atmosphere that encourages people to attend a certain square, for example. As illustrated in *Light for Cities: Lighting Design for Urban Spaces. A Handbook, "*to draw on a 'family of luminaries' is a tried and trusted method" (Brandi & Geissmar-Brandi, 2007, p. 50). Through a careful arrangement of luminaries and poles is possible to create a very appealing public space. Brandi and Geissmar-Brandi support that the family group of luminaries should be placed at different heights starting from the ground floor with, for example, illuminated bollards (explained later) and going upward "up to 16 meters" (Brandi & Geissmar-Brandi, 2007, p. 51). With this approach lighting rhythm emerges and pedestrians are attracted to frequent public spaces longer (reminding that pedestrians are not only one that can benefit from the proper light system, but also activities on the spot can enjoy the benefits). Considering shopping or restoration areas and commercial streets, public lighting can also represent a strategic technique that plays a decorative role. In this sense, lighting "could be one of those last finishing touches that reinforce a unique idea" (Brandi & Geissmar-Brandi, 2007, p. 52).

While it is true that lighting is an item of vital furniture for public space, this is also costly both in terms of light pollution and for energy, besides it is an expenditure. Considering lighting demands for energy, thus, energy-efficient luminaries like LED are preferred. As reported in the *International Dark-Sky Association* (IDA) website, LED luminaires can solve all the problems just cited, except the costs (which occur for every kind of need). In fact, LED can solve high energy demand problems by dimming and saving light and energy when not necessary. Consequently, having less lighted areas means that light pollution can also be positively altered (International Dark-Sky Association, s.d.). Moreover, luminaries and bulbs should be shielded in order to avoid skyglow, glare and light pollution. Figure 3.16 has been made by IDA and tries to collect some examples of appropriate lighting furniture.

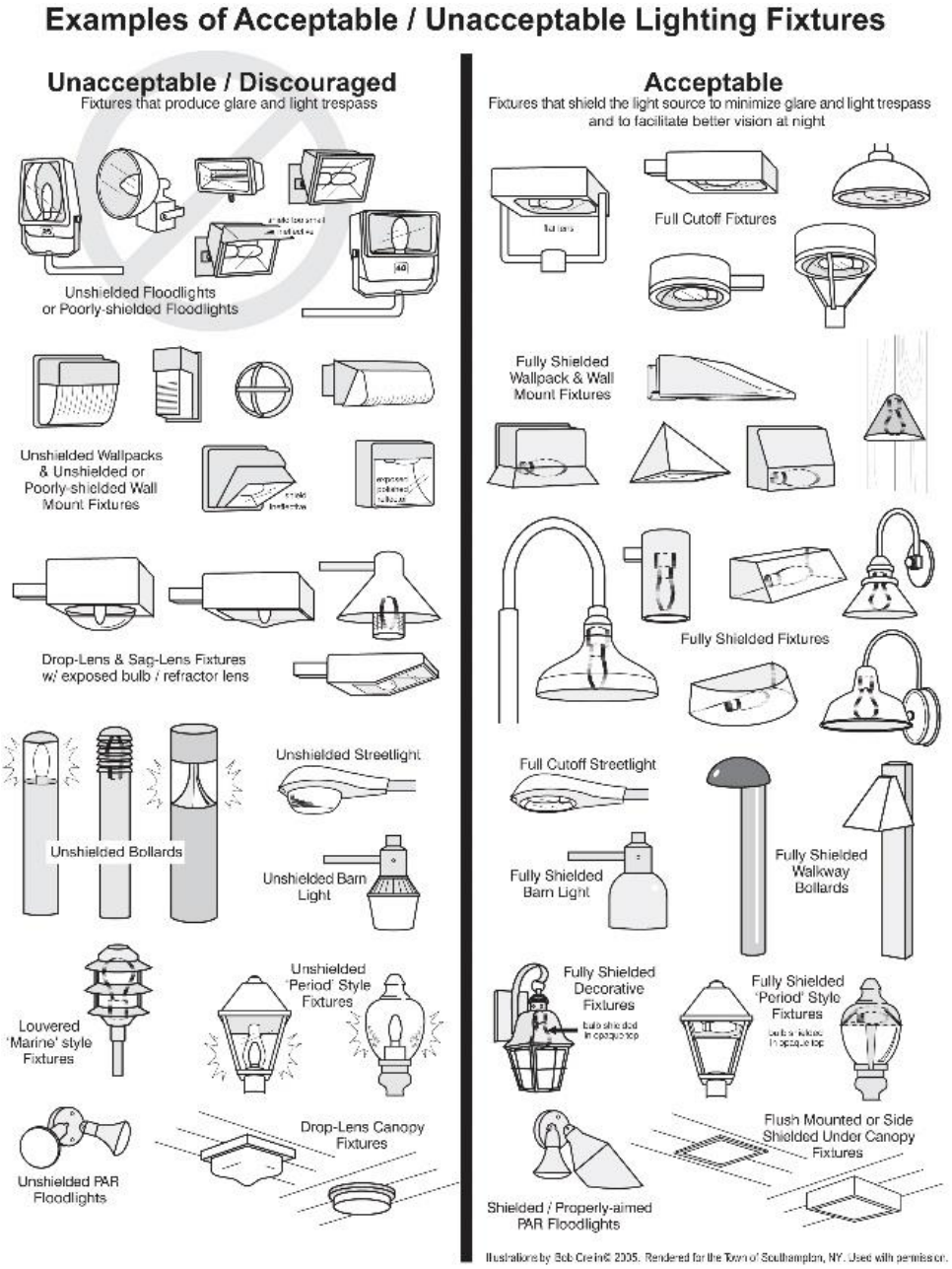

Figure 3.16 – Compared example of acceptable and unacceptable luminaries
Source: International Dark-Sky Association (https://www.darksky.org/our-work/lighting/lighting-for-citizens/lighting-basics/)

Garbage bins

Whoever would lay down on a flowerbed made of waste or sit down on a bench next to litter and rubbish? The answer is easy: nobody. The cleanliness of public spaces and particularly of a public square will surely affect its vitality. Generous bins located at the main affluent spots of public spaces enhance people to use them and, even better, recycling bins offer the possibility to recycle properly. In fact, Alec Cooley, the Director of Recycling Programs at Keep America Beautiful[12], states that locating garbage bins (possibly recycling) "can reinforce the community's values as an inviting, clean and environmentally conscious place to visit" (Cooley, 2017). To facilitate pedestrians for recycling, a widespread strategy is to introduce clear signage by associating different colors to each different type of waste so that, in doing so, people will automatically recognize the correct bin.

Fountains and water bodies

The presence of water elements in public spaces has several important benefits. Firstly, its thermal, sustainable and natural benefits positively affect its surrounding urban microclimate but, in this Chapter, water elements and fountains will focus on its social side to encourage walkability. Before explaining the numerous advantages from which a community can benefit from water elements, it is necessary to point out that these kinds of urban furniture cannot be applied everywhere. In cities with droughts problems (e.g. Los Angeles, Phoenix and El Paso) droughts are a real problem against which local communities have to fight (hardly or softly) every year. It comes alone that fountains and similar would be a needless waste of such a precious resource. Nevertheless, fortunately, in cities that do not face these environmental issues, fountains can be the element that makes the difference regarding a public square due to many reasons. Public squares, plazas or parks can survive without a fountain but, conversely, we can find fountains only in the public realm and especially only in squares, plazas, parks or in open or semi-open public spaces. This leads to the strong public character of this water element. It could sound wired but, actually, there is another kind of place where water elements abound, and those are in Buddhist temples. This is because water elements have a lot of acoustic benefits coming from the sound they release and, today, water bodies are applied for "meditation and visualization sessions" (Sheppard, 2017). It does not mean that people must meditate to enjoy fountain or other water elements, but people can benefit from them because they release a quiet and relaxing environment visually and acoustically. This is also extremely positive for activities in the fountain's visual proximity - like restaurant businesses – enjoying a delightful landscape over the plaza. Water can come in every aspect, as long as it is visually and acoustically accessible. There is another component through which people can interact with water elements, that is by touching it, even if this is not always possible.

[12] Established in 1953, Keep America Beautiful is a non-profit organization that "provides the expertise, programs and resources to help people End Littering, Improve Recycling, and Beautify America's Communities" (Keep American Beautiful, s.d.)

According to White (1980), fountains and similar are fundamental to public vitality (Figure 3.17). Thus, once they are installed, people should be able to interact with them in every manner they can, otherwise, it does not make any sense to install it (White, 1980). Moreover, he states that "Safety is the usual reason given for keeping people away. But there are better ways than electrocution to handle this problem" (White, 1980, p. 48). However, another water bodies' positive effect of is "its ability to reflect its surroundings. Thus, water surfaces can be placed in the immediate vicinity of buildings in order to enhance their image" (Oikonomou, 2005, p. 132) creating an visual impact.
If climatic conditions allow it and the square location does not suffer from draughts, fountains for drinking water could be a great deal for attracting people and stimulate walkability.

Figure 3.17 - Water element attracting children in London, UK
Credit: © Robert Tudor
Source: Unsplash (https://unsplash.com/photos/V5ZKl33OQvE)

Food

However, what attracts people the most is food. "Food attracts people who attract more people" (White, 1980, p. 52) having then the possibility to exponentially increase walkability. This can happen especially in squares (Figure 3.18), where passenger or workers from nearby offices go to have their meals, and when they forgot their packed lunch, a food truck must be there or, conversely, a variety of food trucks can be the reason for not having carried it. As White pointed out, "If you want to seed a place with activity, put out food" (White, 1980, p. 50). Food trucks and vendors are fundamental in their primary function that is serving sandwiches, hot dogs and similar. However, they also own

a very powerful attracting value resulting in a real meeting point where workers and passengers stop to eat and socialize. Food vendors, whether they are trucks, cafè-bars or restaurants, usually have fantastic business acumen, or at least they should. Wherever pedestrian flows are present, food vendors also do (White, 1980). Therefore, there is also a subjective component that lets the vendor choose among multiple and diverse options, it is up to the vendor to choose the best one before it gets stolen by another competitor. Besides location choice, the "optical leverage" (White, 1980, p. 52) of these kinds of activities plays a crucial role, especially in public squares. In this case, the entire area full filled with other components of urban furniture spread in an organized system, could largely benefit or be disadvantaged by the food vendors' disposition and appealing. This does not mean that particularly designed elements are needed, but some chairs and tables in the shade of a parasol would be enough, creating a spectacular pedestrian environment (White, 1980).

Less impacting but still attractive and useful are the vending carts offering water, beverages and other types of snacks for those who are in a hurry and do not have time to have a relaxing and enjoyable meal.

Figure 3.18 - Food trucks next to informal sitting places in Pionner Square, Portland, OR
Credit: © Sean Benesh
Source: Unsplash (https://unsplash.com/photos/87luthTDnmQ)

Bollards

The last – but not least - element of urban furniture analyzed are the bollards. Usually, they are not noticed by pedestrians because of their low and thin size and because they are taken from granted. They are not compulsory, but actually, bollards are key elements in

urban furniture in terms of pedestrian safety to enhance walkability. Obviously, they are not the only tool to secure pedestrian from vehicle's traffic, there are a lot of strategies, standards, and measures to apply to pedestrian surfaces close to thoroughfares - like crossings and sidewalks - but bollards are the most commonly used type of physical barrier because they help to fully protect pedestrians from automobiles without being too much in the way.

There is a very large variety of bollard's typologies according to their specific purpose and site location. They can be fixed or removable depending on the purpose of having a total pedestrian area or semi-total (to allow trucks for loading and unloading services of restoration activities, for instance). They can differ according to the interval distance between one another according to the site requirements (different measures for schools, civic and institutional buildings, for instance). Moreover, bollards can have a decorative and landscape function to limiting a particular area (a flowerbed in front of an institutional building, for instance) and, finally, there can be short-term bollards to use for single special events in squares or public spaces in general (Reliance Foundry, 2019).

3.2.7. Weather shelters

The ways in which pedestrians are sheltered are crucial. This is because shelters offer the possibility to enjoy public spaces even with hostile weather events (for example rainfalls and elevate solar heating), hence contributing to reaching walkability although adverse climate conditions. Weather shelter provides a repair for pedestrians while they are walking and there is an unexpected heavy rainfall from nowhere or when you want to shop during lunch-break but there is a burning sun. The need of creating shelters for pedestrians can be exploited by animating façades facing public squares or plazas, which aesthetical and visual component is fundamental (as explained earlier in this chapter) for creating an appealing and interesting public environment.

Pedestrian shelters are very useful in very busy places and especially where people have to wait, having thus the possibility to do it by being protected from sunlight or rainfall. That is why, with a proper set of benches and sitting areas, shelter protection is a strong recommendation for TOD squares. There are many ways in which weather shelters can be provided. Surely vegetation could be a good option, but it depends on the foliage dimension and on the fact that during some period of the year trees can be barren. However, vegetation benefits will be better explained in the next Chapter 4. However, besides vegetation, "Weather protection for pedestrians in public spaces can be provided by canopies, awnings or lattice work" (Institute of Public Administration, 1977, p. 12), being all of them absolutely essential to transit stations, or at least for its surrounding environment. In this case, weather shelters can be scattered within the square and exploit them by creating a stunning and comfortable environment even during hot and wet days.

3.2.8. Public art

All forms of art, whether they are enclosed in a museum or they are accessible for everyone creating open-air museums (e.g. the project developed to regenerate the Bairro Alto neighborhood in Lisbon), always fascinate and arouses curiosity. Regarding public spaces, public art "potentially includes all forms of creative expression in public space" (Fisher, 1996, p. 43). One thing is for sure: public art directly affects people that use the public space where it is located (Figure 3.19). However, this cannot happen so automatically. As previously explained for other public space elements (urban furniture, for instance) the single art sculpture, graffiti or illumination is strictly related to its surroundings, that is: a dirty, neglected public space will not improve thanks to public art itself, but there must be a general requalification of the area otherwise the public art got lost and abandoned. Only after a proper regeneration, the area can benefit from public art, which impacts can result in a very extraordinary upgrade of a certain place.

Public art has numerous benefits. It can be seen as a mean through which the community "enhances meaning in civic spaces, and adds uniqueness to communities. Public art humanizes the built environment" (Walsh, 2018). It has also economic benefits and it can be exploited as a strategy in this way. All forms of public art differ from one another creating a sense of uniqueness around an artistic mural, sculpture or a design element intrinsic in the work of art itself. This sense of uniqueness, especially if placed in an already busy area,

Figure 3.19 - The Cloud Gate sculpture made by the British Indian artist Anish Kapoor in Chicago, IL
Credit: © Ravi Patel
Source: Unsplash (https://unsplash.com/photos/2B5aWwADOn4)

creates a dynamic environment around it, resulting in an incredibly positive effect in the surrounding areas and activities that would be highly supported by visitors.
The uniqueness issue was introduced by Lynch in *The Image of the City* (1960), referring to the concept of imageability:

> "that quality in a physical object which gives it a high probability of evoking a strong image in any given observer. It is that shape, color, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment" (Lynch, 1960, p. 9).

To conclude, public art is able to bring close community and artists through works that represent them and the work of art's area. It has, then, social effects creating a sense of place and identity (or "imageability") but public art can also be useful in economic terms, being a unique item, in fact, public art can attract locals but also foreign visitors and commercial and restoration activities would benefit from it. finally, keeping it simple, it is much better to see an artistic mural instead of a blank wall.

3.2.9. Preservation of historic and civic buildings

As a form of art, architecture also plays an important role in public spaces. Buildings shape squares and streets, thus, the more appealing they are, the more walkable is the ground space they draw. Civic and historical buildings have much more to say in this context. We can say that aged buildings have the same function of public art wherever they surround public space and are perceivable from pedestrians. In fact, also old buildings reveal economic benefits. As Jacobs (1961) pointed out, whilst new building construction is characterized by economic value mainly according to their location and design, "the economic value of old buildings is irreplaceable at will. It is created by time" (Jacobs, 1961, p. 199) resulting in a diverse element within the environment enhancing imageability and, therefore, walkability. Besides the flow of local and (possibly) foreign visitors, aged buildings attract people. Aged buildings have something special that is intrinsic in themselves. Whether it is the memory they represent or the architectural style from which they are shaped and designed, "Americans prefer to picture themselves living around old buildings" (Rocchi, 2015).

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4. Adaptation measures

Chapter 4 aims to understand how public squares and plazas adapt to CC through urban design with a basic background thinking: "What was made by people can also be changed by people" (Beck, 1992, p. 157). Adaptation measures in response to the climate impacts identified in Chapter 1 are the core of the chapter. The measures to avoid the UHI effect, drought and flooding will be analyzed and developed at different scales assuming that, contrary to mitigation and walkability, adaptation measures benefit more through local and punctual actions on the built environment instead of interventions at larger scales (regional or global). Thus, urban design is the delivery vehicle through which adaptation measures take place.

As seen in Chapter 1, adaptation means "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007, p. 6). It has already been argued that both mitigation and adaptation measures are needed. The latter is considered more recent than mitigation ones, but there has been an advancement in CC adaptation measures through recent studies and researches "in urban areas specifically" (Carter, et al., 2015, p. 3). Adaptation measures are wrongly considered less important than the mitigation ones because their narrower radius of action, which actually it is right. While mitigation strategies point towards the roots of the problem, adaptation actions look like having a passive behavior. The core aspect of adaptation measures lies in the method by which communities sustainably approach to an ever-evolving changing future (Arizona State University, 2007). The key concept of adaptation measures and of the current Chapter is that by being more local-efficient, adaptation strategies can largely vary from North to South and from East to West, from coastal cities to inner-land cities and so on. As highlighted by Smit et al. (2000), adaptation measures vary because climate stimuli vary. This means that weather and climatic conditions come in very different forms and impacts on humans and the built environment where they live. Therefore, diverse strategies to adapt to CC are requested from every single environment in order to better and stronger accommodate CC impacts (Smit, Burton, Klein, & Wandel, 2000, p. 229-230). In many cases one single measure can operate both towards mitigation and adaptation objective but, in other cases, they can be in contrast. For example, if we think about the positive externalities that high urban densities have on pedestrian behavior, we might also have to consider that narrow and tall buildings increase temperature because they do not allow natural ventilation leading to the generation and/or incrementation of the UHI effect. Therefore, it is necessary to fit together all the objectives and needs of both mitigation and adaptation actions within the sustainable urban and suburban environments (Shaw, Colley, & Connell, 2007). Another important factor to consider is the relationships between the different effects of adaptation measures taken at different scales. In fact, there are differences between "large-scale adaptation strategies at the conurbation scale (e.g. networks of open spaces) and smaller scale options (e.g. orientation of individual buildings)" (Shaw, Colley, & Connell, 2007, p. 17). However,

in order to understand the best and proper adaptation actions to apply to public squares in suburban areas, only measures at the smaller scale (those regarding the buildings enclosing the square area and the square itself) will be considered.

4.1. The UHI effect

As previously explained, the UHI effect is one of the most frequent consequences of CC and it strictly deals with anthropogenic behaviors. Many scientists and researchers state that UHI "is the most documented phenomenon of climate change" (Santamouris, Cooling the cities – A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments, 2012, p. 682). The UHI effect is a very wide and complex phenomenon that can vary according to a multitude of factors resulting under different characteristics, intensity degree and impacts. The UHI effect generated in cities involves wide areas of them both in vertical and in the horizontal direction. Limiting the research to the public square element and what surrounds it closely, for the purpose of this thesis what matters and thus what it will be considered are two types of UHI zones (Figure 4.1). The first is the *Surface Urban Heat Island* (SUHI), that is where impacts of the UHI effect can be perceived at the ground level and "is defined by the temperature of the surface that extends over the entire 3-D envelope of the surface" (Roth, 2013, p. 146). The second is called *Canopy Layer Urban Heat Island* (CLUHI), that starts from the ground level (incorporating it) up to "below the tops of trees and roofs" (U.S. Environmental Protection Agency, 2008, p. 3).

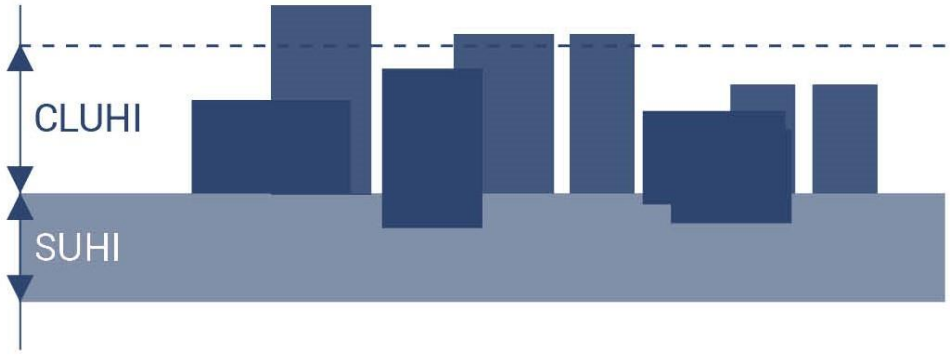

Figure 4.1 - Layers of interaction between the UHI effect and the built environment
Source: Author's elaboration

Once these preliminary assumptions are made, we can then analyze which are the best and most efficient solutions to apply to answer to the five main causes of the UHI effect (underlined in Chapter 1) and adapt communities to the UHI effect in the built environment at different scales. Therefore, the following pages discuss adaptation to the UHI effect and they have been subdivided according to three different approaches that interact with the built environment: the building scale, the urban space, and the urban geometry.

4.1.1. Building scale

The mandatory introduction before starting to argue on buildings is that everything that will be explained at this scale regards only those buildings that limit the square.

Two are the types of surfaces that interact with the UHI effect at the building scale: the surfaces of the building, intended as those covering the vertical surfaces, and the roofs that coating the horizontal surface. What is particularly important in this context is the materials of which the buildings are made of. Buildings play a crucial role in the creation of a warmer built environment because they can influence both the SUHI and the CLUHI affecting the entire climatic space surrounding them, which is where people live. The main influence that buildings have on the UHI creation concerns their coating.
In the next pages will be given a brief overview of the benefits of cool materials that strike on the UHI effect from the point of view of their reflectance features. The aim is not to understand the specific energetic benefits and when they may occur or may not but, rather, the following pages point to understand how this kind of material can be useful in adapting to CC. A single chapter alone would not be enough to investigate on all the benefits of cool materials. In fact, besides the reflective properties of cool materials, there are many other more specific and case-to-case variables that interplay with solar reflection which can be ever-changing (e.g., the geographical location, the building shape and its exposure to sunlight, the building's roughness, and so on).

Cool materials

As previously said, buildings are covered by the materials both on vertical and horizontal surfaces (façades and roofs, respectively). Both of them can be covered by cool materials, which most important property is albedo because it "directly determines the absorptivity of an opaque surface" (Oke, Boundary Layer Climates, 1987, p. 229) and help to lower as much as possible the temperature difference between urban/suburban areas and the rural ones, which can reach "up to 10 degrees of temperature difference" (Santamouris, et al., 2001, p. 203). By reflecting and not absorbing solar radiation, reflective materials make the buildings' interior cooler resulting in lower demand energy. This benefit can be perceived as mitigation rather than adaptation measure and, actually, it is. Reflective materials are just one of the several strategies that fall back both in the mitigation and in adaptation measures, that is, they can be both a tactic to adapt our built environment to CC but also a way to reduce GHG emissions.
Looking at the adaptation side of cool materials, cool materials are characterized by high albedo features able to reflect solar radiation instead of holding it. For the purposes of the thesis, the most important aspect of cool materials is that high albedo surfaces are also characterized by lower temperatures compared to those with low albedo and, since buildings encompassing public square are made of materials, their albedo properties affect the temperature within public spaces (Shahmohamadi, Che-Ani, Maulud, Tawil, &

Abdullah, 2011, p. 7). Without going in-depth with energetic issues of materials, the discriminant factor to decide whether a building coating is reflective or not is its color. As explained in Chapter 1, high albedo materials are light-colored and low-albedo materials are dark-colored. However, reflective materials "can also have a number of indirect effects, such as glare and increased reflected radiation on pedestrians and building façades (included on glazed openings)" (Erell, Pearlmutter, & Williamson, 2011, p. 79). Thus, a strategic approach comprehensive of all the different aspects that interplay between the building's materials and the people that living around it is necessary. In order to have both buildings covered with cool materials without creating disturbs of glare on pedestrians, a strategy usually practiced is to place vegetation next to the building's sides that are exposed to solar radiation. It is in this context that cool materials are able to adapt to the surrounding building of a square; by reducing temperatures of building's façades and, consequently, decreasing the temperature in their surrounding environments.

For what concerns the roofs, "the most promising passive strategies seem to be the use of highly-reflective coatings (cool roof) and the placement of a vegetation cover on top of the roof surface (green roof)" (Costanzo, Evola, & Marletta, 2016, p. 247). According to Gartland (2008), roofs represent around 20% of the total surfaces in suburban and urban areas. As in the case of façades, also roofs can be adapted to CC by using light-colored materials that reflect more solar radiation than the dark-colored. In this instance, the difference between façades and roofs lies in their solar exposure, which is much higher in the case of roofs, depending in turn according to their slope. Moreover, if buildings can be supported by vegetation in adapting to CC, also roofs (when they are flat) can implement vegetation on them. But vegetation applied at the building scale will be detailed later. Returning to roofs made of cool materials they can be applied roofs belongs to separated and not so tall houses since they can be visible from the street level. In this case, white or bright colors may not be appreciated by the house owner that could decide to change the roof color (Moriyama & Takebayashi, 2012). Thus, a valid alternative to white and bright roofs are colored cool roofs which can also avoid if glare problems occur, "especially for steep slope roofs" (Synnefa & Santamouris, 2012, p. 55). As it happens with every material, even the cool ones are subject to deterioration. It is important to remind that cool material properties can perform with lower efficiency if they are aged (Prado. & Ferreira, 2005, p. 298). Thus, in order to obtain the same result constantly over time, regular maintenance and, when needed, a replacement is necessary.

Green roofs and green walls

The second adaptation measure applicable at the building scale is subdivided in green roofs and green walls, considered as sustainable envelopes that contribute to limiting the UHI effect. "Since in densely urbanized areas there are few residual spaces that can be converted into green areas, one solution could be to turn traditional black flat roofs into green ones" (Susca, Gaffin, & Dell'Osso, 2011, p. 2119). A fundamental characteristic of

green roofs is that they can tackle CC due to the presence of vegetation that cools air through the processes of "evaporation and evapotranspiration" and "by reducing impervious surfaces which cause temperatures to rise (Ngan, 2004, p. 5). Moreover, "In addition to increasing roof membrane life, green roofs provide shade and insulation, resulting in energy savings and mitigation of the urban heat island" (Getter & Rowe, 2006, p. 1279). There are no uniform benefits from green roofs, the intensity and the "performance of green roofs is dependent on the status of the vegetation, the roof position and the ambient air flow conditions" (Lalosevic, Komatina, Milos, & Rudonja, 2018, p. 2). As Getter and Rowe state (2006), green roofs increase the membrane life of the building's roof. This is possible thanks to a multiple reflective and absorbing layer stratification that enlarge the increase the space before the solar radiation impacts on the building's roof.
Green roofs are generally divided in:

- Extensive green roofs
  This typology of green roofs includes all the roof vegetation on a thin substrate with little or no irrigation and management. In this type of green roof vegetation is established either artificially by seeding or planting, or naturally: mosses, succulents, few herbs and grasses are the kind of vegetation findable on extensive green roofs. According to the U.S. EPA, since extensive green roofs require very little maintenance and irrigation, they can be perfectly fixed on buildings located in climatic areas that suffer from dry climate conditions and where drought events could occur (U.S. Environmental Protection Agency, 2008).

- Intensive green roofs
  On the contrary, intensive green roofs present roof vegetation on a thin substrate but with irrigation and management. As in the other type, also in this case the vegetation can grow naturally or artificially and the vegetation typologies could be perennials, grasses, small trees, rooftop farming, and all those plant species that require management (U.S. Environmental Protection Agency, 2008).

Besides green roofs, green systems can be applied also on their façades. Green walls are helpful elements that present several benefits in adapting to the UHI effect. Potentially, they could have even more benefits than the green roofs if we consider that the surfaces of the façade are usually wider than the roof one, especially regarding buildings located in dense urban and suburban settlements (Köhler, 2008). Moreover, green walls are relatively easy to install since "Little ground space is required, installation costs are low, and over a 10-year period, the ecological benefits are significant" (Köhler, 2008, p. 434). In recent years, greening systems have been subjected to an advance in technology and today there are many definitions and nomenclatures to refer to them. However, Manso and Castro-Gomez have identified two main categories: green façades and living walls. They state that green façades (Figure 4.2) consist in "climbing plants grow along the wall covering it", whilst

living walls (Figure 4.3) "include materials and technology to support a wider variety of plants, creating a uniform growth along the surface" (Manso & Castro-Gomez, 2015, p. 864). They further categorize green façades in: direct, when vegetation is directly attached

Figure 4.2 - Direct green façade
Credit: © Alexey Shikov
Source: Unsplash (https://unsplash.com/photos/qarKz3qU5NA)

Figure 4.3 - Living wall in Madrid, Spain
Credit: © B. Alter
Source: TreeHugger
https://www.treehugger.com/natural-sciences/madrids-green-wall-is-flourishing-as-is-the-caixa-forum.html

to the building wall, and indirect, when a supporting structure is to the building wall, and indirect needed (Manso & Castro-Gomez, 2015).
Therefore, comparing the green roofs and the green walls can be considered as extensive, referring to green façades, and intensive, referring to the living wall (Osmond & Sharifi, 2017).
Besides their fundamental environmental performances which allow to mitigate the UHI effect and to cooling air, the presence of greening systems in built areas is crucial for their appealing potential, thus, having also social and psychological benefits (Manso & Castro-Gomez, 2015). In fact, just looking at Figures 20 and 21, it is understandable that green walls or façades have an elevated attraction value, and this is vital when talking about public spaces like squares. The aesthetic aspect is important in the urban or suburban square because they are able to increase walkability, by the way, because, as Sutton states, to be appreciated, the greening system "it must be seen and experienced" (Sutton, 2014, p. 6). However, greening systems could also bring economic benefits. Considering the aesthetic values of green roofs, in fact, they are not always visible from the ground public space, but they can be enjoyed by people when they are accessible. Obviously, we are talking about intensive green roofs, where a combination of environmental and social benefits can take place at the same time if, for example, a restaurant, bar or any other recreational activity is located on rooftop buildings, a strategic solution to exploit spaces that, otherwise, would be empty and heavy UHI contributors.
To conclude, it is clear that even if cool roofs made up of cool materials, green roofs and green façades are applicable at the building scale, only one or a weak bunch of buildings alone cannot impact hard on the UHI effect but, rather, a system of green or cool buildings set in dense urban or suburban areas would help to hedge the effort. Thus, to obtain significant results at the city scales, cool materials should be applied at multiple building scales.

4.1.2. Urban space

The adaptation solutions that are considered in the "urban space" layer are those that contribute to reducing the UHI effect working at a larger approach scale than the previous one.

Urban vegetation

Among the several causes of the UHI effect, the absence of vegetation is probably the aspect that, wherever lacking and needing to be implemented, could have the most significant improvement in reducing the UHI impacts because it has large environmental benefits, besides social and psychological effects. Within the context of the thesis, vegetation can be used to adapt to the UHI effect with twofold effect according to the number of buildings involved (Akbari, Davis, Dorsano, Huang, & Winnett, 1992, p. 28):

1. "Indirect effect", those that refer to the modification of a whole urban space like a public square changing its "environmental conditions" (Akbari, Davis, Dorsano, Huang, & Winnett, 1992, p. 28). A typical example of the indirect effect is the process of evapotranspiration, which involves both evaporation and transpiration of plants. According to the U.S. EPA, the transpiration is given by the fact that "Trees and vegetation absorb water through their roots and emit it through their leaves" (U.S. Environmental Protection Agency, 2008, p. 3). Whilst evaporation is "the conversion of water from a liquid to a gas" (U.S. Environmental Protection Agency, 2008, p. 3). It is obvious that vegetation performances strictly depend on the species and, thus, on their location. Furthermore. Evapotranspiration can also be introduced by other types of vegetation in the form shrubs and green verge, they are smaller, and they usually get overlooked but, at the local and pedestrian scale, they can donate a modest positive influence on cooling air temperature affecting the SUHI. When vegetation is lacking in urban or suburban areas, it means that the built environments struggle with breathing. Urban and suburban areas can breathe thanks to the evapotranspiration, the fundamental function of vegetation for the purpose of this thesis, besides providing shading.

2. "Direct effect" are those providing shade and wind speed reduction are generally influencing one single building only (Akbari, Davis, Dorsano, Huang, & Winnett, 1992). Vegetation shading and vegetation in general, have, in turn, a twofold function since it is commonly known that, besides the environmental effects previously explained, it has an astonishing impact on pedestrians, increasing the effort that people could spend on walking. However, as it is valid in every street and any public space, also public plazas and squares would benefit of cooler air if trees and vegetation are placed within the public space but also right next to buildings because of two reasons. First, they can cover building façades avoiding glare from reflective surfaces that, otherwise, would heat the pavements on the public squares and that would warm the air in the square during hot summer days. Contrary, during wintertime, shaded areas could be a problem for pedestrians but, at the same time, trees and shrubs can provide repairs from biting wind gusts. The second aspect strictly depends on the tree species and their foliage dimensions but, thanks to leaves and branches, trees shading located in plazas could offer shading places where to rest and relax during lunch break or while waiting for public transport. In general terms, it is been found that during summers only 10 to 30 percent of solar radiation strikes the shaded area provided by the tree foliage,

making the tree shadings a fresher place to be (U.S. Environmental Protection Agency, 2008).

Even though both the effects of vegetation described are very important to adapt to the UHI effect, many studies state that the most important between the two functions is shading. In particular, "the significant characteristic of the landscape element is its shape, volume and leaf density" (Rosheidat, Hoffman, & Bryan, 2008, p. 200). However, considering both the functions together, helpful results in tackling the UHI effect can be obtained. In fact, according to Laïlle et al., by providing shadowing, vegetation can avoid warmer temperatures at the surfaces shadowed "and, combined with the cooling effect of evapotranspiration, this ensures that the air below the tree canopy remains at a more pleasant temperature" (Laïlle, Provendier, Colson, & Salanié, 2014, p. 8). To conclude, it is important to stress that native plants are preferred instead non-native plants because the formers are "accustomed to the local climate conditions" (Santamouris, et al., 2004, p. 50) and therefore they can perform better the process of evapotranspiration. As will be later explained, native vegetation is highly recommended in dry climate areas.

Cool pavements

According to Gartland, pavements cover the built environment approximately from 25 to 50 percent of the total surfaces (2008) resulting in one of the main causes of "higher temperatures" (van Ooststroom, 2011, p. 26). As for cool roofs, also in the case of pavements white and light-colors are preferred to the black and darker ones. Therefore, in order to reduce the UHI effect, the key component delineating pavements are, once again, the materials and their colors of which they are made. If we consider pavements in their broader terms – including also roads and sidewalks - the two most common materials are asphalt and cement. Gartland states that "there are two ways to make pavements cooler: (1) by increasing their solar reflectance, and/or (2) by increasing their ability to store and evaporate water" (Gartland, 2008, p. 85). To satisfy the first option, light-colored materials should be applied to pavements surfaces but, exactly as in the case of cool roofs, to brightness may generate glare problems (Gartland, 2008), affecting pedestrians and the surrounding buildings. Referring to the second requirement, instead, the capacity to evaporate and store water represents its perviousness (or porousness). Besides the benefits of cool pavements that would arise when flooding occurs (later explained), porous pavements can also reduce the UHI effect by "Evaporating water draws heat from the pavement, keeping the pavement cooler in the sun" (Gartland, 2008, p. 85). Since the reflectance issue of cool materials has already been argued, a brief in-depth on this last pavement characteristic is needed.

The porous feature of pavement can be obtained by having pavements made of porous materials themselves. In this pavement pattern, the process that establishes is similar to the evapotranspiration method happening with vegetation, that is "water passes through the

voids and into the soil" (U.S. Environmental Protection Agency, 2008, p. 8) getting absorbed and transformed in water vapor due to heat of the pavement surface, "thus drawing heat out of the pavement" (U.S. Environmental Protection Agency, 2008, p. 8). Although asphalt and concrete in their natural form are the opposite of cool pavements, if the material of which is made of getting modified with a more porous one, they can increase their capacity to drain water. There is plenty of pavement typology with high permeable properties, among which: "permeable asphalt pavements, porous concrete pavements, pervious cast concrete pavements, and interlocking concrete pavements" (Li, Harvey, & Jones, 2013, p. 98). According to Gartland, pavements could be of two types: asphalt, usually black colored "with solar reflectance values of 5–10 per cent" (2008, p. 86), or concrete, usually "light grey in colour with solar reflectance values usually between 35 and 40 per cent" (2008, p. 88). There are types of pavements that are cool by themselves, and others that can be made (Table 1).

Table 4.1 – Types of cool pavements according to solar reflectance and application

Type of pavement	Solar reflectance	Usual application
Portland Cement concrete	35% – 40%	Roads, parking lots, sidewalks and other paved areas
White topping	35% – 40%	Covering existing asphalt pavements on all types of roads, parking lots, sidewalks and other paved areas
Interlocking concrete pavers	They are often tinted with pigment, so interlocking pavers can have a wide range of reflectance values if light colored pigments are applied	High load conditions such as industrial and warehouse operations, airplane taxiways and airport hubs, as well as in lower load applications such as sidewalks and driveways.
Colored asphalt seals and seal coats	Depending on the color applied	All types of surfaces, especially used to designate different traffic areas (bike lanes versus car lanes) and for decorative design purposes
Open-graded asphalt pavements	Up to 30%	Roads, parking lots and other applications
Pavement texturing	Depending on the color applied	Street paving, traffic calming, pedestrian areas, medians and

		boulevards, parking lots, playgrounds and other applications
Porous block pavement systems	30% - 50%	Pedestrian walkways, driveways, parking lots, overflow parking, fire lanes or any other less frequently travelled surfaces

Source: Author's re-elaboration based on data taken from: "Heat Island: Understanding and Mitigating Heat in Urban Areas" (Gartland, 2008, p. 92-99)

To conclude, cool pavements can be achieved via high perviousness materials or high reflectance materials. However, as for all the adaptation measures, also cool pavements should be adapted to the climatic conditions according to the location because, as underlined by Buyung and Ghani, pavements perform better in humid climatic regions where rainfalls are frequent and humidity is constant, otherwise they could get the opposite result causing higher temperatures than "conventional pavement" (Buyung & Ghani, 2017, p. 6).

Water bodies

Water elements in urban and suburban areas can have important impacts on the reduction of the UHI effect because "surface water acts as a cooling element in cities (Theeuwes, Solcerová, & Steeneveld, 2013, p. 8894). According to the Ph.D. thesis of Kleerekoper, the processes of cooling air can be performed by water bodies through "evaporation, by absorbing heat when there is a large water mass which functions as a heat buffer - or by transporting heat out of the area by moving" (Kleerekoper, 2016, p. 81). The performance of water bodies within built environments depend on multiple factors, the most important one is the air exchange above the wet surfaces (Manteghi, Imit, & Remaz, 2015).
Water sparkling is commonly considered as an important waste of such a precious resource. The drawback of water sparkling and water surfaces as adaptation action is its limited availability. To cope with such lacking, grey water or water coming from rainwater storage could be used (Bougiatioti, 2005, p. 121). Water elements are better enjoyed in dry climates, where summers are hot and not in places where the humidity is already existing. water bodies are elements of urban design besides its environmental benefits. In fact, using water bodies for cooling function, their shapes, locations, and dimensions could also be exploited to create paths that direct pedestrians or that remove them from certain forbidden spaces.

4.1.3. Urban geometry

Everything that has been discussed reducing the UHI effect so far deals with urban geometry. This paragraph deals with the UHI effect through the consciousness that every

location and orientation directly affects the intensity of UHI. In this sense, buildings are physical barriers to normal environmental fluxes – like natural ventilation - that would normally occur if cities and their suburbs would be flat. Public squares are surrounded by buildings; therefore, public squares are directly affected by the climate influenced by urban geometry and, vice versa, their orientation and H/W ratio should be designed according to the local climate to better adapt to CC.

H/W ratio

We have already discussed the height (H) to width (W) ratio (H/W) in the previous Chapter 3 from the "sense of enclosure" point of view, but H/W is also a fundamental pillar of urban geometry. Considering its influential character on shading and on ventilation of urban spaces, H/W here is thought as an adaptation measure to involve in urban planning and urban design processes with specific regard to public squares. With appropriate and balanced dimensions, buildings heights and square (or street) widths can orient both wind and shadows affecting, therefore, the "thermal comfort" (Taslim, Parapari, & Shafaghat, 2015, p. 121). According to the Kleerekoper's Ph.D. Thesis on thermal comfort in Dutch neighborhood, urban geometry and its density "influence the incidence of radiation on materials that can store heat, and the trapping of radiation by multiple reflections between buildings and street surface" (Kleerekoper, 2016, p. 86). As previously explained, H/W ratio is strictly dealing with two conditions: shading, which should in order to allow the "optimal shading" and ventilation: optimal shading, obtainable according to the orientation of buildings and the climate conditions affecting the location, and natural ventilation,

1. Optimal shading
   As seen before, a sustainable method to shadow buildings is through the use of vegetation with a strategic location allowing a covered layer before the solar radiation strikes on buildings. Nevertheless, shadowing can be obtained also by the buildings themselves with accurate H/W ratio. Through the Hotkevica Master Thesis, it has been possible to understand "how much area is exposed to the sun and for how many hours" (Hotkevica, 2013, p. 60). In her work (Figure 4.4), she matched different H/W (2:1, 1:1, 1:2, 1:3) to four different building's orientations (N-S, NE-SW, NW-SE, W-E) identifying the diurnal solar exposure areas according to time. Her research has been made considering street's H/W ratios, but they can also be applied for square contexts. The results show that with 1:2 and 1:3 H/W ratios at all the four square possible orientations, and with 1:1 H/W ratio W-E oriented, the buildings surrounding the square but also the pavements are highly subjected to solar radiation (Hotkevica, 2013). These most vulnerable square conditions are enclosed in the red box of Figure 23. The important and useful research made by Hotkevica shows that shading can be obtained not only by

vegetation, which still remains fundamental but also by building's H/W ratio. In this context, to match adaptation and mitigation goals, and overall and intersected vision is needed. Thus, it is reasonable to link optimal shading with a sense of enclosure, where a 1:3 H/W ratio has been considered the most realistic for the public square to accommodate pedestrians (Chapter 3). This scenario (illustrated

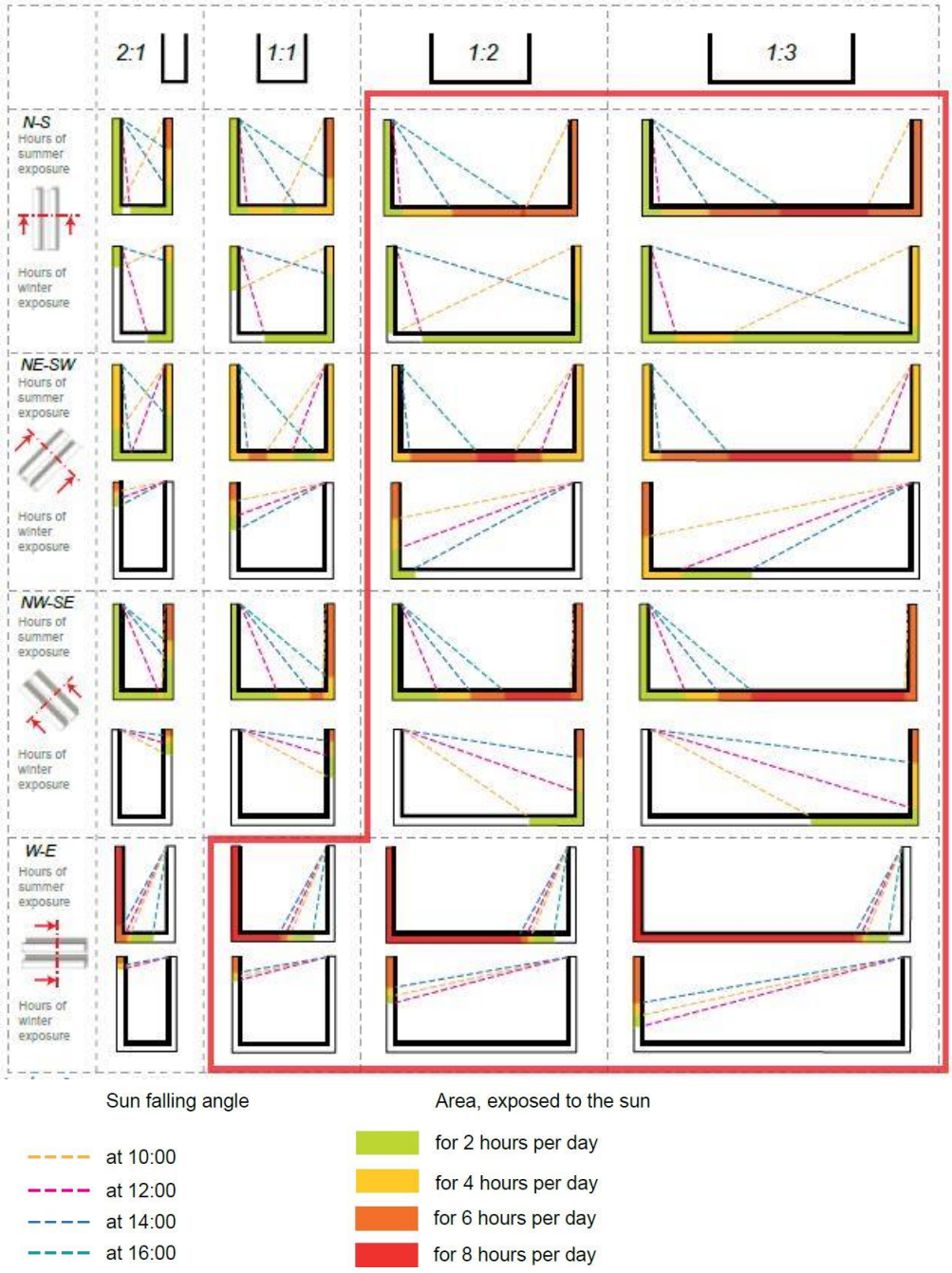

Figure 4.4 - Buildings and pavements solar exposure according to different H/W ratios and orientations
Source: (Hotkevica, 2013, p. 61)

on the right side of the Figure 4.4) is the most critical among all those analyzed by Hotkevica because are those that let buildings and pavements to higher solar radiation exposure due to their lower H/W ratio (it is obvious that with 1:6 ratio the solar exposure would be higher and critical but is also true that at that H/W ratio sense of enclosure is not perceived). This result leads to thinking that in order to obtain shadows in urban and suburban squares, buildings alone are not sufficient and, consequently, a balanced proportion of H/W and other adaptation measures – first of all, vegetation – should be integrated to obtain shadowed and cool urban squares.

2. Natural ventilation

   Besides the features of the fundamental material of the building itself and the just explained shading value, it is also crucial the orientation of the square (and the related surrounding buildings) to favor UHI effect reduction by natural ventilation. At urban and suburban square scale, wind flows play an important role to blow the heat away and alleviate high temperatures caused by the UHI effect. Assuming that the most common H/W ratio for plazas is 1:3 (in this case is more appropriate to consider it as H/W= 0,33), buildings on the edge are quite widely separated from the ones in front of them. As underlined by Oke et al. (2017), wind flows interact with the built environment not only because they break on buildings, but wind flows are affected by their H/W ratio. If the relation between buildings is characterized by large space in between (H/W < 0,35) then wind flows act as if they were isolated buildings because the wind breaks on them bypassing them (Figure 4.5a) continuing its natural flow (Oke, Mills, Christen, & Voogt, 2017). The authors affirm that with shorter distances between the buildings edging the square (that is, H/W ratio between 0,35 and 0,65), interferences between wind flows occur (Figure 4.5b). In this case, "the vortex in the cavity behind the upwind building is reinforced by the flow down the windward face of the next building" (Oke, Mills, Christen, & Voogt, 2017, p. 87) resulting in the possible violent wind flows. The third type of wind flow that may occur is called "skimming flow" and arise when the H/W ratio is higher than 0.65. In this case, such a close proximity allow very weak wind flows to enter in the so-called "urban canyons" where "the flow above the roof has become partially de-coupled from that in the canyons" (Oke, Mills, Christen, & Voogt, 2017, p. 87) as illustrated in (Figure 4.5c).

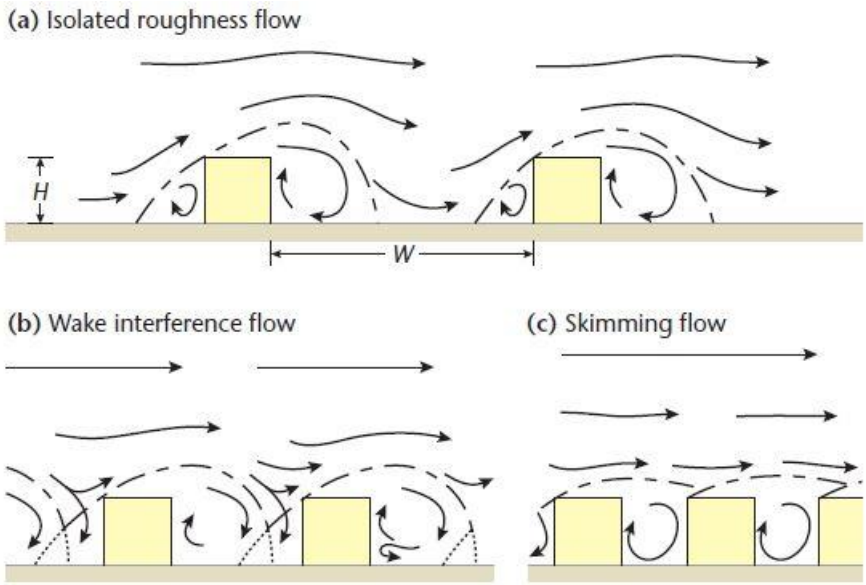

Figure 4.5 a), b), c) - Wind flows behaviors according to different H/W ratios
Source: (Oke, Mills, Christen, & Voogt, 2017, p. 88)

Concluding, the UHI effect is one of the major and negative consequences of CC. The positive aspect is that it can be reduced by both mitigation (which are not treated in this thesis) and adaptation actions, reducing its impact on the public realm and its pedestrians. The scope of this paragraph is to identify measures to draw from in order to better adapting to such a problem. Assuming H/W equal to 1:3 (or 0,33) as a standard one for square, it is very challenging to provide shading by building heights and widths only. Vegetation is always a good element to implement, especially in those squares characterized by very low H/W ratios. In fact, thanks to the foliage area, trees can shade buildings and pavements representing a valid possible incrementation to add in wide urban squares and plazas.

A useful strategy concerns the orientation of the buildings that surround the square which partially allow every orientation, excluding the N-S one, according to the diurnal time. Regarding ventilation, a clear natural flow should be provided by buildings' H/W ratios to allow air exchange. Whilst it can be difficult to obtain a significant air exchange with elevated H/W ratio, urban and suburban square should be planned with lower H/W ratio (e.g. H/W= 0,35) being aware to do not exaggerate, otherwise, sense of enclosure would become overwhelming and natural ventilation could not reach the SUHI.

4.2. Flooding

Floods are natural disasters meaning that is they are intrinsic effects of climate nature and that is natural to happen. Besides the climate regions, upon which depend on the frequency of rainfalls and their intensity, floods can occur in every U.S. county randomly. Always focusing on urban public squares and plazas as the key point for pedestrian life, they are commonly constructed and planned in order to accommodate social interactions and to boost economic activities rather than an extreme event like floods (Silva & Costa, 2018).

In fact, they are normally not prepared for such natural disasters and their presence immediately shifts from being essential and vital to being one of the reasons why such natural events become a complete catastrophe, as it happens wherever a land-use change has become anthropized. As described in Chapter 1, CC changes the frequency and intensity of the rainfall, "leading to some regions suffering increased storminess and hence increased flooding incidents" (Lamond, Booth, Hammond, & Proverbs, 2017, p. 210).
Flood adaptation measures can occur at three different urban scales: local, district and regional. If drainage systems are integrated at all those spatial scales, they can provide a strategic and efficient way to accommodate heavy rainfalls resulting in helpful to avoid flooding (Wong, 2006). To deal with the purpose of the thesis only the actions at the square level (within the local scale) will be treated. Adaptation measures to flooding at the local and square level have been grouped by category typology as follows:

- Urban greenery

  It considers all the vegetation that present at the ground level regarding public spaces and also vegetation in the form of green walls and green roofs, rather than wider green spaces (e.g. urban parks and similar) because, even though the latter can infiltrate larger amount of rainfalls, the focus in this instance is on the public square capacity to adapt to floods. Due to the high value of impervious surfaces in dense urban and suburban areas, it is difficult to deals with extreme rainfall events when they occur (Kim, Lee, & Sung, 2016). Vegetation and green spaces applied on building's surfaces have two main benefits: "1) increasing water interception due to vegetation cover, and; 2) increasing storage capacity and infiltration of the soil" (Zimmermann, Bracalenti, Piacentini, & Inostroza, 2016, p. 2242).

- Reservoir

  There are several types of reservoirs helping to control flooding, for this instance, we take into account detention reservoirs, which can function as a big bowl storing excess of water coming from heavy rainfalls. The fact of locating such a structure within the square can have multiple benefits. The first is the direct effect it could have on the amount of water stored within the basis that would otherwise become surface runoff. The second is related to its recreational function emerging once the rainfall event ends and the square, fulfilled with water, can "provide facilities for water based recreational activities" (Hettiarachchi, 2016, p. 57). Even if the reservoir could be placed "somewhere upstream" (Hettiarachchi, 2016, p. 57), locating it within the plaza can also

function as a sort of arena where, when rainfalls do not occur, the reservoir becomes a basketball playground or a skate park, for example.

- Bioretention

  The bioretention category deals with vegetation that, in case of flooding, helps to avoid or at least limiting surface runoff due to the fact that trees and plants require the presence of soil. In technical words, this means a highly porous and permeable surface. Once the surface runoff is absorbed by the vegetation soil, then it could go through two processes. The first is related to the connection of a drainage system which allows water absorbed to be channeled. The second involved a further infiltration into the underneath soil layer (Blick, Kelly, Skupien, Friedman, & Jacobus, 2004, p. 9.1). Bioretention option can be provided in two forms: "a bioretention basin or a longer, narrower bioretention swale" (Blick, Kelly, Skupien, Friedman, & Jacobus, 2004, p. 9.1).

- Permeable pavements

  Besides their fundamental cooling function which allows evaporation, permeable pavements are especially useful in mitigating floods due to their capacity that allows urban and suburban areas to act as "sponges". Generally, permeable pavements are block pavers characterized by open joint spaces in between one another (Shafique, Kim, & Kyung-Ho, 2018). In this way permeable pavements are able to "collect, treat and infiltrate freely any surface runoff to support groundwater recharge" (Scholz & Grabowiecki, 2007, p. 3831). According to Hu et al., it is not easy to define a general and standard real efficiency of permeable pavements because it depends on "the types of permeable pavements, the clogging situation of permeable pavements, and the initial water content at the beginning of the storm event" (Hu, et al., 2018, p. 9). Also, porous pavements can contribute to runoff reduction and stormwater infiltration but, compared to permeable pavements, their properties allow lower water infiltration.

- Infiltration techniques

  In this case, infiltration techniques refer to infiltration trenches which consist of substrate layers made of rocks of different sizes (Chahar, Graillot, & Gaur, 2012). Thanks to this layer made of stones, water in the soil can infiltrate easier and faster, allowing a larger amount of water to enters the soil that otherwise would be transformed into surface runoff. Usually, infiltration techniques are "used for small drainage areas" (Chahar, Graillot, & Gaur, 2012, p. 275) but,

if integrated with other flood adaptation measures together they can cover wider areas like those of public squares.

The categories identified above, have been matched with some real examples worldwide by Silva and Costa (2016, p. 7-9) and are proposed in Table 4.2.

Table 4.2 - Flood adaptation measures to flooding and examples

Category	Function	Adaptation measure typology	Project Name	Location
Urban greenery	Water interception, Stormwater infiltration	Green walls	Caixa Forum plaza	Madrid
			Westblaak' car park silo	Rotterdam
		Green roofs	Dakpark	Rotterdam
			Promenade Plantée	Paris
			European Patent Office	Rijswijk
			Womans University	Seoul
			High Line Park	New York
Reservoir	Flood control, Detention, Storage	Artificial detention basins	Parc de Diagonal Mar	Barcelona
			Parc del Poblenou	Barcelona
		Water plazas	Benthemplein square	Rotterdam
			Tanner Springs Park	Portland
			Parc de Joan Miró	Barcelona
			Escola Industrial	Barcelona
		Underground reservoirs	Postdamer Platz	Berlin
			Museumpark car park	Rotterdam
			Place Flagey	Brussels
Bioretention	Stormwater infiltration, Runoff reduction	Bioswales	Trabrennbahn Farmsen	Hamburg
			Elmhurst parking lot	New York City
			Ecocity Augustenborg	Malmö
			Museum of Science	Portland
			High Point 30th Ave	Seattle
			Moor Park	Blackpool
			Ribblesdale Road	Nottingham

		Bioretention planters	South Australian Museum	Adelaide
			Columbus Square	Philadelphia
			Derbyshire Street	London
			Onondaga County	New York
			Edinburgh Gardens	Melbourne
			Taasinge Square	Copenhagen
		Rain gardens	Australia Road	London
			East Liberty Town Square	Pittsburgh
Permeable pavements	Runoff reduction, Stormwater Infiltration	Open cell pavers	Can Caralleu	Barcelona
			Zollhallen Plaza	Freiburg
		Interlocking pavers	Green park of Mondego	Coimbra
			Bakery Square 2.0	Pittsburgh
			Praça do Comércio	Lisbon
		Porous paving	Percy Street	Philadelphia
			Greenfield Elementary	Philadelphia
Infiltration techniques		Infiltration trenches	Etna Butler Street	Pittsburgh
			Community College	Philadelphia
			Elmer Avenue Neighborhood	Los Angeles

Source: Author's re-elaboration based on: (Silva & Costa, Flood Adaptation Measures Applicable in the Design of Urban Public Spaces: Proposal for a Conceptual Framework, 2016, p. 7-9)

4.3. Drought

Drought is probably the natural disaster towards which the design of the square and its characteristics can do less. This is because "Unlike other urban disasters (e.g., flood, earthquake, and fire), urban drought happens silently and often without visible warnings" (Zhang, et al., 2019, p. 2). Besides the several factors under which drought gravity depends, which have been underlined in Chapter 1 (duration, intensity, and geographical area affected), droughts are also affected by the "demands made by human activities and by the vegetation on a region's water supplies" (Wilhite & Glantz, Understanding the Drought Phenomenon: The Role of Definitions, 1985, p. 3). This implies that droughts adaptation measures concerning public squares are limited to two actions: drought-tolerant vegetation and water storage.

Vegetation choice, to allow trees and plants to perform their multiple fundamental functions (described before) in an efficient way even during extreme and long-lasting natural events. To do so, native plants and trees are preferred because they can properly survive droughts. Thus, the most important plant function in this context is called "drought resistance" (DR)

and it is available in those species characterized by high adaptation capacity that "enable them to escape, avoid, or tolerate drought stress" (Basu, Ramegowda, Kumar, & Pereira, 2016, p. 3). The problem regarding vegetation during the drought period is linked to the irrigation issue. Native plants can last for a very long period without being irrigated whilst, other types of species could suffer if they do not be irrigated constantly. Thinking about cactus in the desert is a good one, but it would be quite uncommon and dangerous to have cactus in public square which are recommended to be safe for pedestrian flows (including children). There are several and not dangerous types of drought-tolerant plants proper for climate regions where drought happens or where the dry climate is constant (South West U.S.). In such cases, drought-tolerant plants can survive thanks to their water efficiency properties, such as: "extensive root systems, thick leaf waxes and periderm, good stomatal control, and the capacity for leaf cells to function at low water contents are needed" (Coder, 2018). According to Coder (2018), in order to obtain heat and drought-resistant plants in Southern U.S. climatic regions, they should be (Coder, 2018, p. 2):

- Natives, because of their adaptability to specific local climate conditions;
- Multilayered, in terms of quantity of branches and leaves allowing high water-efficient property;
- Taller, rather than wider, in terms of crown shape since "cone or cylinder shaped crowns" have a "great effect on heat dissipation and water use" (Coder, 2018, p. 2);
- Small leaves sized, rather than large because they "shed heat and have few pores from which to lose water" (Royal Horticultural Society);
- Broad-leaved trees, since they are able to "reflect 25% more light than conifer trees on average" (Coder, 2018, p. 2);

The other applicable adaptation action is water storage installation, to be able to rely on the water resource in order to supply to agricultural needs during droughts. This kind of adaptation action is similar to what explained water reservoirs but with a huge difference. The reservoirs used for flooding purposes have the function to accommodate water in excess that occurs with storms and heavy rainfalls. In the case of droughts, in contrast, water storage would serve for the opposite purpose, that is to save water from rainfalls.

Even if few measures have been identified, droughts adaptation measures are clearly difficult to apply to public squares and to public spaces in general but that does not mean they are not important. On the contrary, they are fundamental to prevent urban droughts problems (especially those related to vegetation), but through planning processes and policies rather than the Urban Design ones.
The next and final Chapter 6 will analyze case studies in different climatic regions across the USA and they will be based around TOD areas in order to verify if all the components developed so far match in some way and, if any, how they develop strategies to adapt and mitigate CC.

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PART III

Case Studies

Introduction

Chapter 5 analyses the square design of 10 TOD projects around the U.S., which have been selected according to the different climate regions that characterize the United States, the third-largest country in the world (Mattyasovszky, 2019). Project by project, all the mitigation and adaptation measures identified and separately developed in Chapters 3 and 4 respectively, will be managed in this instance as a unique and comprehensive system that works in symbiosis under the common aim of tackling CC. To do so, all the case studies are analyzed with a "virtual survey" through the use of the Google Maps Street view tool and Google Earth software.

Mitigation actions have been conceived as actions to reach the walkability, according to the New Urbanists theories. Thus, it will be looked at all the walkability components (urban compactness, mixed-use, building edges and façades, sense of enclosure, urban furniture, weather shelter, and public art, if any). Regarding adaptation actions, they have been considered as measures to adapt to CC impacts that occur according to different climate regions. Likewise, it will be verified if the selected squares in TOD projects have been planned to face specific climate vulnerabilities. Thus, the material color of buildings' envelopes, pavements, vegetation and the square geometry will be considered. This implies that the location of each case study will automatically delete some adaptation measures. For example, in regions characterized by dry spells and poor total yearly precipitations, flooding measures will not be a discriminatory factor on the evaluation of the square project and, in contrast, droughts measures in flooding vulnerable areas are considered superfluous.

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5. Climate Regions and TODs in the U.S.

As pointed out several times during the development of the thesis, all the measures (mitigation and adaptation) strictly depends on their location since different climate zones occur with different locations. There are several types of climates characterizing the U.S.
The first scholar dealing with climate regions that proposed a climate classification was the German geographer, botanic and climatologist Köppen in 1900 which studies have been updated several times by Geiger in 1954 and 1961 (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). More recently, Trewartha proposed adjustments to the original classification of Köppen – called KCC - in terms of "both the original temperature criteria and the thresholds separating wet and dry climates" (Belda, Holtanová, Halenka, & Kalvová, 2014, p. 2) resulting in a new classification better known as Köppen-Trewartha classification (KTC), which this thesis will refer to. The KTC includes "6 main climatic groups. Five of them (denoted as A, C, D, E, and F) are basic thermal zones. The sixth group B is the dry climatic zone that cuts across the other climate types, except for the polar climate F" (Belda, Holtanová, Halenka, & Kalvová, 2014, p. 3). Considering that the UHI effect actually depends on the city structure and geometry, rather than climate regions the climate impacts depending on climate regions are drought and flooding. All the 6 groups in the U.S.

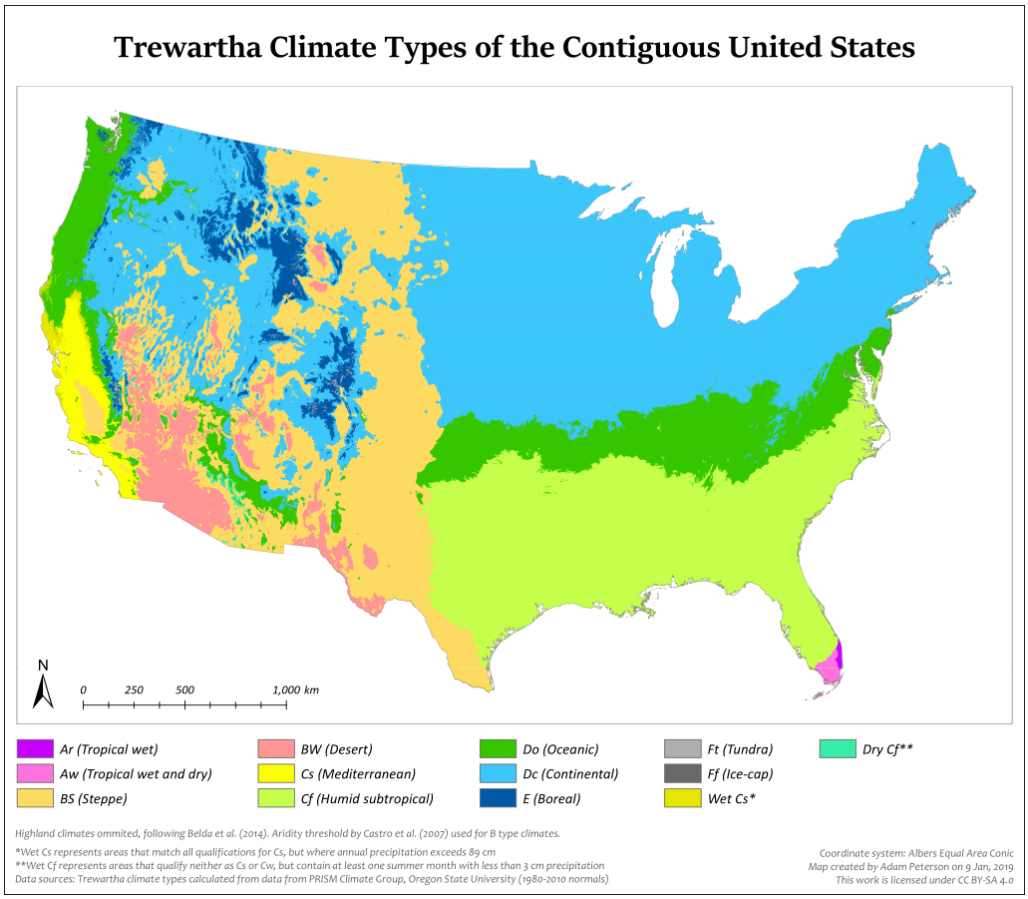

Figure 5.1 – KTC in the U.S.
Credit: © Adam Peterson (22 September 2016)
Source: Wikipedia
(https://en.wikipedia.org/wiki/Trewartha_climate_classification#/media/File:US_trewartha.svg)

included in the KTC and are represented in Figure 5.1. The map illustrates that, except polar climates, all the 5 types are present in North America, which is characterized by a net division between East and West.
While in the former there are mainly three types of climates (*Dc*, *Do*, *Cf* and also *Aw* and *Ar* climates in the South end of Florida) according to different latitudes and they are clearly separated, in the Western part of U.S. there are 4 types of climates which are completely mingled with their respective subtypes, ranging from boreal climates to desert ones.
Once these assumptions are made, it is possible to understand that the climatic characteristics that occur in TOD projects across the U.S. could be very different and so do the adaptation and mitigation measures to tackle CC in different locations. Having public squares in suburban areas as the prime target to analyze, the location choice referred to the *Urban to Rural Transect* subdivision defined by Duany, Sorlien and Wright in The SmartCode (2003). The first tricky challenge was concerning the case study selection. The research to identify TOD projects as case studies has been carried out firstly with the objective to choose projects located in different climatic regions and verify how the interested public square behaves in different climate conditions. The second discriminant factor in the choice process was about finding projects in the suburbs (T3), rather than in urban areas (T4, T5). This step brought about a large number of possibilities but with one crucial element missing, a proper public square possibly in front of the transit station or at least within the entire TOD project. Several times the TOD projects found presented a mere widening in front of the station with not enough material to work on, which lead to the next choice step. Given the rarity of TOD projects in suburban areas located in different climatic regions and including a proper square, the selection process enlarged the research allowing TOD projects in more dense and inner urban areas, without considering neither only suburban projects nor super dense areas in the city centers. Therefore, the case studies' choice has been enlarged to the T4 (General Urban) and T5 (Urban Center) zones, besides the T3 (Sub-Urban) of the *Urban to Rural Transect*. The zones identified in the research differ mainly in density characteristics: T3 is made of 1-to-2 story buildings, T4 made of 2-to-3 story buildings and, T5 made of 3-to-5 story buildings.
The problematic research of the right case studies immediately arose one crucial aspect: the concrete lack of public squares in the suburbs, the urban areas targeted by the New Urbanist and TOD's objectives. The difficult choice led to an appeal by the TOD Institute, which website lists several successful TOD experiences across the U.S. that has been helpful for the case studies choice. Nevertheless, the 10 case studies identified are:

- Wilshire Vermont (Los Angeles, California)
- Fruitvale Village (Oakland, California)
- Orenco Station (Hillsboro, Oregon)
- CityPlace (West Palm Beach, Florida)
- Market Common (Arlington, Virginia)
- Rockville Town Center (Rockville, Maryland)

- Pentagon Row (Arlington, Virginia)
- Richmond Village (Oakland, California)
- Santana Row (San Jose, California)
- The Gateway (Salt Lake City, Utah)

A more specialized survey on climate impacts has been carried out for each case study analyzed. In order to understand if the TOD project areas are more or less subjected to the UHI effect, flooding and/or drought, each case study analysis has been developed through three steps. First, the UHI effect is a though the impact to measure to compute and, although every Comprehensive Plan of the relative cities has been consulted, the information resulted inhomogeneous and they were often lacking. Therefore, the UHI effect intensity has been extrapolated in relation to the Extreme Heat (EH) days per county. This was possible through the interactive map supplied by the NRDC (National Resource Defense Council, s.d.) and represented in Figure 5.2.

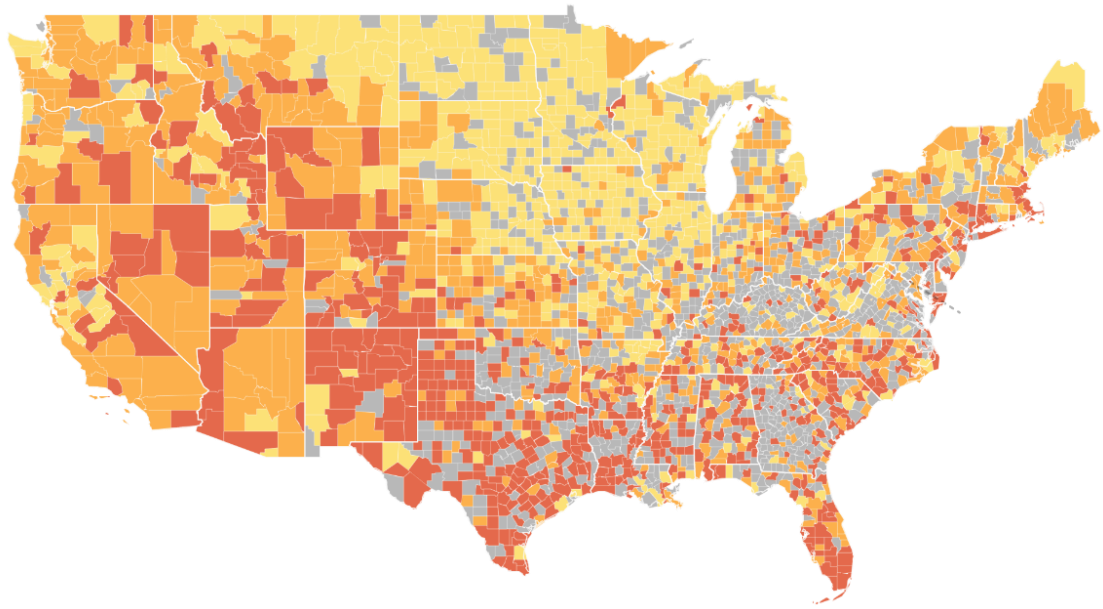

Figure 5.2 - Map of Extreme Heat days by US county
Source: (National Resource Defense Council, s.d.)

Extreme Heat is intended a period of days with "high heat and humidity with temperatures above 90 degrees" (Ready, s.d.), which is equal to around 32 C°. Although the map does not refer to the real UHI effect values, the information provided by the number of days with EH is of significant importance due to the close link between UHI and temperatures. In fact, the number of days with Extreme Heat will be more severe in dense urban areas than in the rural ones; thus, the location of the TOD project (T3/T4/T5) will be the discriminant factor to determine the UHI effect in each TOD project.
As suggested by the NRDC, the EH have been grouped into three class in order to define the level of intensity the different US counties are subjected to. Therefore, counties up to 9 days (included) are classed as low subjected to UHI and EH, those from 9 to 14 days as medium subjected and those over 14 days as highly subjected.

Second, to define the level of risk of flooding, it has been carried out research through the online tool FEMA Flood Map Service Center (Federal Emergency Management Agency, 2019) to understand the flooding hazard of the TOD areas interested by the research. Three classes of risk have been identified according to the FEMA classification[13]. Therefore, three classes have been extrapolated: Low risk of flooding, for areas within zone C, X, Moderate risk of flooding for areas within zone B, X500, and High risk for areas within zone A, AE, A1-30, AH, AO, AR, A99, V, VE, V1-30, D.

Third, it has been conducted the same operation to verify drought occurrence through the maps (Bolinger, 2019) obtained using data from the U.S. Drought Monitor for the last two decades (1999-2019) as represented in Figures 5.3, 5.4. Due to lacking information about long-period data, the only significant levels of drought available that have been considered are the two most grave: the D3 - Extreme Drought and the D4 - Exceptional Drought. The D3 (the second-highest level of drought) "where major crop and pasture losses are common, fire risk is extreme, and widespread water shortages can be expected requiring restrictions" (National Climatic Data Center, s.d.), and D4 (the highest level of drought) that "corresponds to an area experiencing exceptional and widespread crop and pasture losses, fire risk, and water shortages that result in water emergencies" (National Climatic Data Center, s.d.). As for the other climate impacts, also for the evaluation of drought the intensity has been considered by grouping the weeks of drought in three ranges: from 0 to 50 weeks, from 50 to 150 weeks and the most sever from 150 ahead.

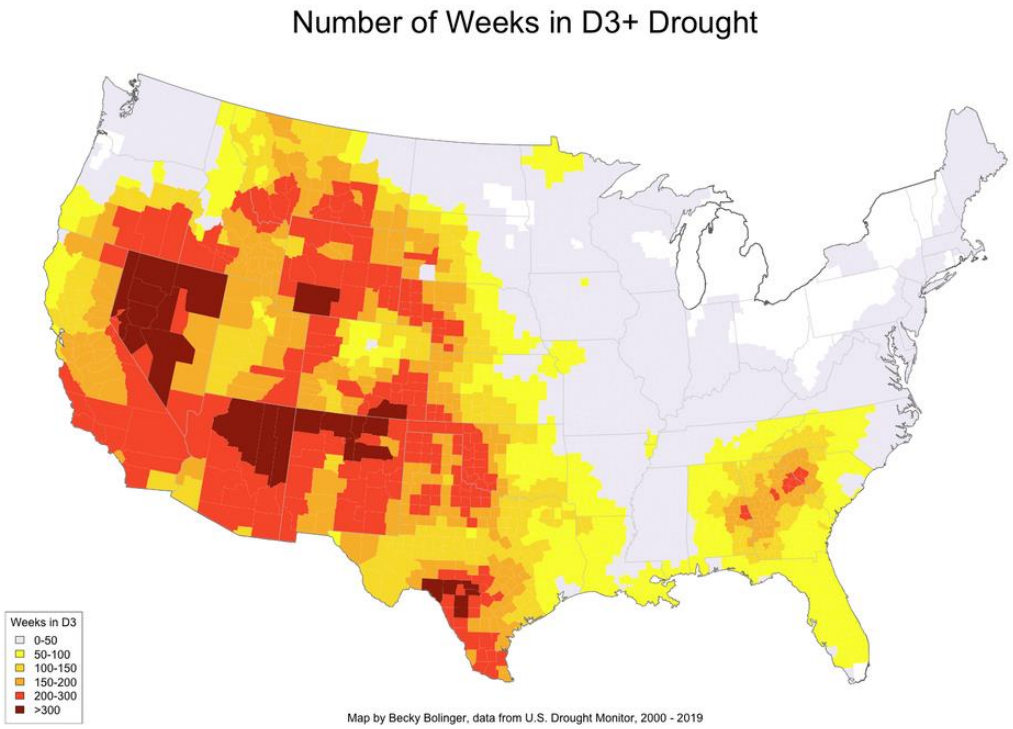

Figure 5.3 - Map displays the number of weeks counties that have experienced D3 drought or greater
Credit: © Becky Bolinger
Source: (Bolinger, 2019)

[13] http://www.floodmaps.com/zones.htm

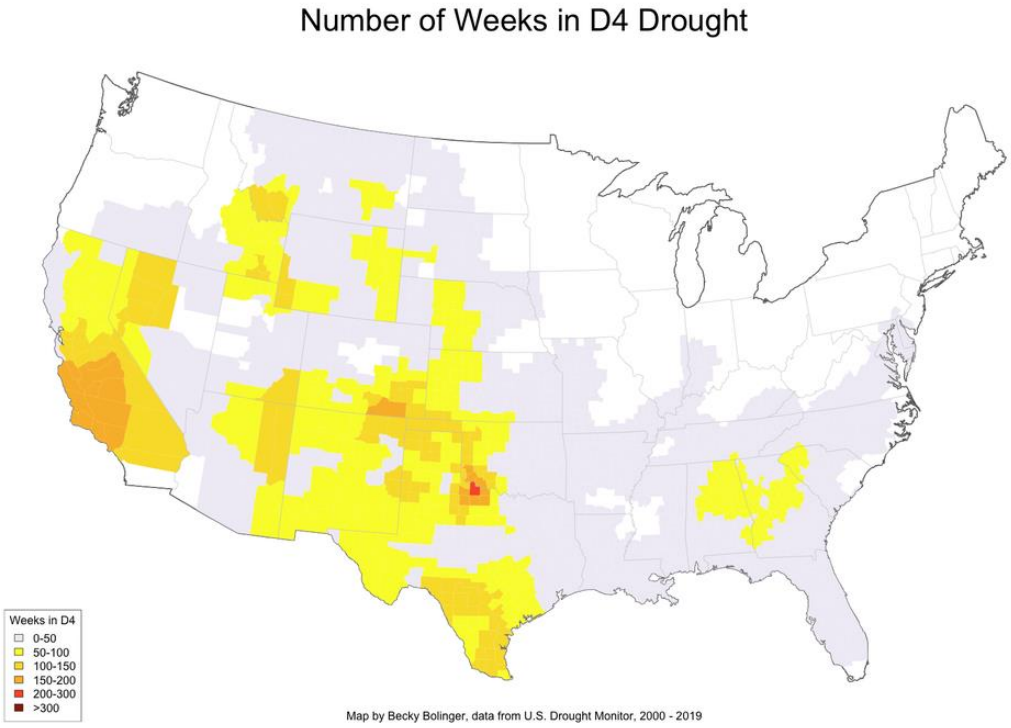

Figure 5.4 - Map displays the number of weeks counties that have experienced D4 drought
Credit: © Becky Bolinger
Source: (Bolinger, 2019)

According to the three impacts' classification described, the type of climate impacts and their severities has been evaluated for each case study and they are summarized in Table 5.1. Considering that the blank cells have no value due to insufficient data, the results show that all the TOD projects examined are located in flooding areas at minimum risk, thus, flooding is the less worrying impacts. Contrary, the UHI effect, and EH hazard is the one that could occur with more continuity across the case studies, presenting at least the medium impact' severity for all the examples and the minimum value only in the case of San Jose, California. The latter state is the protagonist of drought impact in negative terms. In fact, all the case studies confined within California's boundaries present the higher value of drought risk, which is of lower severity in the other TOD projects. The analysis summarized in Table 5.1, is useful to understand what type of impacts the TOD projects examined and their public squares are more vulnerable. In the following pages, are presented different sheets, one for each case study, in order to identify whether and how the 14 mitigation and 14 adaptation measures have been applied in the TOD projects to tackle CC and be prepared for the most worrying climate impacts identified in that specific area. In order to achieve this objective, a virtual but meticulous survey has been conducted through the use of the Google Maps Street view tool and Google Earth software.

Table 5.1 – Classification of climate impacts for each case study

TOD project	Location	Climate type	Climate Impacts			
			UHI & Extreme Heat	Flooding	Drought	
Wilshire Vermont	Los Angeles (CA)	Subtropical/Mediterranean (*Cs*)	2	1	3	2
Fruitvale Village	Oakland (CA)	Subtropical/Mediterranean (*Cs*)	2	1	3	2
Orenco Station	Hillsbro (OR)	Temperate Oceanic (*Do*)	2	1	1	1
CityPlace	West Palm Beach (FL)	Tropical Wet (*Ar*)	3	1	2	2
Market Common	Arlington (VA)	Humid Subtropical (*Cf*)	3	1	1	2
Rockville Town Center	Rockville (MD)	Temperate Oceanic (*Do*)	NDA	1	1	1
Pentagon Row	Arlington (VA)	Humid Subtropical (*Cf*)	3	1	1	2
Richmond Village	Oakland (CA)	Subtropical/Mediterranean (*Cs*)	2	1	3	2
Santana Row	San Jose (CA)	Subtropical/Mediterranean (*Cs*)	1	NDA	3	2
The Gateway	Salt Lake City (UT)	Continental (*Dc*)	2	1	2	2
			2	1	2	

Legend -UHI & Extreme Heat		
DAYS	≤9	1
	> 9 - 14	2
	> 14	3

Legend - Flooding		
RISK	Low	1
	Moderate	2
	High	3

Legend - Drought		
WEEKS	0 - 50	1
	50 - 150	2
	> 150	3

Source: Author's elaboration

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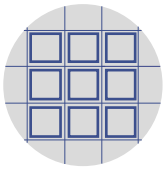
LEGEND

MITIGATION measures 14

Urban morphology

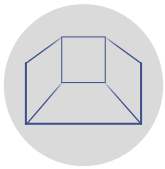
Mixed-uses

Interconnectivity



Active edges and façades

Sense of enclosure



Urban furniture

Seating

Public signage

Lighting

Recylce bins

Food

Bollards

Water bodies

Other elements

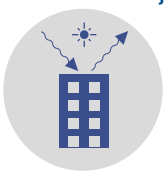
Weather shelters

Public art

Civic buildings

UHI effect

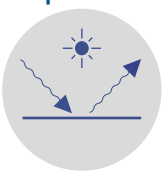
Cool roofs and façades



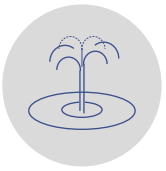
Green roofs & green walls

Vegetation

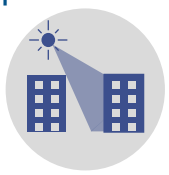
Cool pavements



Water bodies

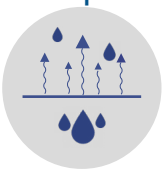


Optimal shading



Natural ventilation

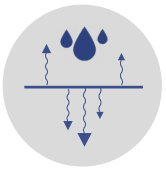
Permeable pavements



Floods

Green roofs & green walls

Permeable pavements



Water reservoir

Bioretention

Droughts

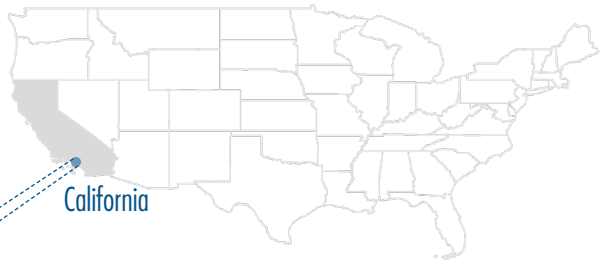
Drought-tolerant plants

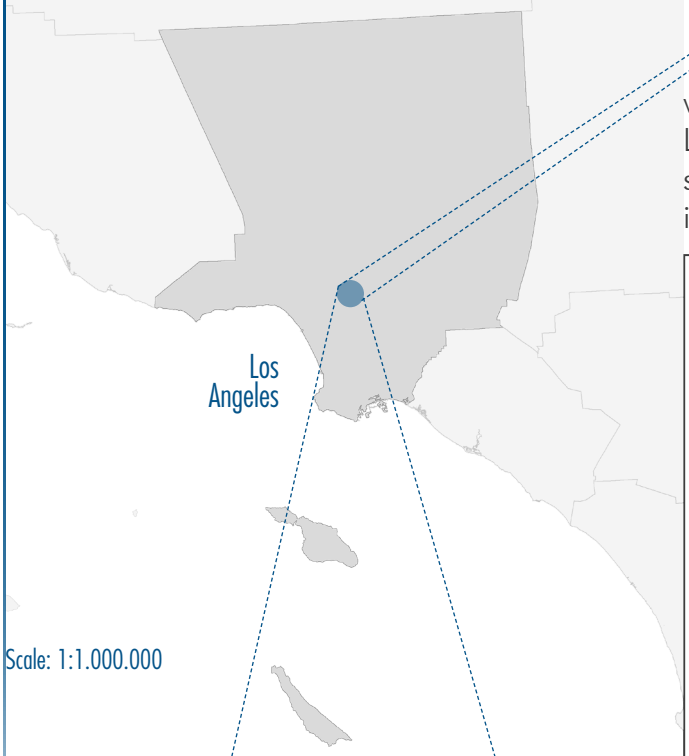
Water storage

Wilshire Vermont (Los Angeles, California)

Geographical BACKGROUND

Wilshire Vermont station is a TOD project in the Koreatown district of Central Los Angeles (CA). Here the climate is subtropical/mediterranean type (Cs), thus it experience hot and dry summers and mild winters. The station serves both the Red and Purple Lines connecting the city center with the North-Western zones of the LA county. The role of the square in the project is crucial.





Scale: 1:1.000.000

> "Located on more than three acres, this new mixed-use development consists of six levels of residential apartments (449 units), built above 36,000 sq. ft of commercial retail space on the ground level. The design integrated public spaces - the street and public plaza - with private outdoor environments. The project is located above an existing MTA Metro Rail subway station and includes a new entry into the station, considered a major public transportation hub in Los Angeles. The consultant team coordinated the project's design with the City of Los Angeles Neighborhood Initiative's master plan."
>
> Source: A Healthy Beautiful Environment [1]

Square GENERALITIES

TOD location
T5 - Urban Center

Station typology
Underground

Orientation
N-S

H/W ratio
0,67(31 m/46 m)

Tranist node
Metro (Red and Purple lines) and Buses

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

ABSENCE

Block size: 2.102 [ft]

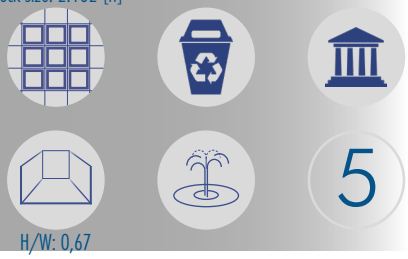


Figure 5.5

Figure 5.6

Figure 5.7

ADAPTATION measures

14

PRESENCE

ABSENCE

H/W > 0,65

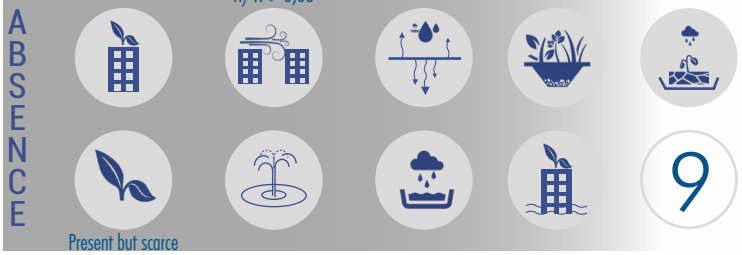


Figure 5.8

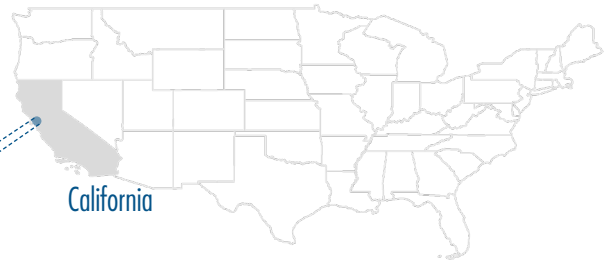
Figure 5.9

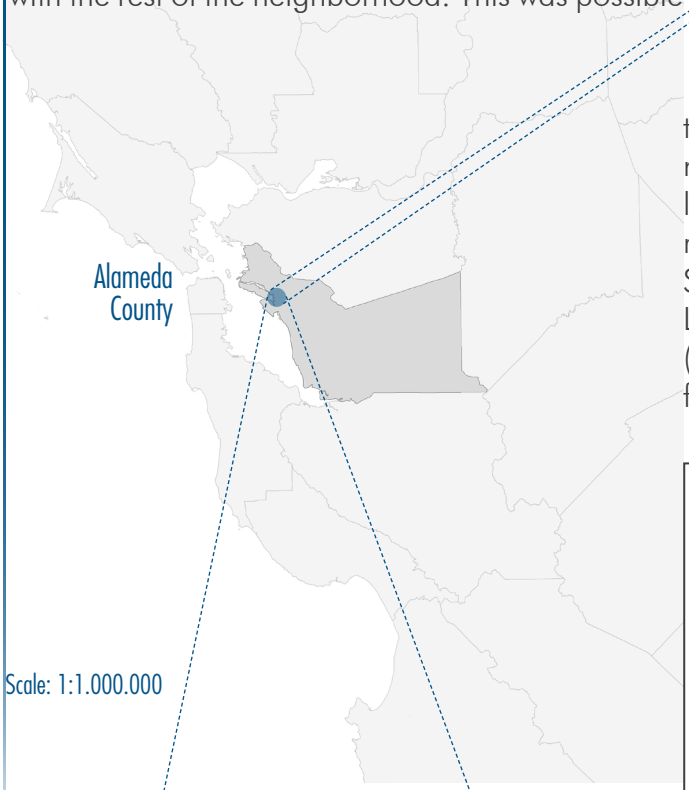
Figure 5.10

Fruitvale Village (Oakland, California)

Geographical BACKGROUND

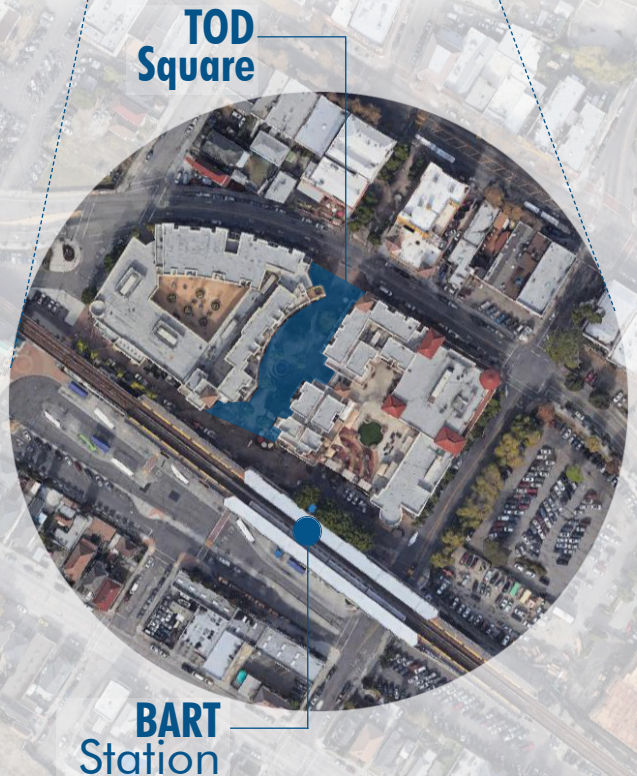
The station of Fruitvale Village deals with the Bay Area Rapid Transit (BART) connecting an old neighborhood to Oakland's downtown. The project is a mixed-use TOD aiming to create a connection with the rest of the neighborhood. This was possible thanks to a pedestrian plaza shaped like a corrdior relating the BART station with the Internationl Boulevard, which is the commercial core of the entire neighborhood two blocks to the North.





Still located in California, around 340 miles from Los Angeles, the climate type is still mediterranean (Cs). Thus, the climate hazards are still the UHI effect and extreme events.

> "The ground floor of Fruitvale Village is home to locally-owned retail spaces. The second floor offers Office spaces for important community resources and organizations. Finally, 47 one- and two-bedroom apartments offer housing on the third floor. Of the 47 units, 10 are designated as affordable units for residents earning between 35 – 80% of the Area Median Income."
>
> Source: The Unity Council [2]



Square GENERALITIES

TOD location
T4 - General Urban

Station typology
Elevated

Orientation
NE-SW

H/W ratio
0,78 (12,5 m/64 m)

Tranist node
Rapid transit/Commuter rail, Light rail (BART) and Buses

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

Block size: 936 [ft]

9

ABSENCE

H/W: 0,78

5

Figure 5.11

Figure 5.12

ADAPTATION measures

14

PRESENCE

8

ABSENCE

H/W > 0,65

6

Figure 5.13

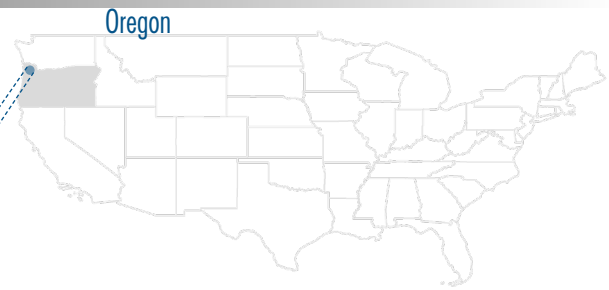
Figure 5.14

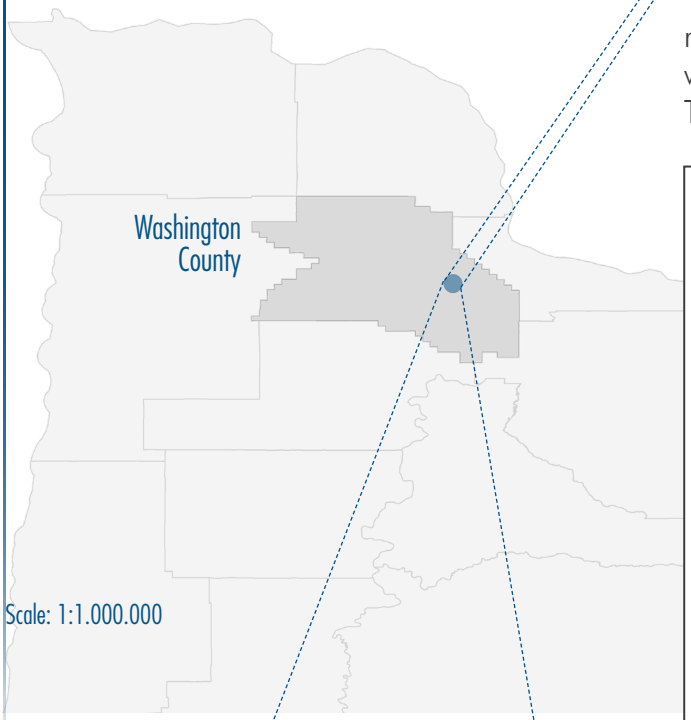
Figure 5.15

Orenco Station (Hillsboro, Oregon)

Geographical BACKGROUND

The Orenco station is located in the Portland West suburb of Hillsbro connected with the downtown thanks to the efficient Metropolitan Area Express (MAX) Light Rail system. The role of the plaza in this case is crucial since it is located next to the station stop. The climate class is temperate oceanic climate (*Do*) characterized by cool summers and wet winters ranging from elevated to low temperatures. Thus, climate extremes are





> "Completed in 2003, the Orenco Station neighborhood of Hillsboro, Oregon, a suburb of Portland, remains a shining example of neighborhood transformation from suburban sprawl into a pedestrian-friendly, high-density, mixed-use, transit-oriented community. Orenco Station, a case-study of transit-oriented, walkable, New Urbanist developments, has won numerous awards including the 1998 Oregon Governor's Livability Award, the 1998 Best Masterplanned Community in America Award by the National Association of Home Builders, and the 1999 AIA/ULI/FTA/STPP Transit Communities Livable Design Award."
>
> Source: CNU [3]

Square GENERALITIES

TOD location
T4 - General Urban

Station typology
Ground level

Orientation
W-E

H/W ratio
0,25 (20 m/78,6 m)

Tranist node
Light rail (Orange line of the MAX Light Rail)

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

Figure 5.16 - © Buhacoff

Figure 5.17

Figure 5.18

ADAPTATION measures

14

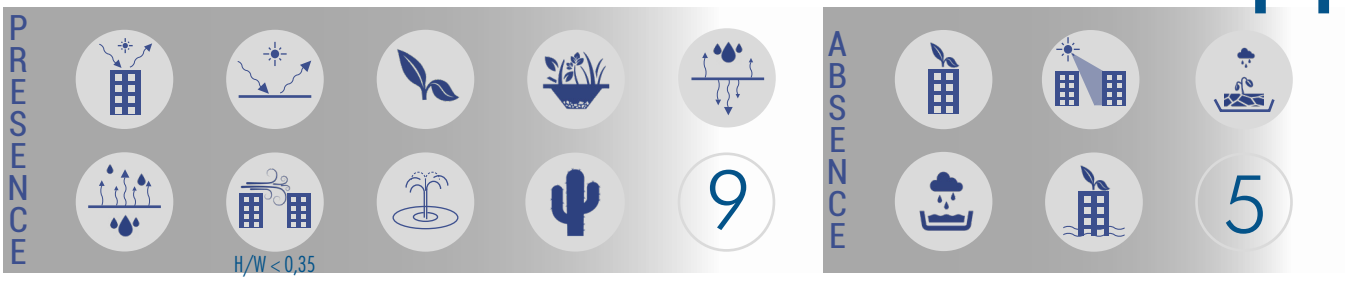


Figure 5.19

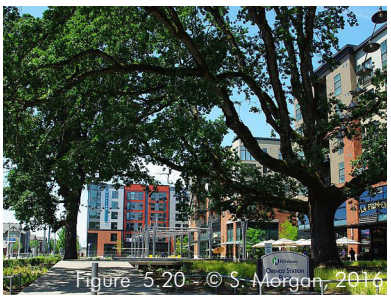


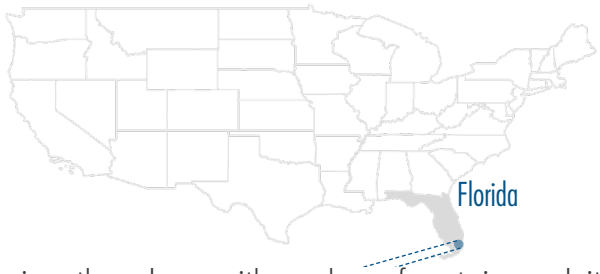
Figure 5.20 - © S. Morgan, 2016

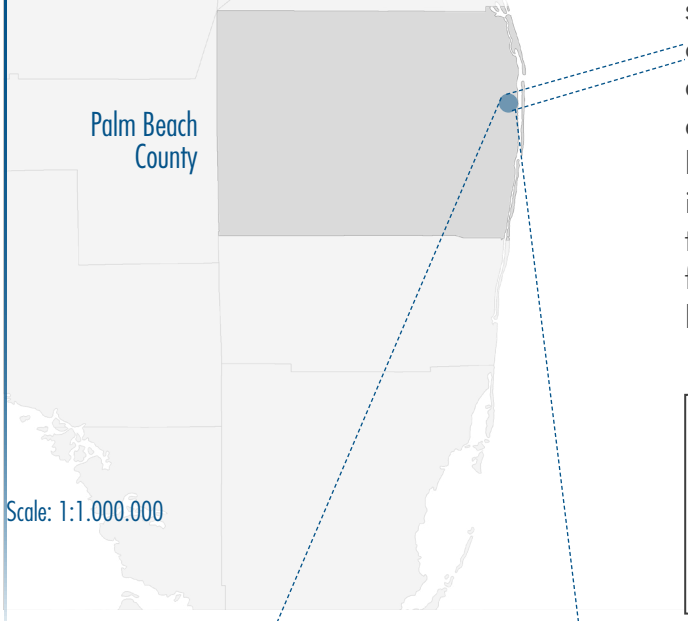
Figure 5.21 - © M.O. Steven

CityPlace (West Palm Beach,Florida)

Geographical BACKGROUND

City place is a high-density mixed-use project conditioned by a tropical wet climate (*Ar*) able to host a huge variety of entertainment and retail activities. Central to CityPlace project is Rosemary square, located around 8 minutes walking from Brightline station. The square is characterized by a church facing the plaza with a show fountain and it is surrounded by double palm tree lines allowing shadowing. The latter's presence, considering the climate type, is mandatory to attract people during daytime, giving the possibility to enjoy the vibrant environment the Rosemary square can offer to inahbiants both during daytime and nightime. The plaza is become the pincipal meeting place of the area thanks to the pedestrain axes with active ground floor that connect the square with the surroundings blocks and thanks to the climate measures adapted.





> "CityPlace was designed according to the DPZ code and is integrated seamlessly into the street grid."
>
> Source: CNU [4]

Square GENERALITIES

TOD location
T5 - Urban Center

Station typology
Ground level

Orientation
W-E

H/W ratio
0,29 (16,2 m/56 m)

Tranist node
Commuter rail (Tri-rail) and Buses

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

Figure 5.22

Figure 5.23

Figure 5.24

ADAPTATION measures

14

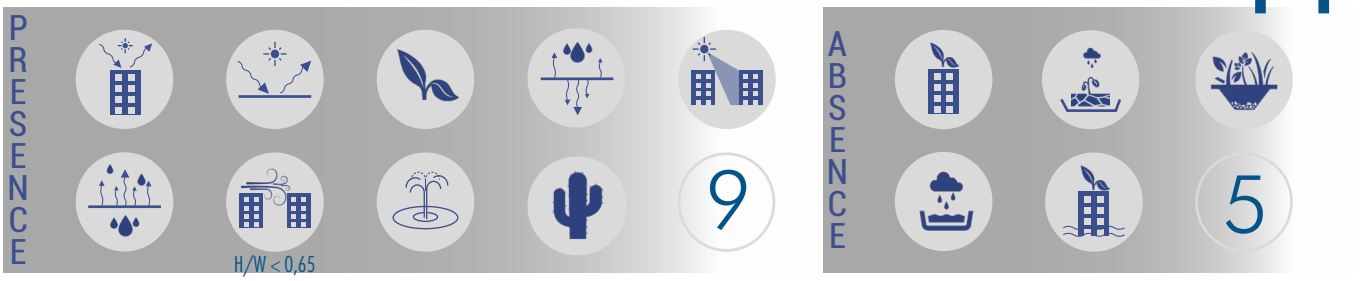


Figure 5.25

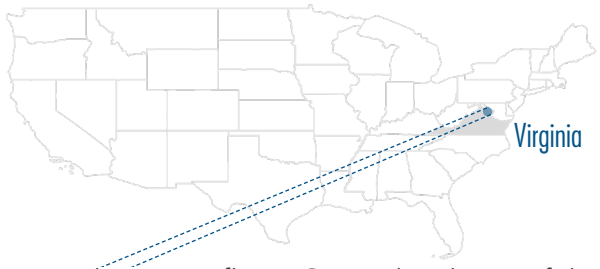
Figure 5.26

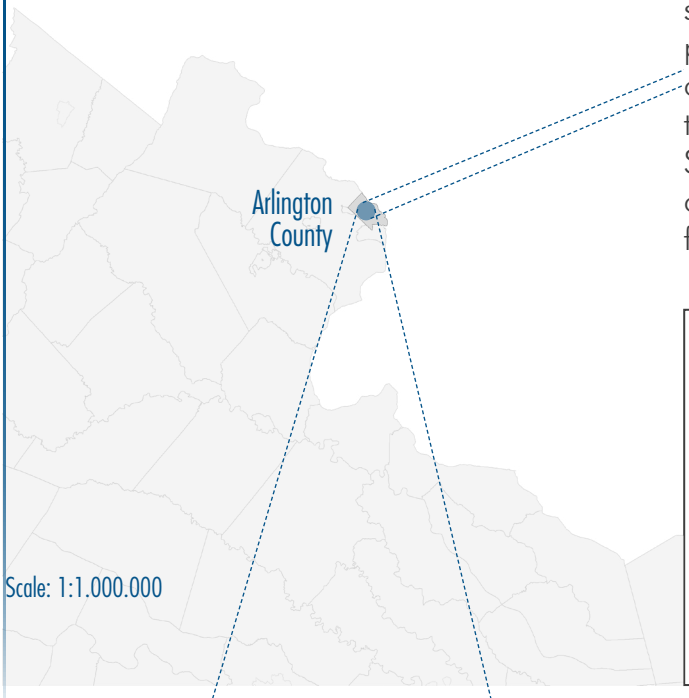
Figure 5.27

Market Common (Arlington, Virginia)

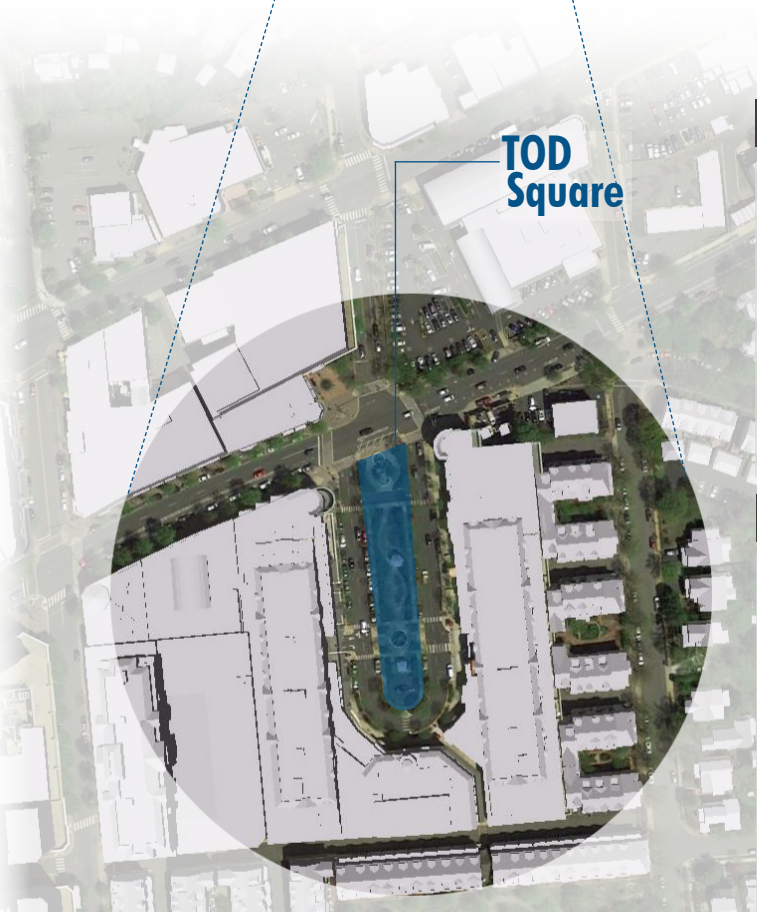
Geographical BACKGROUND

Market Common TOD project is affected by a humid subtropical climate (*Cf*) with cold winters and quite hot and humid summers. The project is in between two metro stations and is characterized by the "U" square around which are developed commerical and retatil spaces at ground floor, and residences on the upper floor. Given the shape of the project, the square take the forms of a pedestrain corridor, linking the main infrastructural axes on the North with the commercial center's entry on the South. The public square is pedestrian-oriented because it offers a variety of attracting elements (e.g. fountains, shaded seating areas and a playground).





> "The Market Common Clarendon won the 2005 Urban Land Institute Award of Excellence and was featured on the cover of Winning Shopping Center Designs as it won the 28th International Design and Development Award from the International Council of Shopping Centers."
>
> Source: Jacobs/Ryan Associates [5]



Square GENERALITIES

TOD location
T5 - Urban Center

Station typology
Underground

Orientation
N-S

H/W ratio
0,4 (18,4 m/45 m)

Tranist node
Metro (Orange and Silver lines) and Buses

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

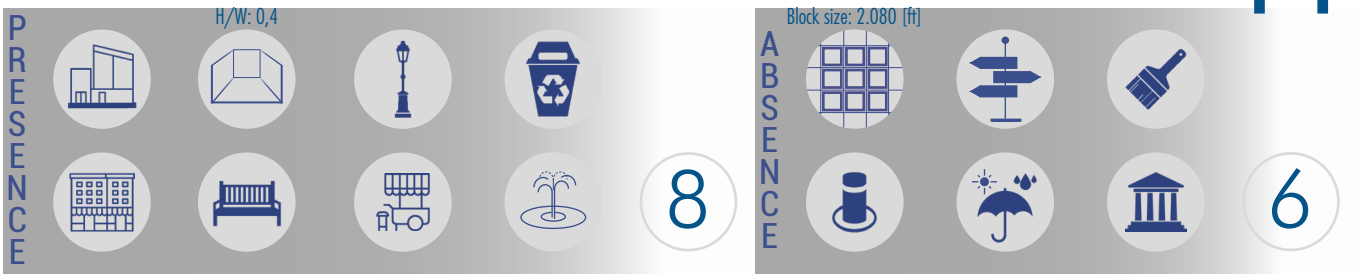


Figure 5.28

Figure 5.29 © Bozzuto Group

Figure 5.30

ADAPTATION measures

14

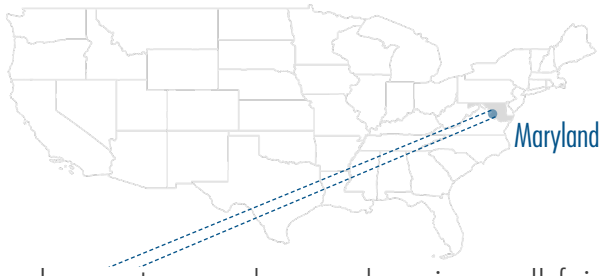
Figure 5.31

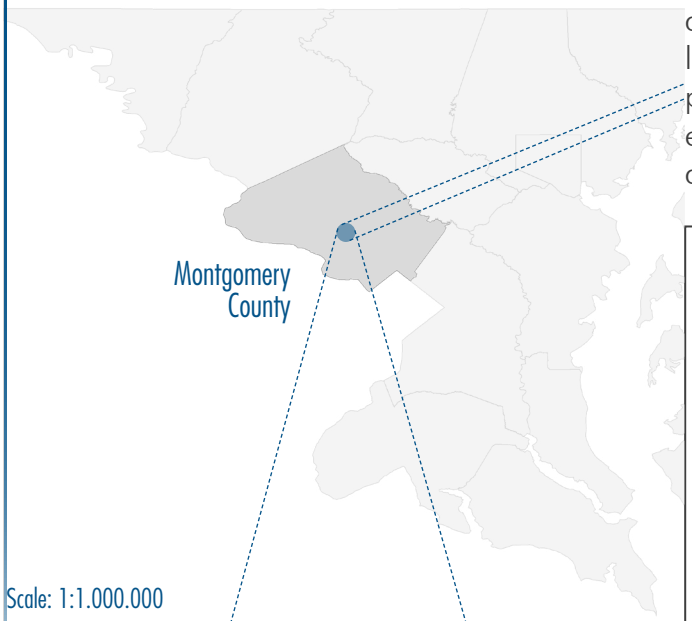
Figure 5.32

Rockville Town Center (Rockville, Maryland)

Geographical BACKGROUND

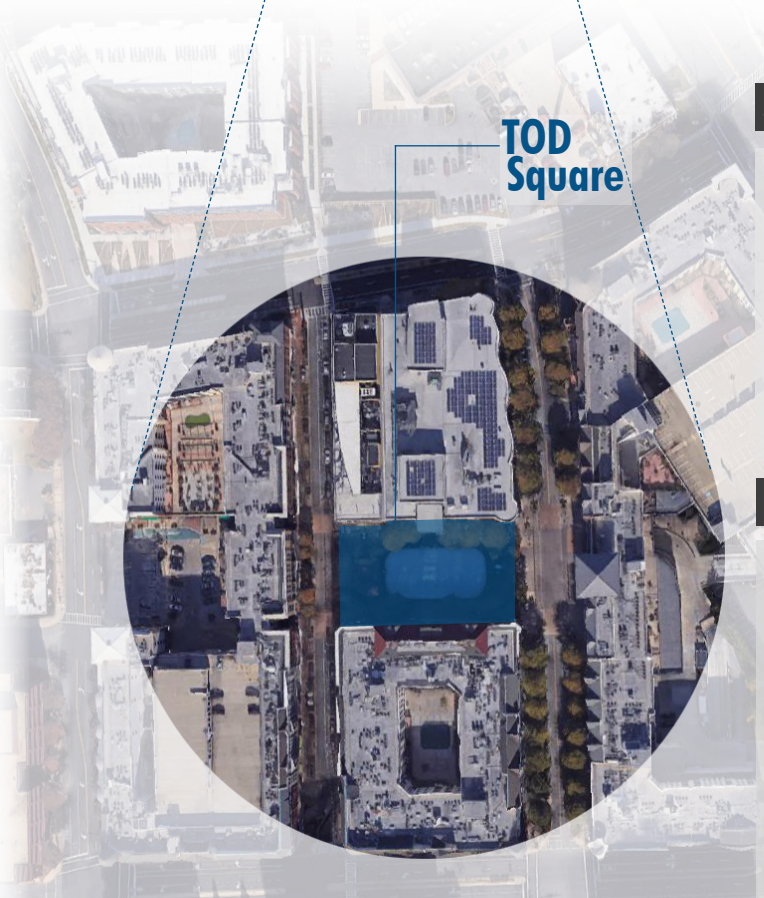
The Rockville Town Center project connect the city of Rockville with the Washington urban core through an efficient rail tranist system that offers both undergorund Metro and elevated commuter rail services. The project is affected by a temperate oceanic climate (*Do*). The current TOD lies on a redevelopment area where a shopping mall failed. The square is the node on which pedestrian pathways gravitate allowing a safe and pedestrian environment connecting the transit station with the activities and residencies around it.





Scale: 1:1.000.000

> "Rockville Town Square features a broad town plaza, state-of-the-art library, arts and business innovation center and pedestrian-oriented shops and restaurants with condominiums and apartments above. The redevelopment incorporates a variety of facades and other architectural elements; a six-story clock tower; an inviting streetscape of wide sidewalks, street furniture and trees"
>
> Source: Buntin, S.B. (2011) [6]



Square GENERALITIES

TOD location
T5 - Urban Center

Station typology
Underground and Elevated

Orientation
N-S, W-E

H/W ratio
0,52 (18,8m/36m)

Tranist node
Metro (Red line) and Commuter rail (MARC)

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

Block size: 528,4 [ft]

13

ABSENCE

H/W: 0,52

1

Figure 5.33 - © Dan Reed, 2013)

Figure 5.34 - © Simmons B. Buntin

Figure 5.35 - © Dan Reed, 2007

ADAPTATION measures

14

PRESENCE

0,35< H/W >0,65

10

ABSENCE

4

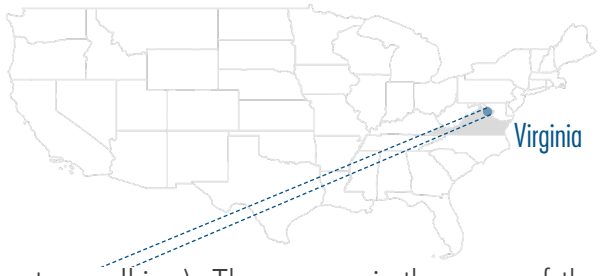
Figure 5.36 - © Dan Reed, 2012

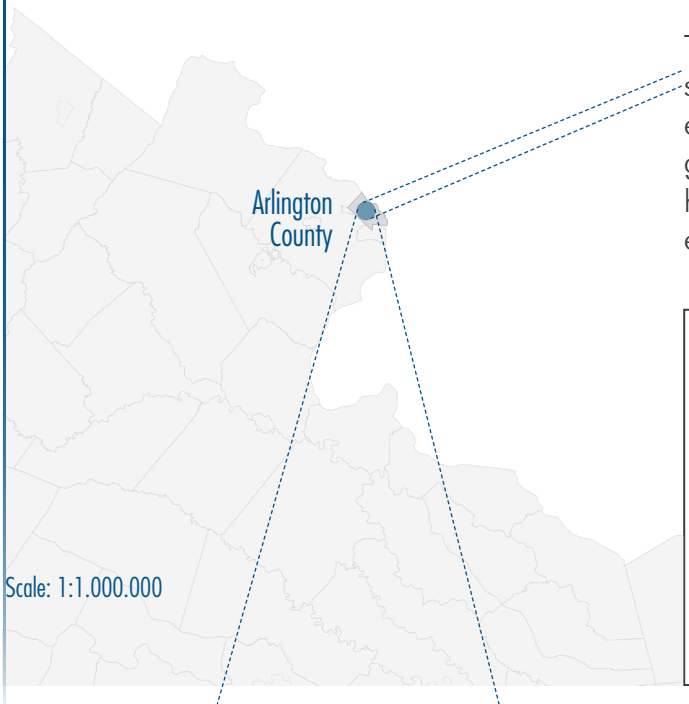
Figure 5.37 - © Simmons B. Buntin

Pentagon Row (Arlington, Virginia)

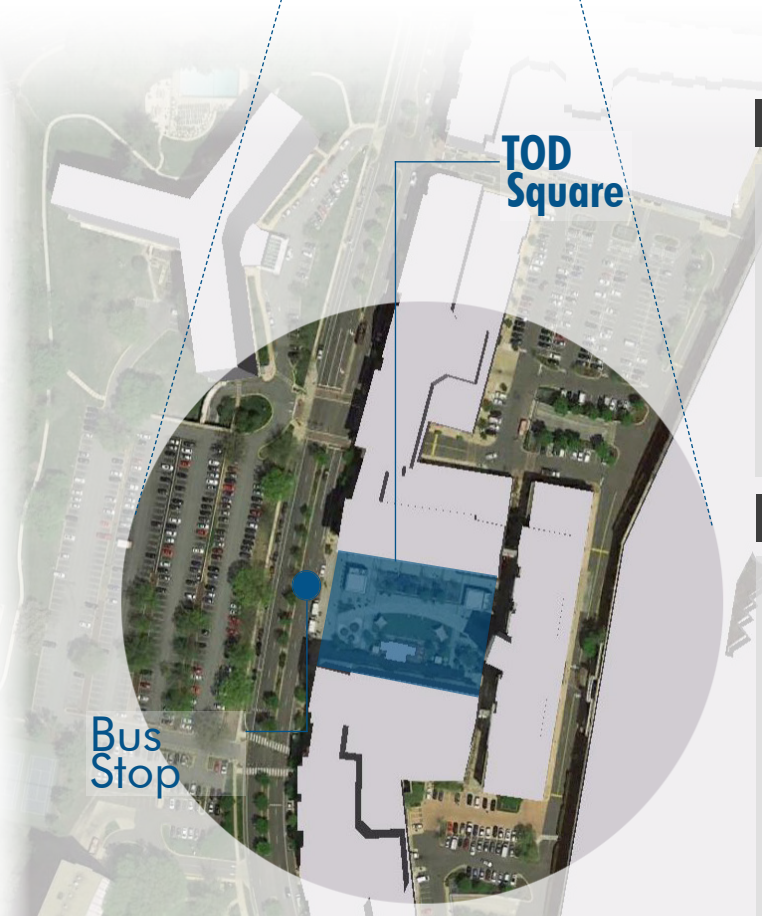
Geographical BACKGROUND

Pentagon Row is a mixed-uses, dense TOD project in the Washington suburb with a humid subtropical climate (*Cf*) that characterizes the area. The TOD is directly linked with Washington inner areas through a bus stop in front of the square and is easily accessible from the Pentagon City Metro station (about 10 minutes walking). The square is the core of the TOD project, it adapts to the local climate offering sheltered spots during hot summer days and ice rink entertaining local population and attracting foreigners from surrounding neighborhoods. The square has cool pavements and presents vegetation on the edges and laws, resulting in a pleasant place to be.





> "Pentagon Row is a vibrant shopping and entertainment destination with a unique combination of specialty retailers, exciting restaurants and amenities. This outdoor, walkable shopping center features dozens of specialty shops and an ice skating rink. Eat inside, outside or fireside."
>
> Source: StayArlington [7]



Square GENERALITIES

TOD location
T5 - Urban Center

Station typology
Underground and Ground level

Orientation
W-E

H/W ratio
0,38 (24 m/64 m)

Tranist node
Metro (Blue and Yellow lines) and Buses

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

H/W: 0,4

9

ABSENCE

Block size: 2.080 [ft]

5

Figure 5.38

Figure 5.39


Figure 5.40

ADAPTATION measures

14

PRESENCE

0,35< H/W >0,65

8

ABSENCE

6

Figure 5.41

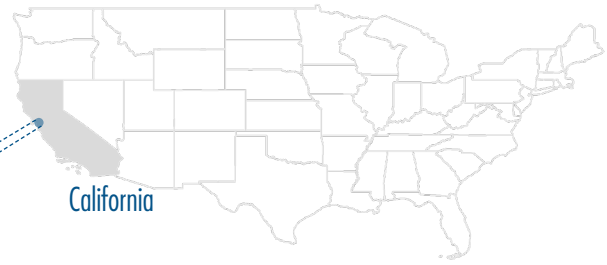

Figure 5.42

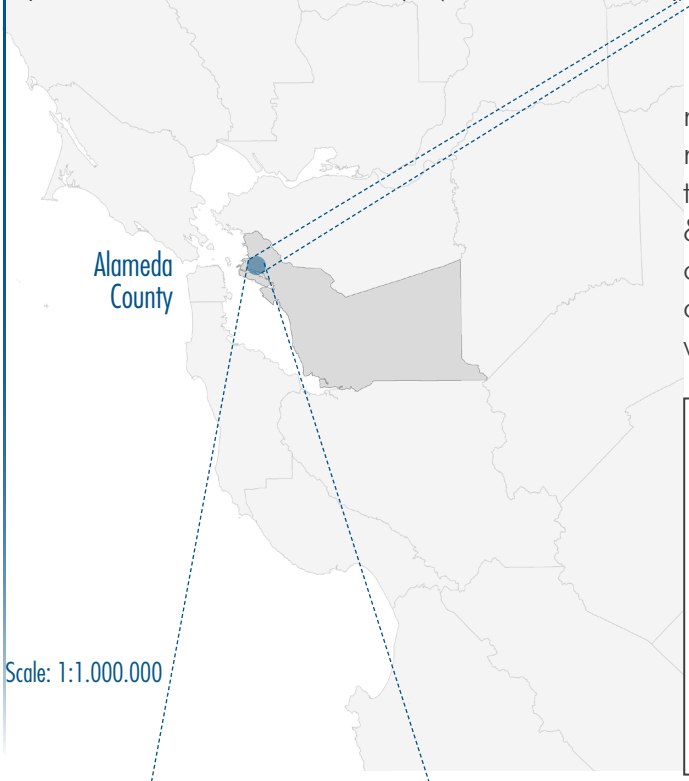

Figure 5.43

Richmond Village (Oakland, California)

Geographical BACKGROUND

The Richmond station is the terminus of the Red and Orange lines of the BART rail system connecting the N-W part of Oakland with San Francisco. Richmond is a suburban TOD village affected by a mediterranean climate (Cs) characetrized by residential uses surrounding the station with a square and a pedestrian walkway directing to the station. The station ticipity is represented by the "park & ride" character, offered through a drop-off & pick-up area and a structured parking which allow commuters to approach to Oakland's inner areas without using the automobile.





> "Richmond Transit Village has successfully transformed underutilized land while promoting transit ridership and home ownership. It has also helped to revitalize the historic commercial core of Richmond and encouraged other mixed use projects in the area."
>
> Source: HDR Calthorpe [8]

Square GENERALITIES

TOD location
T3 - Suburban

Station typology
Ground level

Orientation
W-E

H/W ratio
0,25 (10,5 m/41 m)

Tranist node
Rapid transit/Commuter rail, Light rail (BART)

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

Block size: 1143 [ft]

7

ABSENCE

H/W: 0,25

7

Figure 5.44

Figure 5.45

Figure 5.46

ADAPTATION measures

14

PRESENCE

H/W < 0,35

1

ABSENCE

13

Figure 5.47

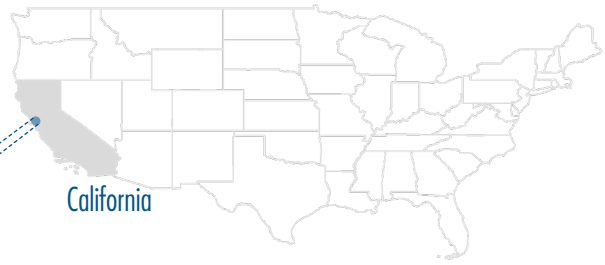
Figure 5.48

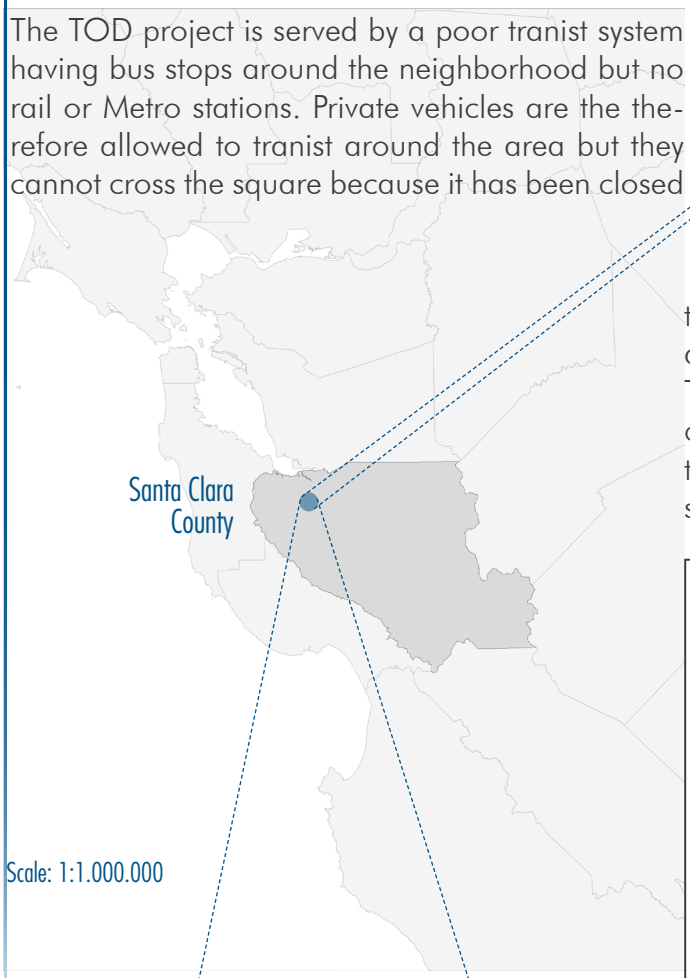
Figure 5.49 - © Pi 1415926535, 2018

Santana Row (San Jose, California)

Geographical BACKGROUND

The TOD project is served by a poor tranist system having bus stops around the neighborhood but no rail or Metro stations. Private vehicles are the therefore allowed to tranist around the area but they cannot cross the square because it has been closed to motor vehicles allowing a safe pedestrain-friendly environment, at least within the public square. The square is considered as a luxury pedestrian and commercial corridor, full of activities at ground floor that create rythm on façades with vegetation and seating areas in the middle.





> "The project replaces a 1950s-era suburban shopping mall that formerly occupied the site, exchanging an aging single-story mall with a densely designed, multi-story mixed-use community that incorporates all of its parking needs within the new structures. The heart of the project is the retail main street, highlighted by a median park and lined with ground-floor retail, restaurants and public gathering spaces"
>
> Source: SB Architects [9]

Square GENERALITIES

TOD location
T4 - General Urban

Station typology
Ground level

Orientation
N-S

H/W ratio
0,42 (16 m/37,5 m)

Tranist node
Buses

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

H/W: 0,42

11

ABSENCE

Block size: 2.544 [ft]

3

Figure 5.50 - © Ryan Ritchie

Figure 5.51 - © Sergio Ruiz

Figure 5.52

ADAPTATION measures

14

PRESENCE

0,35< H/W >0,65

9

ABSENCE

5

Figure 5.53

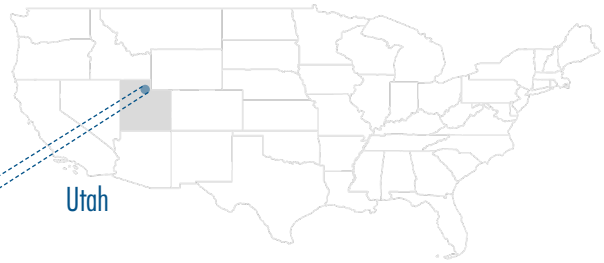
Figure 5.54

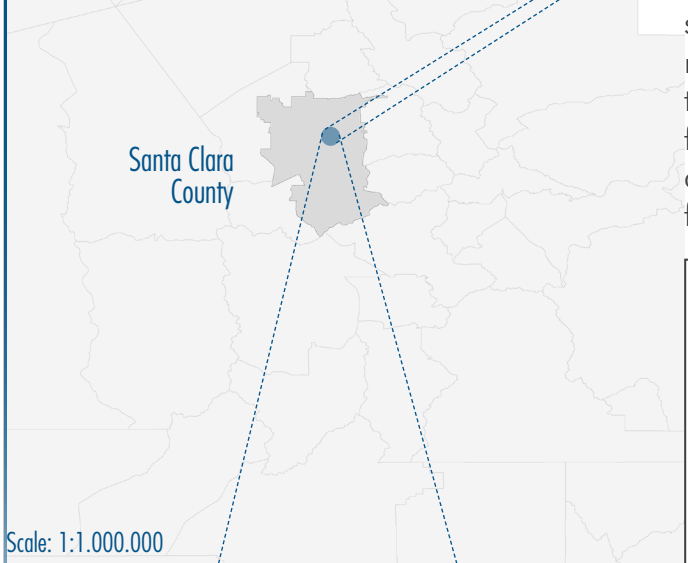
Figure 5.55

The Gateway (Salt Lake City, Utah)

Geographical BACKGROUND

The Gateway is a versatile TOD project characterized by residential units, offices, and commercial and retail activities centered in the Olympic Legacy Plaza. The latter has faced several redevelopment before and after the Olympics Games (2002) resulting today a crucial node for the community. The square is affected by a continental climate (*Dc*) characterized by very different seasons, very cold winters and hot dry summers. The large fountain is the focus of the square, surrounded by seating areas and lawns making it a pleasant and relaxing place for its users





> "The Gateway isn't a mall. It's Salt Lake City's downtown destination for shopping and dining, entertainment, community-driven events, urban living, and creative office space. With direct access to public transit, The Gateway serves up a one-of-a-kind blend of unique retail, hip nightlife, a cutting-edge arts and culture scene, an innovative technology hub, and more."
>
> Source: The Gateway [10]

Square GENERALITIES

TOD location
T5 - Urban Center

Station typology
Ground level

Orientation
N-S, W-E

H/W ratio
0,3 (24,3 m/81 m)

Tranist node
Commuter rail, Light rail (Blue and Green lines UTA TRAX)

CLIMATE HAZARDS

UHI effect & Extreme Heat

Extreme events & Flooding

Droughts

MITIGATION measures

14

PRESENCE

H/W: 0,3

11

ABSENCE

Block size: 2.653 [ft]

3

Figure 5.56

Figure 5.57

ADAPTATION measures

14

PRESENCE

H/W < 0,35

10

ABSENCE

4

Figure 5.58

Figure 5.59

Figure 5.60

From the sheets' elaboration (summarized in Table 5.2, 5.3) emerges the gap between mitigation and adaptation measures applied in the selected TOD projects. Public squares are designed for pedestrians only, thus, walkability should be always an intrinsic value of public squares. Nevertheless, as explained in Chapter 3, promoting walkability is not only a matter of providing the pedestrian space itself, rather, is the way the pedestrian space is settled and organized within the square. It is through this kind of approach that mitigation measures have been evaluated, with quite satisfactory results. The important aspect is that, in the majority of the cases where mitigation measures were lacking, they were referring to some elements of the urban furniture (e.g. garbage bin) which, in spite of their importance, they do not affect the public square walkability as whole (as sense of enclosure and mixed-use would do). In particular, the least frequent elements to enhance walkability are the civic buildings and public art installations, which have been found present only 2 and 3 times out of 10 case studies, respectively. Contrary, the presence of active edges and façades, seating areas and proper lighting systems are always present in all the 10 case studies, meaning that every public square is provided of pleasant and comfortable environments usable both during the daytime and night-time. Moreover, mixed-use buildings, restoration activities, public signage, water bodies, and recycled bins are quite constantly applied. However, all the TOD projects analyzed resulted in having an average of 10 out to 14 mitigation measures overall, none of which without falling below 7 measures.

Table 5.2 - Mitigation measures comparison according to TOD's projects

Measure present / Measure absent	Mitigation measures														Total	Average
TOD project, State	Mixed-use	Interconnectivity	Edges & façades	Sense of enclosure	Seating	Food	Public signage	Bollards	Lighting	Water bodies	Recycled bins	Weather shelters	Public art	Civic buildings		
Wilshire Vermont, CA	■		■		■	■	■	■	■			■	■		9	10
Fruitvale Village, CA	■	■	■		■	■	■		■	■	■				9	
Orenco Station, OR	■	■	■	■	■	■	■	■	■	■	■				11	
CityPlace, FL	■	■	■	■	■	■	■	■	■	■	■	■		■	13	
Market Common, VA	■		■	■	■	■			■	■	■				8	
Rockville Town Center, MD	■	■	■		■	■	■	■	■	■	■	■	■	■	13	
Pentagon Row, VA	■	■	■	■	■	■	■		■	■	■	■			11	
Richmond Village, CA		■	■		■		■		■		■	■			7	
Santana Row, CA	■		■	■	■	■	■	■	■	■	■	■			11	
The Gateway, UT	■		■	■	■	■	■		■	■	■	■	■		11	
Total	9	6	10	6	10	9	9	5	10	8	9	7	3	2	103	
Average	7															

Source: Author's elaboration

If walkability is encouraged through the square design, the lower emphasis is applied to adaptation measures. According to their climate vulnerabilities, in fact, TOD's public squares turn out to be weakly prepared and ready to adapt to CC. The results emerging from the virtual survey report that none of the adaptation strategies is ever-present in each case study, some of them have never been found in any of the case studies resulting in average 8 adaptation measures out of 14 (57%) for a single TOD project. Considering green roofs, for example, their benefits have been largely explained in Chapter 4, but none of the case studies analyzed apply them to exploit their benefits. Considering also the medium risk of drought for the overall case study analysis, also water storage could be a strategic idea to insert within the squares or plazas design, as explained in Chapter 4, but none of the TOD projects include this adaptation measure. Nevertheless, water storage could be placed in areas out of the public square and, in this case, drought-tolerant plants would be the most important action to apply in tackling drought periods. In this instance, 8 TOD's squares out of 10 have cared for drought issues by inserting drought-tolerant plants. The element that seemed to be the most important, is represented by the measures dealing with cool pavements and permeable pavements which occur in the 90% of the TOD projects.

Table 5.3 - Adaptation measures comparison according to TOD's projects

Measure present / Measure absent	Adaptation measures															
	UHI effect								Flooding				Drought			
TOD project, State	Cool roofs & façades	Green roofs & walls	Vegetation	Cool pavements	Permeable pavements	Water bodies	Optimal shading	Natural ventilation	Green roofs & walls	Permeable pavements	Water reservoir	Bioretention	Drought-tolerant plants	Water storage	Total	Average
Wilshire Vermont, CA	■			■	■		■						■		5	
Fruitvale Village, CA	■		■	■	■	■	■			■			■		8	
Orenco Station, OR	■		■	■	■	■		■		■		■	■		9	
CityPlace, FL	■		■	■	■	■		■		■			■		9	
Market Common, VA	■		■	■	■	■		■		■		■	■		9	
Rockville Town Center, MD	■		■	■	■	■	■	■		■		■	■		10	8
Pentagon Row, VA			■	■	■	■		■		■		■			8	
Richmond Village, CA								■							1	
Santana Row, CA			■	■	■	■	■	■		■		■	■		9	
The Gateway, UT	■		■	■	■	■	■	■		■		■	■		10	
Total	7	0	8	9	9	8	6	8	0	8	0	6	8	0	78	
Average	6															

Source: Author's elaboration

Through a cross-check analysis between the climate impacts and vulnerabilities (Table 5.1), and the mitigation and adaptation measures verified and summarized in Table 5.2 and 5.3, it has been possible to understand the climate behavior of each public square or plaza examined. The results for each TOD's public square are described as follows:

- Wilshire Vermont (Los Angeles, California)
  The square above the Wilshire Vermont Metro station is a recognizable place due to building façades located at the entry/exit of the square, that people have to go through to reach the underground transit platform. The edges are active and the ground floor is animated with retail, commercial and restaurant activities ready to host and entertain a great number of commuters. Being vulnerable to EH and drought periods, the square presents a narrow and enclosed environment allowing optimal shading but suffering from it in terms of sense of enclosure and natural ventilation. Although drought-tolerant plants have been planted to face drought issues, they are scarce and isolated, providing poor shading to the buildings' façades more exposed to solar radiation. Therefore, besides cool and permeable pavements, there are no measures to cool the square environment and adapt to CC.

- Fruitvale Village (Oakland, California)
  The Fruitvale Village is located in the Oakland suburbs and represents a successful example of TOD. The square analyzed, which is actually a pedestrian corridor linking the BART station with the main commercial boulevard, is located in one of the two phases that characterize the whole TOD project. The pedestrian corridor, being a street and not a square, is characterized by buildings on both sides narrowing the sense of enclosure, typical of more widen spaces. Nevertheless, its design enhances walkability through attention to the details creating a pedestrian-friendly environment. Like the previous case study, the main climate hazards concern the EH and drought, partially faced by the corridor design. In particular, shading is obtained by the narrowness of the corridor and by the drought-tolerant vegetation homogenously distributed along the pedestrian path. Although flooding risk is at the minimum level, permeable and cool pavements characterize the entire walkway.

- Orenco Station (Hillsboro, Oregon)
  Orenco Station is another successful example of the TOD project. The public square in front of the transit platform is well furnished by almost every kind of urban amenities creating a vibrant and comfortable public space, except for civic building, public art and weather shelters. The shading function is neither provided by the urban geometry, due to the unbuilt Southern side of the public square facing the station nor by vegetation, only present in small dimensions except for an isolated huge tree that shades the main restoration activities at the ground floor. The wide

located buildings at the edge with an uncovered side, allow natural ventilation and the consequent air exchange in the public square.

- CityPlace (West Palm Beach, Florida)
  After the TOD redevelopment, the Rosemary square becomes the core and meeting point of West Palm Beach downtown. The entire environment is characterized by local architecture, a large fountain in the center of the square that faces a local church making the square a place ready to accommodate people every time of the day and able to host concerts and other public events for the community. Except for public art, every element to boost walkability is present and organized in a cozy way, retail, commercial and restoration activities fill up the ground floor and also the first floor, shaped as long porticoes running all along the square perimeter. This is particularly helpful to adapt to EH, which the square location suffers from at the highest level. Another adaptation measure to cool the environment is the central fountain, having a cooling function, besides attractive. The vegetation is crucial in the square because, by being located along the building edges, it provides a cool effect both for inner building spaces and also for pedestrians using the square. Although the presence of drought-tolerant plants, the square does not offer water storage to tackle a moderate drought risk.

- Market Common (Arlington, Virginia)
  Located along the famous Rosslyn-Ballston Corridor, the Market Common is a TOD project that offers a well-organized mixed-use environment around a central long square, located around 10 minutes walking from the underground station. The public square is characterized by a vehicular street that surrounds the square on each side, lowering the pedestrian safety also because of the lack of bollards on the sidewalk's perimeter. Moreover, although few ground floor openings, the block that including the square is huge, discouraging walkability. In this case, the square can be considered as a human-scale park given the high amount of vegetation that characterizes it. The Market Common TOD project is more "climate adaptive-oriented" than "climate mitigated-oriented" thanks to its greenness that, despite is not provided by urban geometry, allows shading along the entire walkway, a fundamental resource considering the maximum level of EH identified.

- Rockville Town Center (Rockville, Maryland)
  Probably the most successful among those analyzed, the square of the Rockville Town Center is located around five minutes-walk from the Metro and commuter rail station. Except for the sense of enclosure, the square has got all the elements identified to boost walkability and, looking at images on the sheet, it seems that climate mitigation measures do not lie. In fact, the square designed as the perfect place where to go and gather, relax and hanging out with friends enhancing the

transit transports due to its close proximity. The square is next to a library that reinforces the public domain of the place and is meticulously design for pedestrians. From the adaptation side, although data are unavailable concerning the UHI effect and the EH, the square is prepared to adapt to such climate impacts guaranteeing, at the same time, a comfortable, pleasant, and shaded environment.

- Pentagon Row (Arlington, Virginia)
  In a different location but with the same climate risks of the Market Common, Pentagon Row is another project human-scaled designed with an unbuilt side (that exposed to the West). Although the pedestrian environment of the TOD project could be stunning at a first glance, analyzing it in-depth it is discovered not being such a walkable area. In fact, the absence of bollards and the excessive dimension of the block that encloses the square, make it quite uncomfortable and not fully safe. Nevertheless, a passage in the Eastern side of the square is able to link it with the underground Metro station around 10 minutes walking from the square. Moreover, although the square presents a very cozy environment characterized by a central pedestrian path and different fountains, the Pentagon Row is also prepared to accommodate the climate risks except for shading provided by urban geometry and the never-present green roof and façades. Vegetation element is present especially in the forms of lawns (placed in the middle of the square) and bioretention. Also, trees are present but scarcely and isolated.

- Richmond Village (Oakland, California)
  The only case study placed in the T3 *Transect* suburban zone is the Richmond Village, located at the North-West terminus of the BART rail system. The design of the square of the transit station is the least walkable and climate adaptive oriented of the TOD projects studied. Starting with mitigation measures, the square is characterized by a very low sense of enclosure and there are no mixed-use buildings, bollards and restoration activities, making the square a mere pedestrian place linking the car-parking and residential houses with the transit station. From the climate adaptation point of view is even worst. In particular, although the location is affected by the high risk of drought and a medium level of EH, the only adaptation measure applied is found on the natural ventilation, obtained by the low building heights and the absence of dense environments. In such climatic conditions, vegetation and drought-tolerant plants could be a strategic action to adapt to CC, but actually, the only vegetative elements are represented by low shrubs which are, obviously, not considered as a real adaptation measure. The pavement surfaces are impervious and made of dark-color materials, which enhance the UHI effect, rather than limiting it.

- Santana Row (San Jose, California)
  Although it presents weak transit connections, a further example of a successful TOD pedestrian corridor is offered by Santana Row. Previously crossed by one road on both sides, they have been closed to vehicular traffic to boost walkability. The latter is enhanced by a pedestrian-friendly environment with several and diverse commercial, retail and restorative activities at the building's ground floors. The central stripe is the real pedestrian-oriented character of the TOD project, with shaded seating areas, public games, and a fountain. Also, climate adaptation is substantially obtained, especially providing a good portion of the public space shaded by buildings and trees, surely precious for pedestrians in such climate conditions.

- The Gateway (Salt Lake City, Utah)
  The TOD project has faced several redevelopments before and after the Olympics Games (2002) resulting in today a crucial node for the community. Developed on different height levels, the circular public rounded square presents a unique environment in Salt Lake City downtown, connected with light and commuter rail transit stations. The main attraction of the square is the ground-based fountain that entertains the community. The negative side of the TOD's square is represented by the absence of bollards that, considering the vehicular road cutting the square, do not allow a fully safe public space. Considering the local climate risks, the square behaves regularly in every instance, except regarding drought issues in terms of water storage.

Conclusions

The production of the sheets through the virtual survey using the Google Maps Street view tool and Google Earth software has been of paramount importance, besides the only evaluation method available. Thanks to these tools and software have been possible to recognize the presence and absence of mitigation and adaptation measures both at the ground floor, especially through the Google Maps Street view tool, and also from an aerial perspective, especially through the Google Earth software. In this way, physical elements such as benches, vegetation, retail and commercial activities, fountains, pavements typology and many other measures have been easy to investigate in terms of visual presence or absence. Therefore, assembling all the information collected through the case studies analysis and summarized in Table 5.2 and 5.3 the following conclusions can be drawn:

1. Mitigation measures (103 out of 140, or 74%) are more frequently applied than adaptation measures (78 out of 140, or 55%) overall;
2. Mitigation measures identified are 14 overalls, and there have been found with an average of 10 (or 71%) for each case study analyzed;

3. Adaptation measures identified are 14 overalls, and there have been found with an average of 7 (or 50%) for each case study analyzed;
4. The public squares with the highest number of mitigation measures (13 out of 14, or 93%) are the ones concerning the CityPlace, (West Palm Beach, FL) and the Rockville Town Center (Rockville, MA) TOD projects;
5. The public squares with the highest number of adaptation measures (10 out of 14, or 71%) are the ones concerning the Rockville Town Center (Rockville, MA) and the Gateway (Salt Lake City, UT) TOD projects;
6. Table 5.4 shows the coherence between the climate impact of a certain public square, and the real actions applied to tackle that impact. The most respected climate impact is the UHI & EH with 55 out of 80 adaptation measures (or 69%), followed by the 9 out of 20 drought adaptation measures (or 45%), and the least 14 out of 40 flooding adaptation measures (35%). Nevertheless, the flooding risk is at the minimum level in each case study therefore, although little applied, the adaptation measures to flooding can face climate risk. Contrary, the drought measures, although they are quite often applied, can result not sufficient for the climate risk, especially in all the Californian cases circled in blue (Wilshire Vermont, Fruitvale Village, Richmond Village, Santana Row).

Table 5.4 – Climate exposure coherence of each case study

	UHI & Extreme Heat				Flooding				Drought			
TOD project	Climate Impact	N° of measures present	N° of measures available	%	Climate Impact	N° of measures present	N° of measures available	%	Climate Impact	N° of measures present	N° of measures available	%
Wilshire Vermont (CA)	2	4	8	50%	1	0	4	0%	3	1	2	50%
Fruitvale Village (CA)	2	6	8	75%	1	1	4	25%	3	1	2	50%
Orenco Station (OR)	2	6	8	75%	1	2	4	50%	1	1	2	50%
CityPlace (FL)	3	7	8	88%	1	1	4	25%	2	1	2	50%
Market Common (VA)	3	6	8	75%	1	2	4	50%	1	1	2	50%
Rockville Town Center (MD)	NDA	7	8	88%	1	2	4	50%	1	1	2	50%
Pentagon Row (VA)	3	5	8	63%	1	2	4	50%	1	1	2	50%
Richmond Village (CA)	2	1	8	13%	1	0	4	0%	3	0	2	0%
Santana Row (CA)	1	6	8	75%	NDA	2	4	50%	3	1	2	50%
The Gateway (UT)	2	7	8	88%	1	2	4	50%	2	1	2	50%
Total	2	55	80	69%	1	14	40	35%	2	9	20	45%

Source: Author's elaboration

However, the qualitative evaluation of the measures identified are not such detailed, in fact, the analysis also presents some limits. First, the impact severities have been calculated

according to the scale of analysis larger than the one of the singe TOD projects. Regarding the UHI and EH, and the drought risk, they have been considered analyzing maps produced by the NRDC (s.d.) and Bolinger (2019) respectively, at the county scale resulting in quite reliable but not fully precise information. The only type of impact easy to calculate is concerning the flooding risk, the only one that, according to FEMA Flood Map Service Center (2019) always results at the minimum level for all the TOD's public squares. A second limit of the research regards the quality of the information collected to define the mitigation and adaptation measures. Through the Google Maps Street view tool and the Google Earth software, in fact, only a partial evaluation was possible. The vegetation typology planted, the roofs materials, the pavements features, and the H/W ratios and other square dimensions have been assessed as precise and in-depth as possible resulting inevitably in an approximate outcome. Further and more accurate variables, for example, the type and quality of the water and the irrigation systems were impossible to recognize through the type of survey that has been carried out, making the result's analysis not entirely reliable, but still credible.

Therefore, the whole analysis has to be considered not as a hundred percent precise and completely demonstrated, like a field survey would provide but, rather, as an attempt at assessment if and how the TOD's public squares are oriented to climate mitigation and adaptation, at least at a first glance. As previously said, the research should be integrated with further and more accurate information, but the assessment obtained by the thesis can be considered as a starting point for further researches.

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GIS data sources:

California

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- Fruitvale Village, Oakland: Berkely Library Geodata (https://geodata.lib.berkeley.edu/catalog/stanford-mq273bz6123)
- Richmond Village, Oakland: Berkely Library Geodata (https://geodata.lib.berkeley.edu/catalog/stanford-mq273bz6123)
- Santana Row, San Jose: Berkely Library Geodata (https://geodata.lib.berkeley.edu/catalog/stanford-mq273bz6123)

Oregon

- Orenco Station, Hillsbro: Oregon Geospatial Enterprise Office (https://www.oregon.gov/geo/Pages/census.aspx)

Florida

- Rosemary Square, West Palm Beach: Official State of Florida Geographic Data Portal (http://geodata.myflorida.com/datasets/swfwmd::florida-counties?geometry=-91.866%2C24.375%2C-75.387%2C31.173)

Virginia

- Market Common, Arlington: Virginia National International Network (https://www.arcgis.com/home/item.html?id=777890ecdb634d18a02eec604db522c6)
- Pentagon Row, Arlington (https://www.arcgis.com/home/item.html?id=777890ecdb634d18a02eec604db522c6)

Maryland

- Rockville Town Center, Rockville: Maryland Physical Boundaries - County Boundaries (Generalized) (https://data.imap.maryland.gov/datasets/4c172f80b626490ea2cff7b699febedb_1)

Utah

- Olympic Legacy Plaza, Salt Lake City: US Census Bureau, Department of Commerce (https://catalog.data.gov/dataset/tiger-line-shapefile-2016-state-utah-current-county-subdivision-state-based)

Notes

[1]: (AHBE, s.d.)
[2]: (The Unity Council, s.d.)
[3]: (Congress for the New Urbanism, s.d.)
[4]: (Steuteville, 2005)
[5]: (Jacobs/Ryan Associates, s.d.)
[6]: (Buntin, 2011)
[7]: (Pentagon Row, s.d.)
[8]: (HDR Calthorpe, s.d.)
[9]: (SB Architects, s.d.)
[10]: (The Gateway, s.d.)

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Conclusions

The thesis objective was to assess the climate behavior of ten TOD's public squares and plazas through the analysis of ten case studies in different US states characterized by different climate conditions. After a preliminary study on New Urbanism theories and the TOD planning pattern emerged that, being oriented towards increasing density and transit ridership mainly in suburban areas, the TOD aims to reduce GHG emissions by limiting the private transit and automobile usage. To reach this objective, TODs enhance the alternative way of transports focusing on rail transit systems surrounded by bicycle and walkable environments. Being the thesis research based on the public spaces, walkability has been regarded to create a sense of belonging for the local community, especially in the public squares. Therefore, walkability has been considered as a mitigation action and, given the TOD objectives, the probabilities to achieve it are positively confident. The real challenge of the thesis, in fact, was to verify the climatic side of TOD's public squares from the adaptation point of view, which is not deliberatively expressed as a TOD goal. Nevertheless, the first tricky challenge of the thesis was concerning the case studies selection. Due to the rare cases of TOD projects in suburban areas located in different climatic regions including a proper public square, the research has been enlarged to the projects in T4 and T5 zones of *Urban to Rural Transect*. Nevertheless, with the aid of the TOD Institute list, ten TOD projects have been selected trying to obtain TOD case studies in diverse climate conditions. The emerging results from the analysis on the public squares of the ten projects have largely demonstrated that they are only partially designed to face CC. Although the importance of a successful TOD is crucial for tackling CC, their parameters have been taken for granted since their presence in the TOD Institute list. Rather, the central node of the case studies – the public squares - represents a sustainable pattern for the community that uses it, and therefore they have been the study object. To address public squares in this direction, the Urban Design process defines principles and approaches to apply at different scales. Even though sustainable Urban Design principles are the linchpins around which New Urbanists and TOD theories pivot on, their full and concrete application towards tackling CC has not always been found. In particular, whilst some measures, both mitigation and adaptation, were surely not applied, some others were impossible to define due to the virtual survey restrictions. Nevertheless, the measure that was possible to find has been considered in relation to their climate hazards and risks. Each of the TOD's public square examined, in fact, has been evaluated through a cross-cutting check between the mitigation and adaptation measures found, and the climatic risks the public square is affected by. In this way was possible to understand if each public square in the selected ten TOD projects is properly designed to face their specific climate threats.
Regarding mitigation actions, the results have proven to live up to expectations. In particular, from the evaluation of the case study has been possible to notice the effort put on the public square design to privilege the pedestrian environment at the expense of the vehicular one. Other than the Richmond case study, in fact, it is perceived that every public

square has been designed for pedestrians with an eye for details. Although the mitigation measures appeared in different forms and distribution among the case studies, each TOD's public square offers areas for waiting and relaxing, shaded by vegetation and filled up with spaces and activities aiming to involve the community. Even though some elements of urban furniture were sometimes lacking, the overall environments created in TOD's public squares can be considered walkable-oriented. Considering that not all the adaptation measures were clearly visible and or not visible at all (e.g. water storage), different outcomes arise from the climate adaptation evaluation. From the available tools and software emerges that the need to adapt to the UHI effect and EH days is regarded as a priority among all the case studies analyzed, and measures to adapt to such climate impacts are homogeneously spread in TOD's public squares. Of lesser interest, appear to be the drought and flooding risks, due to their unexpected and uncommon character with which they occur. This lack has different implications. Although actions to tackle flooding events are the least frequent among the adaptation measures identified, the risk of flooding in the TOD's public squares is at the minimum, making the flooding measures not strictly necessary. Contrary, the drought measures have been found present in a ½ ratio but, considering the fairly high drought risk (especially in Californian case studies), the drought measures visible through the virtual survey are not sufficiently applied. Surprisingly, none of the case studies presented green roofs and façades, which could be of paramount importance especially in those areas affected by strong UHI effect and EH. The investigation on adaptation measures unveils that, although the climate impacts and risks have been sufficiently respected by the design of the TOD's public squares, the adaptation measures seem to be applied merely by chance, rather than being the result of a proper and accurate climate assessment.

From the case studies analysis emerge that the square design of TOD's projects seems to be more oriented toward achieving the walkability goal and the reduction of the causes of climate change, rather than adapting to such changes. This comes to the conclusion that whilst pedestrian areas are present, linked with the surroundings by walkable pathways and they are furnished to allow pedestrian-friendly environments, the actions to adapt to CC are in some cases weak, seeming to be less important and needed. The thesis states that TOD ideals and principles consider mitigation measures as the primary mission to achieve and consider adaptation measures as a secondary goal. This is confirmed by the fact that, as expressed in the final page of Chapter 1, the difference between mitigation and adaptation measures is a matter of scale, besides objectives. Having a mere regional character, the TOD pattern points to satisfy first its mitigation goals, without worrying about more local issues, leaving adaptations to CC a crucial but partially developed aspect in TOD' squares.

The literature on CC, TOD and Urban Design is wide. Today CC is a trendy topic to investigate in, TOD pattern and New Urbanism spread development processes and ideas that deal with today's issues and Urban Design is a largely well-documented process constantly evolving with current challenges. But, according to the public square, they result

fragmented. The current thesis, therefore, helps to embrace the three macro-topics argued toward the public square. In this sense, the thesis provides an interesting starting point to reflect and analyze in-depth the adaptation issue in TOD's public squares from the thermal comfort point of view involving the perception of local inhabitants too. This would verify the real impact at the local scale of the few and feeble adaptation measures identified and discussed through the Google Street view tools available.

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Annex – The Charter of New Urbanism

The preamble of the Charter states that:

> "The Congress for the New Urbanism views disinvestment in central cities, the spread of placeless sprawl, increasing separation by race and income, environmental deterioration, loss of agricultural lands and wilderness, and the erosion of society's built heritage as one interrelated community-building challenge.
> We stand for the restoration of existing urban centers and towns within coherent metropolitan regions, the reconfiguration of sprawling suburbs into communities of real neighborhoods and diverse districts, the conservation of natural environments, and the preservation of our built legacy.
> We advocate the restructuring of public policy and development practices to support the following principles: neighborhoods should be diverse in use and population; communities should be designed for the pedestrian and transit as well as the car; cities and towns should be shaped by physically defined and universally accessible public spaces and community institutions; urban places should be framed by architecture and landscape design that celebrate local history, climate, ecology, and building practice.
> We recognize that physical solutions by themselves will not solve social and economic problems, but neither can economic vitality, community stability, and environmental health be sustained without a coherent and supportive physical framework.
> We represent a broad-based citizenry, composed of public and private sector leaders, community activists, and multidisciplinary professionals.
> We are committed to reestablishing the relationship between the art of building and the making of community, through citizen-based participatory planning and design.
> We dedicate ourselves to reclaiming our homes, blocks, streets, parks, neighborhoods, districts, towns, cities, regions, and environment" (Congress for the New Urbanism, s.d.)

The twenty-seven principles are organized according to their spatial scale as follows:
The Region: Metropolis, city, and town:

> "1) Metropolitan regions are finite places with geographic boundaries derived from topography, watersheds, coastlines, farmlands, regional parks, and river basins. The metropolis is made of multiple centers that are cities, towns, and villages, each with its own identifiable center and edges.
> 2) The metropolitan region is a fundamental economic unit of the contemporary world.
> Governmental cooperation, public policy, physical planning, and economic strategies must reflect this new reality.
> 3) The metropolis has a necessary and fragile relationship to its agrarian hinterland and natural landscapes. The relationship is environmental, economic, and cultural. Farmland and nature are as important to the metropolis as the garden is to the house.
> 4) Development patterns should not blur or eradicate the edges of the metropolis. Infill development within existing urban areas conserves environmental resources, economic investment, and social fabric, while reclaiming marginal and abandoned areas. Metropolitan regions should develop strategies to encourage such infill development over peripheral expansion.
> 5) Where appropriate, new development contiguous to urban boundaries should be organized as neighborhoods and districts, and be integrated with the existing urban pattern. Noncontiguous development should be organized as towns and villages with their own urban edges, and planned for a jobs/housing balance, not as bedroom suburbs.
> 6) The development and redevelopment of towns and cities should respect historical patterns, precedents, and boundaries.
> 7) Cities and towns should bring into proximity a broad spectrum of public and private uses to support a regional economy that benefits people of all incomes. Affordable housing should be distributed throughout the region to match job opportunities and to avoid concentrations of poverty.
> 8) The physical organization of the region should be supported by a framework of transportation alternatives. Transit, pedestrian, and bicycle systems should maximize access and mobility throughout the region while reducing dependence upon the automobile.
> 9) Revenues and resources can be shared more cooperatively among the municipalities and centers within regions to avoid destructive competition for tax base and to promote rational coordination of transportation, recreation, public services, housing, and community institutions" (Congress for the New Urbanism, s.d.)

The neighborhood, the district, and the corridor:

"10) The neighborhood, the district, and the corridor are the essential elements of development and redevelopment in the metropolis. They form identifiable areas that encourage citizens to take responsibility for their maintenance and evolution.
11) Neighborhoods should be compact, pedestrian friendly, and mixed-use. Districts generally emphasize a special single use, and should follow the principles of neighborhood design when possible. Corridors are regional connectors of neighborhoods and districts; they range from boulevards and rail lines to rivers and parkways.
12) Many activities of daily living should occur within walking distance, allowing independence to those who do not drive, especially the elderly and the young. Interconnected networks of streets should be designed to encourage walking, reduce the number and length of automobile trips, and conserve energy.
13) Within neighborhoods, a broad range of housing types and price levels can bring people of diverse ages, races, and incomes into daily interaction, strengthening the personal and civic bonds essential to an authentic community.
14) Transit corridors, when properly planned and coordinated, can help organize metropolitan structure and revitalize urban centers. In contrast, highway corridors should not displace investment from existing centers.
15) Appropriate building densities and land uses should be within walking distance of transit stops, permitting public transit to become a viable alternative to the automobile.
16) Concentrations of civic, institutional, and commercial activity should be embedded in neighborhoods and districts, not isolated in remote, single-use complexes. Schools should be sized and located to enable children to walk or bicycle to them.
17) The economic health and harmonious evolution of neighborhoods, districts, and corridors can be improved through graphic urban design codes that serve as predictable guides for change.
18) A range of parks, from tot-lots and village greens to ballfields and community gardens, should be distributed within neighborhoods. Conservation areas and open lands should be used to define and connect different neighborhoods and districts" (Congress for the New Urbanism, s.d.)
The block, the street, and the building:

"19) A primary task of all urban architecture and landscape design is the physical definition of streets and public spaces as places of shared use.
20) Individual architectural projects should be seamlessly linked to their surroundings. This issue transcends style.
21) The revitalization of urban places depends on safety and security. The design of streets and buildings should reinforce safe environments, but not at the expense of accessibility and openness.
22) In the contemporary metropolis, development must adequately accommodate automobiles. It should do so in ways that respect the pedestrian and the form of public space.
23) Streets and squares should be safe, comfortable, and interesting to the pedestrian. Properly configured, they encourage walking and enable neighbors to know each other and protect their communities.
24) Architecture and landscape design should grow from local climate, topography, history, and building practice.
25) Civic buildings and public gathering places require important sites to reinforce community identity and the culture of democracy. They deserve distinctive form, because their role is different from that of other buildings and places that constitute the fabric of the city.
26) All buildings should provide their inhabitants with a clear sense of location, weather and time. Natural methods of heating and cooling can be more resource-efficient than mechanical systems.
27) Preservation and renewal of historic buildings, districts, and landscapes affirm the continuity and evolution of urban society" (Congress for the New Urbanism, s.d.)

References

Congress for the New Urbanism, s.d. *The Charter of the New Urbanism.* [Online] Available at: https://www.cnu.org/who-we-are/charter-new-urbanism [Consultato il giorno November 26 2019].