Balancing sustainability and livability in dense urban environments through strategies for the mitigation of the UHI effect

Francisco Marín Nieto
4516281
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This document is the valuable result of a very intense academic year. Where in September of 2016 there were only intuitions, today there is a story. This is a story that I know very well and that, hopefully, is worth being told.

My mentors, Birgit Hausleitner and Alexander Wandl helped me to build this story in my mind and to put it on paper. I would like to thank them for their time and dedication, as well as for their constructive counselling. Sometimes it was a technical solution, sometimes the glue that put everything together.

My parents and my brother gave me their invaluable and unwavering support, and went on site visits when I could not do it myself. I am happy that this story is also theirs.

My Urbanism friends made all this exciting and vivid. This thesis is fuelled by our 3pm coffee breaks, I have no doubts about that.

My Málaga, city of paradise. You are always an inspiration.

Siempre te ven mis ojos, ciudad de mis días marinos. Colgada del imponente monte, apenas detenida en tu vertical caída a las ondas azules, pareces reinar bajo el cielo, sobre las aguas, intermedia en los aires, como si una mano dichosa te hubiera retenido, un momento de gloria, antes de hundirte para siempre en las olas amantes.

Vicente Aleixandre
Sustainability and livability are two important dimensions of urban environments, that are however found to be in a constant imbalance. The achievement of a sustainable and livable city is hindered by the constraints of urban form, and density, in particular, has a crucial role in defining the performance of urban environments in terms of livability and sustainability. Research shows that higher levels of density tend to result in more sustainable and less livable environments, and vice versa. In contemporary research, the understanding of the reasons behind this issue represents an urgency. There is, however, an apparent gap in knowledge in the field.

The manifestation of this imbalance can take multiple forms. Being it an eminently abstract issue, its reduction to a manageable and well-studied problem facilitates research and the exploration of possible solutions. In this respect, the Urban Heat Island effect is a phenomenon that represents the essence of the issue and that is closely linked to spatial factors. The manifestation of the UHI effect in Málaga (Spain) constitutes a concrete problem, especially in the context of temperature rises and an aging population.

The heterogeneity of Málaga’s fabric, where different levels of density are present, can both explain the uneven manifestation of temperature in the city and define limitations and potentials regarding the exploration of solutions. From an analytical point of view, this work seeks to define a criteria for the characterization of different density environments and a way to understand how temperature relates to its form through different scales. From a design-oriented perspective, the goal is to define a systemic approach to the issue and explore the ways in which urban form shapes the spatial manifestation of the solutions.

Ultimately, the introduction of physical measures would not only help to mitigate the UHI effect, but constitute a step towards the necessary balance between sustainability and livability.
# TABLE OF CONTENTS

1 Glossary of terms 2

2 Motivation 4

3 Problem field and analysis 7
   3.1 Context 7
   3.2 An introduction to density, sustainability and livability 14

4 Problem statement 20

5 Scientific relevance 21

6 Societal relevance 22

7 Aim 24

8 Research question, methodology and outcomes 26

9 Theoretical framework 29
   9.1 Sustainability and livability 30
   9.2 “The Net” and “the Self” 36
   9.3 Temperature and the UHI effect 40
   9.4 Density 47

10 Analytical framework 48

11 Analysis - Metropolitan scale 52
   11.1 Temperature 52
   11.2 Density 64
   11.3 Site selection 69

12 Analysis - Meso/micro scale 70
   12.1 Introduction to the sites 70
   12.2 Comparative characterization 81
   12.3 Quantification of surfaces 89
   12.4 Perceptual/subjective analysis 98
   12.5 Identification of potentials 100
   11.6 Conclusions 110

13 Design framework 116

14 Design intervention 123
   14.1 Design of a metropolitan system 123
   14.2 System development in the small scale 132
      ◆ 1 A summer square 134
      ◆ 2 A new corralón 142
      ◆ 3 A sequence of spaces 150
      ◆ 4 A park on the roof 160
      ◆ 5 An open front yard 168
      ◆ 6 A forest in between 176
      ◆ 7 A new city in the making 180
   14.3 Design conclusions 184

15 Transferability 187

16 Reflection 198

17 Conclusion 207

18 References 208
GLOSSARY OF TERMS

SUSTAINABILITY

Sustainability is an intangible aspect of urban form. It refers to the property of systems to meet their own needs without compromising the ability of future generations to meet their own, or the persistence of all components of the biosphere (WCDE, 1987; Brown et al., 1987). It is, therefore, a statement on the relationship between humanity and the environment. (van Dorst, 2013).

LIVABILITY

Livability is also an intangible aspect of urban form. As opposed to sustainability, however, it is "a statement about the relationship between a subject (...) and the environment" (van Dorst, 2013, p. 225). Therefore, it is a term that focuses on the individual as topic of research, and in the way we, as individual entities, perceive the quality of our life in relation to a specific environment. By nature, livability is a subjective concept.

"THE NET"

Taken from Manuel Castells’ theory on the Network Society (1996), it is a concept that symbolizes the de-centred, interconnected network of elements of different nature. In the case of cities, it responds to the links of each city with other cities and regions, acknowledging the effects of their actions upon the rest.

"THE SELF"

As opposed to the previous, “the Self” refers to the individual assertion of identity and, in the case of cities, represents their tendency to meet the needs of their own inhabitants.

DENSITY

Density is a tangible aspect of urban form. In Urbanism, it describes “the relationship between a given area and the number of certain entities in that area” (Berghauser Pont and Haupt, 2010, p. 11). Usually, density comes in the form of number of inhabitants or dwellings per surface unit. Within density, this Master Thesis will elaborate a more detailed definition of the term:

- on the one hand, through the differentiation between social and spatial densities,
- on the other, with the use of specific parameters, like Ground Space Index or Floor Space Index, that allow for a more meaningful understanding of the consequences of physical density.

GSI

The Ground Space Index (GSI) is the ratio between the buildings’ footprint and the block area (Berghauser Pont and Haupt, 2010). It represents the coverage, or relationship between built and unbuilt at ground level. By definition, it ranges from 0 to 1.

FSI

The Floor Space Index (FSI) is the ratio between the built-up area, considering all floors, and the block area (Berghauser Pont and Haupt, 2010). It represents the built intensity of an area.

TYPOLOGY

Classification capable of distinguishing between urban environments, in which each type can share similar partial components (Hempel & Oppenheim, 1936, as cited in Hausleitner and Berghauser Pont, 2017). The definition of types can be done using a non-parametric statistical clustering method.
THE URBAN HEAT ISLAND EFFECT

The UHI effect describes the fact that cities’ temperatures tend to be higher than in their surrounding rural areas. This becomes especially significant during the night, when all the heat that has been stored during the day in the different materials that built the city is released, resulting in an impediment for the natural cooling process of the air (Oke, 1982).

LST

Land Surface Temperature (LST) is the temperature of the city’s surfaces at a specific time. A LST map can be generated from satellite images, and provides a good approximation to the changes in temperature among different areas.

ALBEDO

Represents the extent to which materials reflect solar radiation. A high albedo generally reduces the UHI effect (van der Hoeven and Wandl, 2013).

SKY-VIEW FACTOR

Represents the extent to which surfaces are exposed to the sky. A low skyview factor increases the UHI effect (van der Hoeven and Wandl, 2013).

SURFACE HARDENING INDEX

Represents the degree of permeability of surfaces. Hard surfaces are the main cause of UHI effect. By sealing the soil, preventing evaporation and the growth of vegetation, they store solar radiation as latent energy (van der Hoeven and Wandl, 2013).

NDVI

The Normalized Difference Vegetation Index (NDVI) reflects the quantity and quality of vegetation in a given area, and can be measured using remote sensing.

PCI

The Park Cool Island effect (PCI) describes the cooling effect of urban forests or parks, which transcends their boundaries (Kleerekoper, 2016).

HELOPHYTE FILTER

A Vertical Flow Helophyte Filter is a vegetated extension that can be used in order to eliminate most of the bacteria and pollutants from domestic greywater and runoff water. These filters use specific species of plants (such as marsh plants) with an extensive root system.
This research project finds its roots in years of observations of a particular urban environment, first in the complete absence of any critical eye, later accompanied by a certain intellectual unrest and an ever-growing questioning attitude. These have during, especially during the last months -maybe years- of academic training, appreciations that would want to transcend the obvious aesthetic differences between urban contexts and search for a meaning in other less-obvious factors. This Master Thesis supposes an outstanding opportunity to address this personal challenge within a reasonably long period of time, while at the same time enjoying the invaluable support of a consolidated research group and the resources that a strong institution like TU Delft can provide.

Urban Morphology is the study of urban environments through their physical form, from which it reads back to the processes that shaped urban settlements in a particular way, tries to understand their current functioning and trends and also project their future. It is, therefore, not just object-centred, but rather a discipline that tries to link different components or aspects of the city among them, based on its form. This is a very valid approach to the specific case of Málaga, where morphology constitutes both the evidence of an unstructured -at times unplanned- urban growth and often a constraint, sometimes a booster, for present and future performances. Simply this triple reading of the city -what it was, what it is and what it can be- is already a stimulating exercise, almost itself a challenge, that justifies the insertion of this Master Thesis within this particular research group.

\[\text{Fig. 1. Parque Laguna de La Barrera, Málaga. Source: author.}\]
Fig. 2. Málaga’s metropolitan area, comprising eight municipalities: Alhaurín el Grande, Benalmádena, Cártama, Fuengirola, Málaga, Mijas, Rincón de la Victoria and Torremolinos. Source: “Áreas Urbanas +50. Información estadística de las Grandes Áreas Urbanas españolas”, Ministerio de Fomento, 2012.
Málaga is a Spanish city situated on the Mediterranean coast, in the south of the country. With its 571,069 inhabitants in 2016 (source: Spanish Statistical Office), it is the sixth largest city in Spain. Its metropolitan area, according to the Ministry of Development, stretches along the Costa del Sol -Coast of the Sun- and the Guadalhorce Valley and comprises eight municipalities (Fig. 2), which added up to 974,003 inhabitants in 2013.

Its current urban form needs to be understood as the result of two different processes, which occurred mainly during the twentieth century: on the one hand, the dynamics of population growth and migratory movements; on the other, the historic succession of urban plans, which shaped the city development. Both facts are interrelated.

In terms of population, the city observed an insignificant growth during the first third of the past century, numbers that reflect a complicated socio-political situation both in the city and the country. After the Civil War -1936-39- and until the fifties, this trend changed slightly, and population grew moderately. Everything changed, however, from the sixties. The “developmentism” that characterized the last decades of Franco’s dictatorship and the “boom” of tourism boosted urban development along the Spanish Mediterranean coast. This was the case for Málaga’s surrounding coastal towns, whose expansion can be clearly linked to tourism. However, in the case of the city itself its rapid development, especially in the seventies, responded to the rural-to-urban migration process that was common to a great number of big Spanish cities. In twenty years, from 1960 to 1980, the city grew from approximately 300,000 to around 500,000 inhabitants.

Since the middle of the eighties, however, and parallel to the general demographic tendency of the country, the growth of the city slowed down. During some years the population has remained stable, ranging between the 560,000 and 570,000 inhabitants (Fig. 3), and today Málaga is facing another stage in which some extra growth is expected to happen, mostly due to migration (sources: Báez Muñoz and Jiménez Melgar, 2014; “Proyecciones de población, 2016-2031”. Instituto Nacional de Estadística (INE)).
Fig. 4. Map of Málaga. Source: author.

Scale 1:100,000

[Right]

Fig. 5. One of many vacant plots in La Trinidad. Source: author.
The evolution and history of the urban development plans of Málaga did also shape the city (Fig.6):

The urban plans of 1929, by Daniel Rubio, and 1950, by José Joaquín González Edo, were the two mayor plans during the 20th century willing to shape the city’s expansion to a great extent, defining land use from the river Guadalmedina to the river Guadalhorce (Moreno Peralta, 1983; Seguí, 1988; Villaverde, 2008). Both ambitious in terms of extension but conservative in terms of city form, these plans proposed a compact development of the city and the definition of a rigid street pattern. Many areas of current Málaga’s fabric can be linked to these plans, and thus show high rates of ground coverage.

With the advent of the sixties and the Spanish “developmentism”, however, González Edo’s plan started soon to be seen by the private sector as too conservative and contrary to their interests. After complaint to the Supreme Court, this plan was invalidated due to formal defect in 1964. This led to a legal vacuum in which even some building ordinances from 1902 had to be applied as an alternative. As a consequence, the biggest expansion that the city has ever seen occurred in the absence of any comprehensive regulatory framework (Moreno Peralta, 1983).

Some of the housing developments of these years, which were mainly built in peripheral areas of the city, can be seen as embracing the CIAM ideals in terms of provision of open spaces, typology of buildings and neglect of the street as the defining element of the urban fabric. The adoption of this urban model concurred, however, with the previously described migration process of the sixties and seventies. It became a governmental affair to promote policies that encouraged construction and the acquisition of property; on the other hand, too often the interests of developers and constructors prevailed over the general good, altogether resulting in areas that obviate any kind of standards regarding building quality or even the provision of basic facilities to the residential tissue. This actually constitutes a distortion of the modern ideas of urbanism, which called for higher but dispersed building as a way of liberating space while maintaining social density. It is not coincidence, therefore, that while the density map shows medium values in the inner core of the city, islands of very high density appear in the areas developed during the last half of the past century (see Fig. 6).

The plan of 1971, by Ricardo Álvarez de Toledo y Gross and Eduardo Caballero Monróis, was vague and still in line with the private interests (Moreno Peralta, 1983). Only after the re-establishment of democracy and the transference of urban competences to the regional governments could a solid regulatory framework be again developed: the plan of 1983, by Damián Quero, Salvador Moreno Peralta and José Seguí, which had to focus on solving some of the urgencies inherited from two decades of unbridled urban growth: the absence of infrastructures, the dearth of basic facilities, like schools or parks or even the lack of paving on the streets (PGOU 1983). Other urban plans followed -1997, 2011- but always on the basis of the plan of 1983, which symbolizes the transition between a chaotic and a normative status, the recovery of a prescriptive approach to urban planning. As previously shown, the Málaga of the early eighties was denser than twenty years before, and this density had to be described and limited. A natural consequence was the adoption of more restrictive values for new developments in terms of density, but also a transition to new typologies, which were seen as a more optimal response to the current standards of society.
Fig. 6. Chronology of urban expansion in relation to urban plans. Prepared by the author based on information extracted from “El proceso de urbanización de la ciudad, compactar la dispersión urbana”, (Marín Cots, 2014) and “Un siglo de planificación urbana en Málaga”, (Burgos Madroñero, 1978).
Fig. 7. Map of population density in 2013. Generated by the author using GIS software, based on the information provided by the Municipality of Málaga on its Open data portal.

Scale 1:100,000

Population density [inhabitants/hectare]
- 450 - 967
- 250 - 450
- 150 - 250
- 90 - 150
- 40 - 90
- 0 - 40

0 1 2 5 km
CONSEQUENCES ON DENSITY

The result of the historical development of Málaga is, today, a city constructed as an aggregation of neighbourhoods of different density. This is visible in Fig. 7, which shows the population density across the city. The highest value, 967.9 inhabitants per hectare, corresponds to Nuevo San Andrés 1 (Fig. 8). A comparison with the densest neighbourhood in Delft, which is Voorhof (Fig. 9), with 240.9 inhabitants per hectare, gives an idea of the magnitude of the values of density in Málaga.

It becomes evident that the evaluation of the impact of density in Málaga represents a concrete concern. This evaluation, however, requires also an abstract perspective. Density is a tangible parameter of urban form, and there is already significant literature on how density relates to other intangible aspects of urban environments. Among those aspects there are two, sustainability and livability, that are particularly interesting, due to their relevance in their urban discourse and to their dependence on density.

What is initially a location-based problem (the unknown effects of different densities in Málaga) offers the possibility of applying both an abstract and a concrete perspective. The two are required and complementary.

Consequently, in the following pages the problem analysis will offer an initial evaluation of the effects of density on sustainability and livability. This evaluation will be both at an abstract (how are density and livability/sustainability linked according to literature?) and concrete level (is this link manifesting in Málaga?).

Fig. 8. Nuevo San Andrés 1. Source: Google Earth

Fig. 9. Voorhof. Source: Google Earth
The implications of different levels of density in relation with sustainability has been widely discussed in urban theory, and the existing literature on the matter shows an apparent consensus on the direct correlation between these two parameters (Elkin et al., 1991; Newman, 1994). This means that it is generally accepted that higher levels of density bring higher levels of sustainability, particularly when talking about its environmental dimension. Among the various reasons for this connection, authors commonly refer to:

- The reduction of the distance among city uses, which leads to shorter automobile trips and promotes walking or the use of non-polluting means of transport (Holden and Norland, 2005, as cited in Boyko and Cooper, 2011),
- A higher profitability of public transport systems, which facilitates their implementation (Churchman, 1999),
- A drastic reduction in the consumption of land as a resource, which helps to prevent the destruction of natural ecosystems (Alexander and Tomalty, 2002; Haughey, 2005; both as cited in Boyko and Cooper, 2011).

Some of these premises, however, are challenged by a more reduced number of authors, who claim that there is not actual empirical evidence of denser cities representing a more sustainable model (Neuman, 2005).

Also within the social and economic dimensions of sustainability, the positive effects of high densities have been long described: for instance, together with the application of mixed uses, high densities have been linked to diversity, social cohesion, higher levels of participation and a stronger sense of community (Jacobs, 1961), as well as more equity and accessibility (Williams, 2004), which count as aspects of social sustainability. Also, from the point of view of economic sustainability, the provision of services and infrastructure becomes more cost-effective, and local services and businesses are more easily supported (Williams, 1994).

This relative consensus has resulted, over the last years, in the promotion of high relative densities in the urban practice, not only regarding new developments, but also in the form of re-densification projects (Jabareen, 2006). The urgency of the environmental problems that characterizes our time has increased the debate and added supporters to the high-density proclaims, sometimes overshadowing the importance of other criteria.
The measurement of the level of sustainability of a city is a complex task, due to the fact that it responds to different measurable factors or indicators.

From a political point of view, the city of Málaga has positioned itself as a supporter of a compact/dense urban model: in 2009, Málaga joined the project CAT-MED -Changing Mediterranean Metropolises Around Time-, a platform that clusters a number of Mediterranean cities and promotes "a compact, sustainable and multifunctional urban model" as the optimal way to counteract the effects of climate change. Figure 10 shows some of the indicators studied in 2009 for the purpose of this platform, which can shed some light on the performance of Málaga as a sustainable city. In terms of mobility, for instance, Málaga is the only city among the ten founding members of the CAT-MED where walking is the preferred option for transportation. The preference of dwellers for this option is easily linkable with high densities. On the other hand, the automobile still scores high in the ranking, which constitutes a contradictory value. This relative car dependence can be motivated by a non-effective public transport system, a low mixture of uses or even cultural reasons.

IS MÁLAGA SUSTAINABLE?

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The relation between density and livability has also been a topic of discussion by theorists. As in the case of density-sustainability, there seems to be a relative consensus on the way density and livability are interrelated; the difference is, however, that this relation tends to be inverse, and as a result high levels of density tend to result in lower levels of livability.

Howley et al. (2008) state that “there is a perception among many that high-density development poses too great a cost on individuals’ quality of life”. This follows the line of Neuman’s “complex city paradox” (2005), which claims that a great number of city dwellers, given the choice of living in vibrant, compact city cores still prefer the less dense peripheries —although land prices might have a great influence in this tendency—. Inhabitants of urban environments tend to see high-density developments as unattractive, due to noise, lack of public spaces, traffic, etcetera (Howley et al., 2008); in addition, higher densities have also been linked to environmental stress (Gillis, 1987, as cited in Boyko and Cooper, 2011). Moreover, every time people tend to demand higher provisions of qualified spaces, both private and public.

There seems to be, therefore, a number of researchers (De Roo and Miller, 2007; Oyedepo and Saadu, 2010; Baum et al., 1987; Gormley and Aiello, 1982; Dave, 2010; Masnavi, 2000; Graham and Glaister, 2003; Coutts et al., 2007, among others, all cited in Boyko and Cooper, 2011) that see an inverse proportionality between density and livability, and this work aligns with that idea.

The measurement of livability depends on multiple factors, and it is not easy to measure. As van Dorst states (2012), “we can define the environmental qualities of the optimum habitat for a buttercup or a frog. But to which extent the living environment contributed to the apparent livability is not simple to determine for humans” (p. 226). Although there are livability indexes, which are sometimes developed by municipalities or other corporations, (often with ranking/marketing purposes) this issue deserves a more thorough study, and a careful selection of which parameters actually correspond to the definition of livability that is being used. And even then, there is no real proof that a high score in such indicators may result on a livable area, due to the subjective character of livability (van Dorst, 2012). Livability, therefore, can only be predicted to some extent.
One visible consequence of the historically dense development of Málaga—until the end of the last century—is the insufficient provision of inner open spaces. In some areas of the city, the ratio of green areas per inhabitant can be as low as 1,74 m²/person, when the WHO recommends a minimum of 9,0 (Reyes & Figueroa, 2010). Most of the streets in the city, especially in the older areas, cannot even host trees. These can be seen as negative factors for sustainability, but they are more related to livability, as they directly affect the quality of life of inhabitants, which cannot enjoy the contact with qualified public spaces and vegetation.

Another indicator of livability that is directly linked to the previous is thermal comfort. In general, cities tend to be warmer than their rural surroundings: this is known as the Urban Heat Island (UHI) effect (Oke, 1982), and has to do with multiple factors, including a lower presence of vegetation or a higher proportion of impervious surfaces (van der Hoeven, Wand, 2013). In Málaga, the lowest temperatures during the summer occur in the vegetated surroundings of the city, and in the few green spaces that are located inside it (Fig. 11). In most of the city, high density is resulting in a diminished capacity of citizens to adapt to high temperatures and to reach thermal comfort (Coutts et al., 2007; Tratalos et al., 2007).
Sustainability and livability, two aspects intimately related to urban environments, are often directly affected by density. As has been just described, they do, however, in an opposite way, generating a dangerous discrepancy: higher urban densities are thought to promote sustainability, while at the same time result in less livable environments. In contemporary urban planning, however, the first correlation seems to have greater influence, and dense environments are being continuously encouraged for reasons of (often environmental) sustainability.

The problem is that, to some extent, the discourse on sustainability might have derived into what Kirby (2013) calls a “rigid normative framework”, in which some complex realities of urban environments are simplified, and the scope of the sustainable actions in cities is never assessed from multiple perspectives. In other words, there are some legitimate questions regarding the value of sustainable urban forms that are systematically being obviated for the common good: the protection of our planet and the conservation of species, including us humans. This becomes true when densification is encouraged without a clear assessment on the effects of such densities on livability. In that scenario, which is very common in contemporary literature and urban planning guidelines, sustainability becomes a concern that “transcends the city and subordinates it to broader goals”, holding the city “hostage to this design imperative or that manifesto” (Kirby, 2013).

It could seem obvious from the beginning that a sustainable urban form would not always be the optimal form for their residents. But in practice, this misalignment often becomes a complete discrepancy, as seen in the case of particular densities. Often, it could be said that in order to achieve greater levels of sustainability in the global scale, cities must face the “sacrifice” of concentrating pollution, being congested, achieving higher temperatures or generating stress. Surprisingly enough, there is not much literature on this inverse relation between sustainability and livability. This undoubtedly increases the urgency for an exploration of solutions. Our world is becoming more urbanized, people are living longer, the standards of living are changing and the effects of climate change might be severe in a few years. Urban dwellers need urgently to be aligned with the sustainability discourse, but the no incorporation of livability parameters to the sustainable model can result in a lack of attachment to these principles, a situation that could only bring negative consequences. Cities, therefore, “have to be places where people want to live because, unless people feel that there are high quality residential environments, then there is little chance that they will ever be sustainable” (Williams et al., 2000; Howley et al., 2008).
In Málaga, this tendency is becoming evident, especially after having witnessed the transition to new urban typologies over the last decades. The city that was produced during the sixties and seventies, where the maximum levels of density occur, is currently seen as unstructured, congested and low in quality. For some practitioners, some of these neighbourhoods are already obsolete. Their obsolescence, however, is not only related to their material state, but also in terms of their response to the new urban trends in relation to spatial quality. Each time more home buyers demand a good provision of controlled, private green areas for their children’s recreation, as well as a high number of parking places and good connections to the main infrastructures of the city. Elements, especially those related to the quality of spaces, that most of the fabrics inherited from the past century cannot easily provide in their current state, either because no space is available or because their upgrading would enter in conflict with other uses.

In this respect, the supply has adapted to the demand -or maybe it has helped to create it- and currently most of the new buildings that are being constructed on the new areas of expansion of the city, like Teatinos, Torre Atalaya or Parque Litoral, belong to the “closed block” typology, which was incorporated to the urban plans of the city in recent revisions. The sustainability-livability imbalance becomes here evident: despite of the fact that the denser areas of the city are proved to facilitate pedestrian traffic, in spite of the municipality’s bet to promote compacity as the most sustainable urban model and the support of citizens to the cause, when it comes to choosing their own neighbourhood, perceived environmental quality factors carry more weight than sustainability.

This situation could represent a problem in the near future: young couples have been recently choosing to move to the newer areas of the city. Older areas of Málaga, therefore, should be able to facilitate a generational replacement in the upcoming years, however, data shows that 48% of empty dwellings correspond to buildings built between 1961 and 1980 (Ocaña, ca. 2005). This means that there is a risk that the largest proportion of Málaga, this is, the areas that were developed during the last half of the 20th century, are being neglected for not being able to meet the current standards of livability. In this scenario, the accommodation of new dwellers could only be achieved by further expansion and depletion of non-urbanized areas, leaving the older ones in a situation of risk, or by the demolition and reconstruction of the most spatially obsolete areas, resulting in the loss of neighbourhoods that are currently vibrant and their probable substitution by closed blocks. It goes without saying that both options are both environmentally and socially unsustainable.
The problem statement has both an abstract and a concrete dimension:

At an abstract level, livability and sustainability are aspects of the urban environment that have often been discussed in relation to density, and that tend to relate in opposite ways. There is, however, a gap in the body of knowledge of the discrepancy between these two aspects, that needs to be addressed.

At a concrete level, the manifestation of this discrepancy in Málaga needs to be evaluated. As a result of an uncontrolled and permissive growth, big areas of the city present very high levels of social density, which are associated to high physical densities in different ways. The performance of these areas in terms of sustainability and livability might not be sufficient. This situation can represent a problem in the future, as population grows and becomes older, livability standards increase and the goals of sustainability become more urgent.

The abstract dimension of the problem statement is linked to the scientific relevance of this Master Thesis, while its concrete dimension refers to the urgencies that define the societal relevance of the work (see following pages).
The scientific relevance of this Mater Thesis is strongly linked to the abstract dimension of the problem statement. The discrepancy between sustainability and livability, which has been extensively discussed in this document, has not been deeply explored in recent literature. From an academic point of view, therefore, the relevance of this Thesis lies mainly in the intention of filling that gap in knowledge.

Sustainability is a “hot topic”. The references to the role of cities in achieving a more sustainable planet are multiple, and there seems to be great consensus about the direct connection between sustainability and urban density.

Such broad consensus, however, has its risks. As previously mentioned, sustainability is in danger of becoming a rigid normative framework, a scenario in which the desirability of its precepts becomes unquestionable. Cities, however, need to gain supporters of the sustainability cause, and for that, they need to be livable places. This constitutes by itself an urgency.

It is also surprising that not much has been studied about the Urban Heat Island effect in the Spanish context. With higher average temperatures than other European countries, its cities are more exposed to the negative effects of UHI. Furthermore, it is known that climate change will bring dramatic consequences, especially to its southern half, where Málaga lies.

In June, 2014, the municipality of Málaga approved the study of the UHI phenomenon in the city. That agreement, however, has remained a dead letter, and in three years, nothing has been done with regard to the UHI effect. This work would be, therefore, one of the first attempts -if not the first- to study this phenomenon in this specific context, making it more relevant from a scientific perspective.

The general aim of the ‘Design of the Urban Fabric’ research group is to study the relations between the physical elements of urban environments and other intangible structures of cities, in different contexts. The link between the goals and approach of this Master Thesis and those of the research group are evident. The definition of urban form through density will be specifically connected to two intangible aspects of our urban environments: sustainability and livability. And at the same time, the improvement of these conditions will require alterations in the urban form.
The societal relevance of this Master Thesis is strongly linked to the concrete dimension of the problem statement.

A recent report from the Spanish Statistical Office shows that Málaga is one of the few provinces that will increase population until 2031 (“Proyecciones de población, 2016-2031”. Instituto Nacional de Estadística (INE)). This does not only affect the province but also the city, which will also gain inhabitants, but mostly due to immigration. The average age of population, as in most of the country, will increase. While currently 16.9% of dwellers in Málaga are 65 years old or older, in 15 years from now this percentage will rise to 24.6%. On the opposite side, the proportion of young people will decrease (article on Diario Málaga Hoy, Oct. 26th, 2016, Fig. 12).

This tendency can have two different lectures:

- On the one hand, the previson that Málaga will grow in the following decades means that the achievement of a sustainable, livable urban form is an urgency. As described previously, there is a danger that unsustainable types of development becomes the norm, which would be detrimental for Málaga’s performance in terms of sustainability. In a scenario of further population growth, it becomes important to ensure the alignment of inhabitants to the discourse of sustainability. Additionally, the older areas of the city need to upgrade in terms of livability, so that they become accepted and can contribute to absorb this growth.

- On the other hand, the aging of population implies that more people will be exposed to the negative effects of the Urban Heat Island. In the past years, a rise in the temperatures in summer has been empirically related to an increase in the number of deaths (article on Diario Sur, Aug. 15th, 2015, Fig. 13). Also in literature, the exposure to warm weather conditions has been stated to be “a global threat to human health and well-being” (Harlan et al., 2006). This means that the implementation of measures for the mitigation of this effect will soon become crucial for the protection of city dwellers, even more in the context of rising temperatures due to climate change.
The population older than 65 will almost duplicate by 2031.

Málaga will be the third province in Spain in terms of population growth.

(…) currently 16.9% of residents in the province are 65 or older, while in 2031 the percentage will be 24.6% (…)

Fig. 12. Source: Diario Málaga Hoy, Oct. 26th, 2016

A historic hot summer increases the number of deaths among aged people and chronic sufferers.

Málaga’s cemetery registers 118 more deaths than in 2014, and a 24% increase if compared to 2013, an increase that the Health Council links to hot temperatures.

Fig. 13. Source: Diario Sur, Aug. 15th, 2015
Just as the problem statement has a double dimension, the aim of the project also responds to this duality:

At an abstract level, the project aims to construct a strong theoretical framework on the discrepancy between sustainability and livability and its connection to form. This will be done using an alternative theoretical approach: the conflict between “the Net” and “the Self”, which belongs to Castells’ theory on the Network Society (1996). It is also required to bridge this conflict, which occurs at a conceptual level, with reality in a manageable way. Temperature is identified as a concept that links sustainability and livability, and the Urban Heat Island effect as the way the conflict between “the Net” and “the Self” manifests in relation to temperature. The connection between the UHI effect and density will be done through the lens of the existing body of knowledge on this environmental issue.

At a concrete level, the aim is to explore the possible spatial interventions that could balance the relation between sustainability and livability in Málaga, with respect to its different densities and with a special focus on those areas that are outstandingly dense. The project will use temperature as a topic that links together sustainability, livability and also density in different forms. In particular, thermal comfort and the Urban Heat Island effect will be used as the theoretical framework for the identification and solution of conflicts in different urban areas. The implementation of actions for the mitigation of this effect could transcend its original definition and become driver for more profound changes in the built environment. The possibilities of this approach in the specific context of Málaga will be researched through design, aiming for the generation of a comprehensive future: a vision in which the city overcomes the dichotomy between “the Self” and “the Net” and is capable of generating a sustainable and livable urban environment.

Fig. 14. Abandoned building in La Trinidad. Source: author.
**Main Research Question**

What spatial interventions can be applied in Málaga in order to mitigate the Urban Heat Island effect, as a way to overcome the discrepancy between sustainability and livability that characterizes dense urban environments?

**Sub-Research Questions**

**Conceptual Background**

How does the discrepancy between “the Net” and “the Self” represent the sustainability/livability discrepancy?

How does the theory on the Urban Heat Island (UHI) effect represent an opportunity for the integration of sustainability and livability?

**Analysis**

In what way is the UHI effect manifesting in Málaga at a metropolitan level?

What is a physical density typology in Málaga? In what way is the UHI effect affected by different morphological features?

**Design Intervention**

What systemic approach is required at city level in order to allow and strengthen the positive effects of the design?

Which spatial measures against the UHI effect be applied in each of the typical areas of Málaga?

How can the effects of the spatial interventions be evaluated regarding UHI the effect, sustainability and livability at city level?

To what extent are the interventions on one typical neighbourhood transferable to the rest?
CONCEPTUAL BACKGROUND

How does the discrepancy between “the Net” and “the Self” represent the sustainability/livability discrepancy?

Literature review. A new perspective on the sustainability/livability imbalance.

How does the theory on the Urban Heat Island (UHI) effect represent an opportunity for the integration of sustainability and livability?

Literature review. A catalogue of spatial characteristics that influence the UHI effect in urban environments, indicating their utility as tools for the analysis and design phase.

ANALYSIS

In what way is the UHI effect manifesting in Málaga at a metropolitan level?

Elaboration and study of temperature using satellite data and GIS-software.

Land Surface Temperature (LST) map. Different representations and scales. Identification of physical features of the territory that determine the extent of the UHI effect.

Elaboration of typological clusters according to density parameters. Study of the response of five representative areas to the UHI effect via field work: mapping of priority areas, quantification of surfaces, subjective/perceptual mapping and identification of potentials.

A collection of comparable data sheets describing the physical characteristics of each area in relation to the physical factors related to UHI, as well as their potentials.

What is a physical density typology in Málaga? In what way is the UHI effect affected by different morphological features?

Elaboration of typological clusters according to density parameters. Study of the response of five representative areas to the UHI effect via field work: mapping of priority areas, quantification of surfaces, subjective/perceptual mapping and identification of potentials.

The design of a metropolitan system, integrating a systemic application of the design interventions across Málaga.

A positive or negative conclusion on the affection of the interventions on the UHI effect, sustainability and livability.

DESIGN INTERVENTION

What systemic approach is required at city level in order to allow and strengthen the positive effects of the design?

Hydrological analysis of the city through remote sensing. Exploration through design at city level.

Design tests and conclusive design interventions for every representative area, considering alterations in the urban form, when necessary.

Exploration through design at neighbourhood level. Application of the UHI design principles to the representative areas of Málaga.

A proposal for a transferability typology, leading to a reflection on its potentials and limitations. A selection of additional areas of the city in which the applicability of design principles is tested.

Selection of a series of representative indicators, taken from literature, for the evaluation of sustainability and livability after the interventions. Evaluation on the changes on the physical features that define the UHI effect.

A collection of comparable data sheets describing the physical characteristics of each area in relation to the physical factors related to UHI, as well as their potentials.

Generation of a transferability typology and a series of fast design tests.

RESEARCH QUESTION, METHODOLOGY & OUTCOMES

METHOD(S)

Literature review.

Literature review.

Elaboration and study of temperature using satellite data and GIS-software.

Elaboration of typological clusters according to density parameters. Study of the response of five representative areas to the UHI effect via field work: mapping of priority areas, quantification of surfaces, subjective/perceptual mapping and identification of potentials.

Hydrological analysis of the city through remote sensing. Exploration through design at city level.

Exploration through design at neighbourhood level. Application of the UHI design principles to the representative areas of Málaga.

Selection of a series of representative indicators, taken from literature, for the evaluation of sustainability and livability after the interventions. Evaluation on the changes on the physical features that define the UHI effect.

Generation of a transferability typology and a series of fast design tests.

OUTCOME(S)

A new perspective on the sustainability/livability imbalance.

A catalogue of spatial characteristics that influence the UHI effect in urban environments, indicating their utility as tools for the analysis and design phase.

Land Surface Temperature (LST) map. Different representations and scales. Identification of physical features of the territory that determine the extent of the UHI effect.

A collection of comparable data sheets describing the physical characteristics of each area in relation to the physical factors related to UHI, as well as their potentials.

The design of a metropolitan system, integrating a systemic application of the design interventions across Málaga.

Design tests and conclusive design interventions for every representative area, considering alterations in the urban form, when necessary.

A positive or negative conclusion on the affection of the interventions on the UHI effect, sustainability and livability.

A proposal for a transferability typology, leading to a reflection on its potentials and limitations. A selection of additional areas of the city in which the applicability of design principles is tested.
The theoretical framework addresses four different topics:

**SUSTAINABILITY AND LIVABILITY**

The definition of sustainability and livability and a description of the nature of the discrepancies between both aspects. In particular, the focus is on the conflicts that appear in the presence of particular densities.

**“THE NET” AND “THE SELF”**

The explanation of those conflicts through the “Net versus Self” perspective: definition of the approach, examples of application and a description of benefits of applying this perspective to the conflicts between sustainability and livability.

**TEMPERATURE AND THE UHI EFFECT**

The identification of temperature as a concept that links sustainability and livability; and the Urban Heat Island effect is the way the conflict between “the Net” and “the Self” manifests in relation to temperature. There is currently an extensive body of knowledge about this effect, which provides connections with physical aspects of the built environment.

**DENSITY**

Density can play a very relevant role in determining to which extent these physical aspects are present in urban environments. A theoretical background on the concept of density is also required for a correct analysis of this aspect.
DEFINITION OF SUSTAINABILITY AND LIVABILITY

Contemporary literature in the field of urbanism is full of references to the terms “sustainable” or “livable”. In the case of sustainability, its relevance in other domains is also evident. “Sustainable” and “livable” are adjectives that are often applied to good urban planning and design; therefore being two terms that possess an evident and inherent positive value. A “sustainable development” or a “livable community” are always desirable, no matter the context.

There is, however, a certain confusion between the two terms, which in some cases are used interchangeably. In order to show this misconception, it can be useful to bring some references to these two concepts from existing literature.

The World Commission on Environment and Development provided in 1987 a widely used definition of sustainability: a sustainable development “is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). It is implicit in this definition, therefore, that sustainability consists on finding a balance between a self-centred behaviour and the common good. Such a vision requires an understanding that people living in other places or belonging to future generations can be negatively affected by practices aiming for an individual well-being or comfort.

While sustainability refers to the long term and requires a global perspective, livability is about the “now” and “here” (Ruth and Franklin, 2014). It is an inherently urban matter, as cities are the places where higher concentrations of people generate a greater negative impact on individuals’ lives. Livability can be seen as more achievable, because often decisions aiming for a more livable environment can be taken at a local scale. There is, however, no such thing as a universal concept of livability, which means that every individual might have a different definition of what a livable city or community is. It is possible, however, to find common grounds, which become the goals of livability policies.

Sustainability and livability are, at the same time, both independent and interconnected concepts. Their independence can be expressed, for instance, by the fact that it is possible to conceive livable environments that are not sustainable: livability is about “meeting the needs of the present” and can therefore coexist with the inability of other individuals to meet their needs. In the other direction and strictly speaking, non-livable, sustainable environments could also exist, however this contradicts the basic definition of sustainability (WCED, 1987) or, in other words, the idea that or that no environment can be considered to be sustainable unless they are also livable (Jenks, Williams and Burton, 2000, as cited in Kennedy and Buys, 2010). This already constitutes a certain degree of interdependence between the two concepts, which can also be expressed by other facts. For instance, Ruth and Franklin (2014) state that “it is conceivable that high levels of livability can be experienced temporarily while undermining ecosystem structure and function, over the long haul livability is intricately tied to environmental sustainability”. As a way of representing the interrelation of sustainability and livability graphically, often the second is drawn inside the first:

As previously explained, such a representation does not imply a subordination of livability to sustainability. Instead, it means that sustainable cities should also be livable environments in order to comply with the definition of sustainability, and that the subsistence of livable environments in the long term requires the system to be sustainable. These clarifications are necessary for the posterior interpretation of other theories. Sustainability and livability are, therefore, two terms with different definitions. It is possible to observe a certain confusion, however, in the use of both words when referring to certain aspects or qualities of urban environments. This imprecision is bidirectional. For instance, Litig and Griessler (2005) include the “subjective satisfaction with work, health, housing, income and the environment” as indicators of social sustainability. According to their definitions, these indicators actually correspond to livability, as they respond to a perceptual, individual judgement of the own condition. This transference of indicators from livability to sustainability
is quite common, and is probably due to the increasing relevance of the second term in contemporary literature. In the opposite direction, some aspects of cities that belong to sustainability can be also assigned to livability. Badland et al. (2014), for instance, include greenhouse gas emissions, energy use or waste generation as indicators for livability, but these are not individual nor subjective in nature, and their relation with the perceived quality of life of a place is only indirect. These are just two examples of these very common misinterpretations.

These differences in meaning and scope can sometimes generate conflicts, when the operations towards a higher sustainability worsen the levels of livability of inhabitants, and vice versa.

Often the visualization of this conflict is immediate. For instance, people report to prefer residential environments in which there is a social homogeneity (Semyonov et al., 2007). From a sustainable point of view, however, this preference can bring negative consequences to urban environments. Social diversity in neighbourhoods contributes positively to the integration of communities (Porta, 2001). This is a clear example of an imbalance between sustainability and livability.

In other cases, the existence of conflicts requires the addition of a spatial variable to the equation. Not every indicator of sustainability or livability is irretrievably linked to urban form. Among those that have a strong spatial component, density tends to play an important role in defining to which extent an urban area is sustainable or livable. In the previous example, the conflict between the livability offered by homogeneous neighbourhoods and the sustainability of socially diverse areas is evident. Homogeneity is, by definition, opposite to heterogeneity. In the case, for instance, of energy consumption in relation to mobility (which is an indicator of environmental sustainability) and air quality (an indicator of livability), the visualization of the conflicts requires an understanding of how urban form influences both parameters. Highly dense environments promote public transport and walking trips, reducing the consumption of energy in everyday travels (Owen et al., 2007, as cited in Boyko and Cooper, 2011). At the same time, the concentration of people and traffic in small areas imply that, in general (and as long as fossil fuels continue to be the main energy source for transportation) citizens living in dense urban areas suffer a lower air quality (Dave, 2010, as cited in Boyko and Cooper, 2011). The conflict, in this case, has been diagnosed through a spatial variable.

In the next pages, figures 18 and 19 show in which ways high levels of density can be linked to different sustainability and livability indicators.
## ENVIRONMENTAL SUSTAINABILITY IN RELATION TO DENSITY

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>REFERENCE</th>
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</thead>
<tbody>
<tr>
<td><strong>Transport</strong></td>
<td></td>
</tr>
<tr>
<td>Reduced fossil fuel emissions</td>
<td>Burton, 2000a</td>
</tr>
<tr>
<td>Lower per capita consumption of energy for everyday travel</td>
<td>Holden and Norland, 2005*</td>
</tr>
<tr>
<td></td>
<td>Frank and Pivo, 1994*</td>
</tr>
<tr>
<td></td>
<td>Owen et al., 2007*</td>
</tr>
<tr>
<td>Higher per capita consumption of energy for long or leisure travel</td>
<td>Holden and Norland, 2005*</td>
</tr>
<tr>
<td>Higher potential for the implementation of innovations, aiming for a more efficient mobility</td>
<td>Haughey, 2005*</td>
</tr>
<tr>
<td><strong>Energy in the built environment</strong></td>
<td></td>
</tr>
<tr>
<td>Lower energy consumption due to heat losses</td>
<td>Steemers, 2003*</td>
</tr>
<tr>
<td>Lower solar accessibility and potential for passive solar power</td>
<td>Steemers, 2003*</td>
</tr>
<tr>
<td>Higher energy consumption during construction</td>
<td>Rydin, 1992*</td>
</tr>
<tr>
<td>Higher potential for green design</td>
<td>Williams, 2000*</td>
</tr>
<tr>
<td><strong>Natural systems</strong></td>
<td></td>
</tr>
<tr>
<td>Lower pressure on agricultural and industrial land</td>
<td>Alexander and Tomalty, 2002*</td>
</tr>
<tr>
<td></td>
<td>Churchman, 1999*</td>
</tr>
<tr>
<td>Higher preservation of green open spaces, flora and fauna within plan boundaries</td>
<td>Haughey, 2005*</td>
</tr>
<tr>
<td>Lower quality of urban ecosystems</td>
<td>Tratalos et al., 2007*</td>
</tr>
<tr>
<td>Higher potential for the introduction of urban agriculture</td>
<td>City of Vancouver, 2008*</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td></td>
</tr>
<tr>
<td>Lower consumption of water</td>
<td>Alexander and Tomalty, 2002*</td>
</tr>
<tr>
<td>Higher levels of water pollution</td>
<td>Hatt et al., 2004*</td>
</tr>
<tr>
<td>Lower capacity of surfaces to absorb rainfall water</td>
<td>Tratalos et al., 2007*</td>
</tr>
<tr>
<td><strong>Consumption of materials and waste generation</strong></td>
<td></td>
</tr>
<tr>
<td>More efficient use of resources</td>
<td>Alexander and Tomalty, 2002*</td>
</tr>
<tr>
<td>Lower capacity to cope with domestic waste</td>
<td>Troy, 1996*</td>
</tr>
</tbody>
</table>

*as cited in Boyko and Cooper, 2011.
<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower air quality</td>
<td>Dave, 2010*</td>
</tr>
<tr>
<td>Public health benefits related to everyday walking</td>
<td>Oakes et al., 2007*</td>
</tr>
<tr>
<td>Lower likeliness of doing physical activity</td>
<td>Xu et al., 2001*</td>
</tr>
<tr>
<td>Higher rate of traffic accidents</td>
<td>Graham and Glaister, 2003*</td>
</tr>
<tr>
<td>Exacerbated traffic congestion and parking problems</td>
<td>Williams et al., 2000*</td>
</tr>
<tr>
<td>Higher presence of obstructing views and overshadowing</td>
<td>Hitchcock, 1994*</td>
</tr>
<tr>
<td>Higher exposure to unfavourable climate conditions (UHI)</td>
<td>Coutts et al., 2007*</td>
</tr>
<tr>
<td></td>
<td>Tratalos et al., 2007*</td>
</tr>
<tr>
<td>Lower access to green areas</td>
<td>Masnawi, 2000*</td>
</tr>
<tr>
<td></td>
<td>Alexander and Tomalty, 2002*</td>
</tr>
<tr>
<td>Lower availability of public open space</td>
<td>De Roo and Miller, 2000*</td>
</tr>
<tr>
<td>Lower water quality</td>
<td>Ham et al., 2009*</td>
</tr>
</tbody>
</table>

*as cited in Boyko and Cooper, 2011.
Fig. 18. Connection between different indicators of social/economic sustainability and higher levels of density. On the next page, the indicators of livability that are associated to each sub-category are also displayed. A (+) indicates that the relation between the indicator and density can be valued as positive (more sustainable/more livable). A (-) indicates an opposite evaluation. Elaborated by the author based on Boyko and Cooper, 2011.

**SOCIAL/ECONOMIC SUSTAINABILITY IN RELATION TO DENSITY**

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>REFERENCE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher overall accessibility</td>
<td>Masnavi, 2000*</td>
<td>+</td>
</tr>
<tr>
<td>Higher number of employment opportunities</td>
<td>Dave, 2010*</td>
<td>+</td>
</tr>
<tr>
<td>Higher presence of quality health, education, … services</td>
<td>Jenks et al., 1996*</td>
<td>+</td>
</tr>
<tr>
<td>Higher attractiveness for businesses, hotels, shopping areas…</td>
<td>Jenks et al., 1996*</td>
<td>+</td>
</tr>
<tr>
<td>Often, higher housing choice and affordability</td>
<td>NHPAU, 2010*</td>
<td>+</td>
</tr>
<tr>
<td>Higher relative prices for dwellings</td>
<td>Alexander and Tomalty, 2000*</td>
<td>-</td>
</tr>
<tr>
<td>Governance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower sense of community</td>
<td>Wilson and Baldasarre, 1996*</td>
<td>-</td>
</tr>
<tr>
<td>Higher levels of social support</td>
<td>Churchman, 1999*</td>
<td>+</td>
</tr>
<tr>
<td>Higher levels of competition over space and other conflicts</td>
<td>Churchman, 1999*</td>
<td>-</td>
</tr>
<tr>
<td>Diversity and equity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher social diversity</td>
<td>Hall and Lee, 2010*</td>
<td>+</td>
</tr>
<tr>
<td>Lower levels of social segregation and exclusion</td>
<td>Burton, 2000b*</td>
<td>+</td>
</tr>
<tr>
<td>Higher inequality and segregation</td>
<td>Churchman, 1999*</td>
<td>-</td>
</tr>
<tr>
<td>Lower crime rates (&quot;eyes on the street&quot;)</td>
<td>Roncek, 1981*</td>
<td>+</td>
</tr>
</tbody>
</table>

*as cited in Boyko and Cooper, 2011.
### Social Livability in Relation to Density

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher pedestrian congestion</td>
<td>Ruback and Pandey, 1992*</td>
</tr>
<tr>
<td>Perceived cramped living environments</td>
<td>DETR, 1998*</td>
</tr>
<tr>
<td>Lower availability of open public spaces</td>
<td>De Roo and Miller, 2007*</td>
</tr>
<tr>
<td>Higher levels of noise</td>
<td>Oyedepo and Saadu, 2010*</td>
</tr>
<tr>
<td>Higher levels psychological stress</td>
<td>Gillis, 1987*</td>
</tr>
<tr>
<td>Higher likeliness of suffering from cognitive overload</td>
<td>Evans and Cohen, 1987*</td>
</tr>
<tr>
<td>Higher likeliness of social and spatial constrains on individual behaviour</td>
<td>Baum et al., 1987*</td>
</tr>
<tr>
<td>Lower levels of privacy</td>
<td>Gormley and Aiello, 1982*</td>
</tr>
<tr>
<td>Lower levels of maintenance</td>
<td>Walton et al., 2008*</td>
</tr>
<tr>
<td>Lower general satisfaction with the neighbourhood</td>
<td>Dave, 2010*</td>
</tr>
</tbody>
</table>

*as cited in Boyko and Cooper, 2011.
DEFINITION OF THE APPROACH

Sustainability and livability, their conflicts and interrelations, could be very well explained through the lens of Manuel Castells’ opposition between “the Net” and “the Self” (1996). This perspective can also help to define a clear differentiation between the two aspects, shedding light on the misinterpretations that have been already described.

Originally, Castells uses these pair of concepts as a way to explain the opposition between the logic of networks and particular identities, or a split between function and meaning (van Dijk, 1999). Through this thesis, he is capable of clarifying the nature of the Information Age, which evolves from the industrial age but has different mechanisms and a more interconnected, de-hierarchized structure. “The Net” symbolizes the de-centred, interconnected network of elements of different nature, while “the Self” represents the individual assertion of identity.

Egger (2006) proposes an extension of this model to sustainability, stating that:

“(…)[T]he city as an element within the global network, where to be considered sustainable it must develop and operate in a way that is in accordance with the common global good (the Net) and secondly, as a system within itself, whereby it must develop and operate in a way acceptable to its own inhabitants (the Self).”

Although the author is here only referring to sustainability, this double perspective actually constitutes a vision on the sustainability/livability dichotomy. In this vision, sustainability corresponds to “the Net”, because responds to the interconnectedness of each city with other cities and regions, acknowledging the effects of their actions upon the rest: Livability, on the other hand, corresponds to “the Self” by representing the tendency of cities to meet the needs of their own inhabitants.
**NUANCES**

Logically, this perspective offers a number of nuances. The definition of the two dimensions seems to respond to quantitative parameters, being “the “Self” associated to the individual while “the Net” corresponds to a group of individualities. This is however a limited vision.

On the one hand, the definition of “the Self” is not limited to the individual sphere. Going back to the original source of this perspective, Castells (1996) mentions cultural identity as one of the aspects that define “the Self”, due to its power as opposing force to the global logics of “the Net”. Cultural identity, however, has a very strong group component. It is based on identification, or “the earliest expression of an emotional tie with another person” (Freud, 1921/1991, as cited in Hall, 1996) and the exclusion of the Other, constituting “a constructed form of closure” (Hall, 1996). This means that the coincidence in time and space of multiple individual preferences and attachments is also a form of “Self”, in spite of its collective component. In line with this, a group of neighbours organized in a platform and fighting against a certain urban project can also represent the unfolding of the powers of “the Self” in the city. “NIMBYism” is therefore just another good example of the opposition of collective, but particular interests to the logics of the common good.

Likewise, the logics of “the Net” do not necessarily manifest themselves in a global scale. Environmental sustainability tends to relate to the scale of our planet, as it “seeks to sustain global life-support systems indefinitely” (Goodland, 1995). References to economic sustainability often occur at national or international level. In the case of social sustainability, its assessment can be also global, but it normally refers to communities, neighbourhoods and cities. This multi-scalar definition of sustainability means that a “sustainable neighbourhood” can imply something completely different depending on whether we are using the environmental, social or economic perspective. An environmentally sustainable neighbourhood is a neighbourhood that contributes positively to the goals of global sustainability. In this case, the inevitable links of flows and connections with other territories transcend the physical scale of the neighbourhood. A socially sustainable neighbourhood, on the other hand, is defined by adjectives like “supportive”, “cohesive”, “committed” or “tolerant”, among others (Goodland, 1995). This means that the social sustainability of an area can be expressed and contained within that area’s limits.

Measurable dimensions do therefore limit the definition of “the Self” and “the Net”. Especially when referring to communities or neighbourhoods, the urgencies of livability and sustainability can coexist and be shared by a similar number of individuals. The correct classification of indicators as belonging to “the Self” or “the Net” requires an examination of the role of that indicator: if it is in line with the logics of the common good and considers the positive affection of one individual or group of individuals over the rest, it probably belongs to “the Net” and represents an indicator of sustainability. Alternatively, if that indicator seeks for the well being of an individual or group of individuals in time and space, regardless of their impact on others, it possibly belongs to “the Self” and represents livability.

As already said, existing literature includes multiple references to intangible aspects of urban environments. In Fig. 21 (see next page), some of this existing terminology has been evaluated from the “Net versus Self” perspective.
SUSTAINABILITY / "THE NET"

ECONOMIC PROSPERITY

Income and expenses
GDP per capita
Debt
Inflation rate
Saves
Consumption indicators:
- material
- energy [...] 

Wealth distribution
Income inequality (GINI)

Employment
Diversity of jobs
Qualification of jobs
Density of new businesses
Labour productivity

Investment
Physical infrastructure
Social infrastructure
Innovation and technology

SOCIAL JUSTICE

Accessibility
- to employment
- to health
- to education
- to amenities
- to diverse types of housing
- to diverse means of transport

Governance
- Sense of community
- Sense of responsibility
- Awareness
- Participation

Diversity and equity
- Social diversity
- Social inclusion
- Cultural relations and integration
- Community networks

Heritage
- Respect to cultural heritage

ENVIRONMENTAL QUALITY

Consumption of resources
- of raw materials
- of food and water
- of energy:
  - for production
  - for transportation
  - in households

Generation of waste
- Soil pollution
- Water pollution
- Air pollution:
  - local
  - remote
- Food waste
- Material waste and recycling rate

Conservation of natural systems
- Land consumption for urbanization
- Land consumption for production
- Respect of biodiversity

LIVABILITY / "THE SELF"

Safety
- Regarding traffic
- Regarding crime

Elements
- Air quality
- Water quality

Quality of spaces
- Provision and quality of public spaces
- Access to playgrounds
- Access to different types of green
- Walkability
- Facilitation of physical activity

Comfort
- Thermal
- Acoustic
- Congestion/stress
Naturally, the goals of livability can be compatible with those of sustainability, an ideal state in which “the Self” and “the Net” are in line with each other. By definition, however, there is a tendency for the aims of sustainability and livability to present a misalignment. As van Dorst (2013) states:

“Liveability thus emphasises the here and now, whereas sustainability emphasises the elsewhere and the future. With liveability as an aim, the needs of the next generation can be pushed to the background. A population of a neighbourhood asking for more parking spaces may leave the next generation a living environment with a lack of green. So a liveability approach in itself may not be sustainable at all.”

The analysis of urban form and its influence on different indicators is a particularly powerful way of revealing disparities between sustainability and livability. Density is just a particular example of an aspect of form with both a physical and social dimension and a strong impact on the levels of sustainability and livability in cities (Howey et al., 2008). Sustainability and livability, however, are merely abstract concepts that encapsulate a large number of indicators. One same urban environment can be livable in some respects while at the same time not livable in others. Similarly, a particular city form can encourage a sustainable behaviour and simultaneously result in an unsustainable performance, depending on which indicator of sustainability is being taken into account. A correct identification of the nature of these indicators is therefore a crucial first step in any descriptive and constructive approach to sustainability and livability in cities, but this is hindered by the already mentioned tendency to misinterpret both concepts.

There is an extensive literature on sustainability and livability indicators. Often, however, this literature misses a reflection on the way these indicators influence each other. For the goal of achieving both sustainable and livable urban environments, the nature of these interrelations needs to be defined from theory, and in any case should it be evaluated hindsight.

The “Net versus Self” perspective can help to build this body of knowledge in two different ways: on the one hand, it helps to categorize the existing overabundance of indicators as belonging to either sustainability or livability.
9.3 TEMPERATURE AND THE UHI EFFECT

TEMPERATURE

Temperature is a concept that represents a connection between sustainability and livability and that is dependent on density. By narrowing the scope down to this matter, the essence of the problem is maintained, while at the same time the abstract goal of balancing “the Net” and “the Self” becomes concrete and more manageable.

This reduction of the perspective may seem to limit the interest of this work to environmental sustainability and livability, discarding the rest of dimensions. This occurs, however, only in operational terms: the implications of temperature, the aspects of “the Net” and “the Self” that are associated to it and its physical manifestation in the city can transcend the environmental dimension and be indirectly linked to society and economy.

The selection of temperature as a driving concept for the work can be justified: on the one hand, temperature is an important component that defines ecosystems, affecting the life of living beings. In the case of humans, the level of influence of temperature in our lives can be high, transcending health and adopting the small nuances that define thermal comfort. With 66% of people projected to live in cities by 2033 (UN, 2014), thermal comfort is an eminently urban matter.

On the other hand, there is a generalized consensus that human activity can influence back temperature. This affection manifests itself through global warming, which is the increase on the temperature of the Earth due to the accumulation of greenhouse gases and deforestation. A great part of these greenhouse gases is produced within cities, due to transportation, or remotely for generating the energy or consumer goods that urban dwellers require. Industrial activities are often placed in proximity to urban cores, so that they can benefit from the accumulation of capital and labour force that constitute cities.

Temperature, therefore, influences and is influenced by human activity. This bidirectional relation could be represented by a scheme like the one shown in Fig. 22.

Such a diagram, however, is not complete, because this double affection happens at two different levels. In this sense, Fig. 23 offers a more accurate representation:

The dotted line means that there is not a strong, direct relation between the way humans influence temperature and the way this temperature is felt back by humans. It is not a cause-effect reaction nor is it space limited. Our actions have often an effect in a different place of the planet, while our perception of the environment occurs necessarily around us. This is easy to see with pollution: the domestic electricity consumed in cities is often produced in energy plants that are far away from inhabited areas, so the air quality of urban environments is not directly affected by the energy consumption of dwellers.

In the case of temperature, the visualization of this paradox requires the understanding of how form (and specifically, density) affects energy consumption and pollution, and of a particular phenomenon of cities: the Urban Heat Island (UHI) effect.
THE URBAN HEAT ISLAND EFFECT (UHI)

The Urban Heat Island effect (UHI) describes the fact that cities’ temperatures tend to be higher than in their surrounding rural areas. This becomes especially significant during the night, when all the heat that has been stored during the day in the different materials that built the city is released, resulting in an impediment for the natural cooling process of the air (Oke, 1982).

Cities characterized by a higher social density do not necessarily need to be warmer, however a greater physical density tends to result on a more pronounced UHI effect (Coutts et al., 2007; Tratalos et al., 2007)). This is due to the presence in cities of a high proportion of hard materials, among other reasons. At the same time, in dense urban environments there are limitations for implementing elements that can have a palliative effect, which results in an even lower thermal comfort.

The Net/Self paradox is here evident and it can be represented, in a simplified way, through a double diagram (Fig. 24):

The diagram also reveals the essence of the conflict, which is the “sacrifice” that urban dwellers need to face for the goal of a more sustainable environment, a sacrifice that compromises their alignment with the sustainability discourse (Williams et al., 2000; Howley et al., 2008; Kirby, 2013).

The literature review has shown a great evidence that dense environments, like Málaga’s, favour a lower rate of emissions, if compared to more sprawled models. The contribution to global warming of such a city is therefore lower.

The existing theory on the UHI effect provides links between different physical aspects of urban environments and the extent to which this effect manifests. The understanding of the role of these spatial features in relation to temperature is of great importance for the analysis and the design process. On the next two pages, Fig. 25 displays a list of these elements.
PHYSICAL FACTORS IN THE UHI EFFECT (I)

SURFACE HARDENING INDEX

Hard surfaces are the main cause of UHI effect. By sealing the soil, preventing evaporation and the growth of vegetation, they store solar radiation as latent energy.

Measurability

A study of the surfaces of a certain area, capable of showing the proportion of the ground that is paved -both for traffic or pedestrian- in comparison to green surfaces, is a valid measurement of an area’s degree of hardening.

Applicability on an intervention

Compared to other measures, it is relatively easy to modify an area’s degree of hardening. In neighbourhoods with high densities, however, any attempt to alter the amount of ground which is dedicated to traffic or pedestrians might create conflict, as soft areas tend to be seen as not usable by dwellers. In the particular case of building roofs, the addition of vegetation could also improve its hardening index. However, such operations need to take into account additional technical and economic issues.

ALBEDO

Represents the extent to which materials reflect solar radiation. A high albedo generally reduces the UHI effect.

Measurability

Albedo can be measured using remote sensing. At ground level, albedo tends to be homogeneous. Surfaces for traffic are generally grey, and in the particular case of Málaga, the type of tiling for pedestrian areas is usually grey too. Regarding buildings, there is a tendency of façades being light in colour and roofs being clay-coloured. Any significant alteration of any of these patrons should be highlighted.

Applicability on an intervention

An alteration in the albedo of any surface is a relatively easy operation. Traditionally, cities in the south of Spain have used white colours in order to improve the thermal comfort of the inhabitants. Any intervention aiming for a higher albedo is in line with this tradition.

Fig. 25. Physical factors of urban environments that influence the Urban Heat Island effect. Source: van der Hoeven and Wandl, 2013.
SPACE FOR TRAFFIC

Traffic space are usually paved spaces, which do not cast shadows and have a high sky-view factor. This makes it heat up faster during the day, but also release the heat faster during the night.

Measurability

As for the case of paved surfaces, an analysis of the proportion of ground that is dedicated to traffic is a good way of determining the contribution of this physical element to heat.

Applicability on an intervention

As long as there are cars, having spaces for the movement of vehicles will be required. The amount of surface dedicated to traffic can be however adapted to new mobility scenarios. The modification of the material of roads, as well as its protection with shading elements could also modify its performance.

BUILDING SKIN

The building skin is the interface between the indoor space and the outdoor environment. This factor multiplies the amount of surface that is exposed to the surroundings and the sky, working both as a collector and a radiator. Therefore, neighbourhoods with a higher proportion of building skin per surface unit can be increasing the UHI effect.

Measurability

This parameter could be measured, in an approximate way, using a 3D model of a given area, or through calculations using perimeter and height data, on GIS-software. The characteristics of the building skin, in terms of materiality, are also important.

Applicability on an intervention

Modifying the amount of building skin in an area is not an easy operation. Altering its materiality, or adding vegetation or other protecting elements is a realizable intervention.
VEGETATION INDEX

Vegetation reduces the UHI effect. However, open lawns cool down in the night faster than forests, due to their higher sky-view factor.

Measurability

The Normalized Difference Vegetation Index (NDVI) reflects the quantity and quality of vegetation in a given area, and can be measured using remote sensing. A quantification of green areas is also useful, and should ideally include a specification of accessibility. Although the cooling effects of vegetation are independent of that factor, its positive effects on the livability of dwellers are increasingly higher if those green areas can be used.

Applicability on an intervention

The addition of vegetation in a given area is always a possibility. There might be spatial constraints in highly dense neighbourhoods, where most of the surfaces tend to be paved, and specifically in areas with a high GSI, which are normally defined by narrow streets.

OPEN WATER BODIES

Due to evaporation, water bodies have a positive effect on cooling down urban environments [see also Manteghi, 2015].

Measurability

The quantification of the surface of water is easily measurable. The depth of the water body is however an additional relevant factor.

Applicability on an intervention

In dense urban environments, the addition of water surfaces can be a complicated task. The insertion of fountains or other water elements with a vertical component can be more achievable.
SKY-VIEW FACTOR

Represents the extent to which surfaces are exposed to the sky. A low sky-view factor increases the UHI effect.

Measurability

In very heterogeneous fabrics, the calculation of the height/width ratio for a whole area can be difficult to achieve. The generation of typical street sections can be an optimal way to reflect a general sky-view factor that can be representative of a neighbourhood.

Applicability on an intervention

The sky-view factor relates to the proportion of open and built spaces. This means that, in order to modify this factor in an existing area, it would be required to replace or add buildings, a type of intervention that is not generally feasible. It is a parameter that can be considered, however, for new developments.

SHADOW

Shadow in urban environments prevents surfaces from getting direct solar radiation, therefore reducing the UHI effect.

Measurability

It is possible to study the shadows of a given area with a solar simulation, which can be done by computer. Such a simulation requires the consideration of multiple moments of the years and times. A more general approach to this indicator would also use typical sections in order to show the shadows that are produced by buildings, trees, etcetera, in a representative case.

Applicability on an intervention

The addition of shadows with trees or other elements is relatively easy, and is only limited by spatial constraints. In line with the sky-view factor, the alteration of buildings masses for the purpose of adding or removing shadows in existing areas cannot be considered as feasible. In new developments, however, it can be a good guiding design principle.
HOW DO THESE PHYSICAL FEATURES RELATE TO THE NET/SELF DISCREPANCY?

As previously mentioned, the UHI effect is the way in which the Net/Self discrepancy manifests in relation to temperature. This becomes also evident when imagining alterations in any of the physical features described in Fig. 25. A lot of the potentials for improvement have to do with the modification of surfaces, addition of green areas or water bodies, etcetera. In highly dense areas, these type of interventions, some of which are extensive by nature, can hardly take place, especially in the case of high GSI. Additionally, such operations can easily generate conflict, as they probably require the alteration of some semi-public surfaces, the reduction of parking or circulation space, or can result in low-quality interventions, if the level of maintenance is low (which tends to happen in highly dense environments, see Walton et al., 2008). There are situations in which even planting a tree might be problematic, if it is perceived to be too close to a façade or makes transit difficult. The general lower sense of community of dense areas (Wilson and Baldasarre, 1996) also hinders the application of any ambitious intervention.

The extent to which each of these elements could be adapted for a better thermal behaviour depends, to a big extent, on the particularities of each type of environment. In this context, density plays an important role, as it creates different morphological conditions in which the performance of thermal comfort can be completely different. Understanding density and the ways of measuring is essential for the concrete identification of problems and potentials in any built environment.
9.4 DENSITY

THE CONCEPT OF DENSITY

The analysis of the historical and spatial context in Málaga has concluded that some areas of the city present high levels of density. This, however, requires a deeper reflection, capable of constituting the starting point of a series of conceptual and concrete explorations.

The concept of density has been intimately linked to the field of Urbanism since its beginnings (Berghauser Pont and Haupt, 2010). Before the twentieth century, density was merely the result of the natural development of cities. This, in the context of industrializing cities during the nineteenth century, led to extremely dense and congested urban environments, a situation that derived in social disorders and diseases (Churchman, 1999). Hygiene, together with the adoption of maximum urban densities, were the two main measures that were taken in order to transform cities into livable, healthy places.

Since then, urban theorists and practitioners have used the concept of density as a normative tool, setting maximum or minimum levels in different periods and locations. Nowadays, it is possible to recognize enormous differences in density in urban settlements around the globe, from urban sprawl -especially in the North American context- to highly dense cities in Asia. Each of these urban models brings its own virtues and issues, depending on which aspect is being studied. There is not, therefore, such thing as bad or good density, and the adequacy of low or high levels of density needs to be assessed separately.

Density is not a unitary concept. It is possible to consider different types of density, each of them providing a concrete type of information and being linked with specific aspects of urban form. It is particularly important to distinguish between density as a social or physical parameter. Density can be commonly referred as the number of inhabitants or dwellings per surface unit. This constitutes a social definition of the term, which can also include others like “jobs per surface unit”, for instance. Although it is a relevant parameter, it offers certain limitations, and as a quantitative measurement it “poorly reflects the spatial properties of an urban area” (Berghauser Pont and Haupt, 2010, p. 12). This statement derives from the fact that, given a certain density, multiple spatial configurations can occur, with very different spatial qualities (Fig. 26). These qualities can be better expressed by the physical dimension of density, which includes a set of ratios that refer to ground coverage, floor area ratio, etcetera. These variables offer more information about the qualities of urban form and allow to establish more accurate connections between the tangible dimension of form and other intangible aspects, such as sustainability or livability.

Both aspects, social and physical, can be relevant. While physical density can be more easily related to ecological aspects of sustainability, thermal comfort, etc., social density shows a more direct connection with social/economic sustainability or liveliness, for instance. This differentiation can be relevant when trying to evaluate the impact of high or low densities on other aspects of cities.

![Fig. 26. The imprecision of the quantitative approach to density: three areas with 75 dwellings per hectare. With an equal number of dwellings, these three examples offer very different qualities. Source: Fernández Per and Mozas, 2004: 206-207](image-url)
The Urban Heat Island effect has been selected as one relevant phenomenon through which the sustainability/livability dichotomy is manifested. From an academic point of view, analysing these effects requires not only an identification of the causes, but also an exploration of which elements are limiting the inhabitant’s ability to cope with heat and where are the potentials for improvement.

Such a perspective requires, logically, a multi-scalar approach to the matter. On the one hand, the general sustainability/livability imbalance has been said to be manifested in the presence of certain densities, which is a parameter that changes through scales. Any abstract confirmation of the dichotomy between “Net” and “Self” needs to be referred to a specific scale.

On the other hand, the existing theory on the Urban Heat Island effect explains that some natural systems, land use, etcetera, have a great impact on the temperature in cities. Analysing the way Málaga is placed in the territory, its surroundings and its different metropolitan systems is a requirement for understanding the causes of the biggest variations in temperature throughout the urban fabric. This, however, says little by itself about the way this effect is perceived by dwellers, nor about which elements in the different urban environments within the city are helping them to cope with high temperatures or where there is space for improvement. In general, it could be said that, while the analysis of the causes of the Urban Heat Island effect may correspond to a medium to big scale, the understanding of thermal comfort and adaptation happens in the medium and small. Therefore, an analysis through multiple scales is required.

A visualization of the Land Surface Temperature in any place in the world can be obtained from the information provided by the Landsat 8 satellite. For a given day and time, images of the surface of the Earth are provided in different thermal bands. These images can be combined in a GSI software in a specific way, obtaining in the end a map that shows the temperature of the surface of a place in that specific moment.

For the calculations, thermal bands 2, 3, 4 and 5 (from the Operational Land Image, OLI) allow the calculation of the Normalized Difference Vegetation Index (NDVI). Bands 10 and 11 (from the Thermal Infrared Sensor, TIRS) provide the values that can be used for obtaining the TOA radiance, the TOA reflectance and the At-Satellite Brightness Temperature (USGS, 2016). Both values (NDVI and At-Satellite Brightness Temperature) can then be used for the generation of the LST map.

For the visualization of the data, two different alternatives are provided: the real surface temperature in the unbuilt space and the total mean surface temperature per block, represented on the buildings layer. While the first is a more realistic representation of temperature in all different open spaces in Málaga, the second constitutes a more intuitive way of seeing temperature differences across different fabrics.

Conclusions on the information provided by these maps can derive from direct observation. In a metropolitan scale, three main questions can be answered:

- How does the Urban Heat Island effect manifest in Málaga?
- If so, is it possible to identify the influence of any physical or programmatic element in the temperature of the city?
- Are there relevant differences in temperature within the fabric that could lead to further explorations in a smaller scale?
MESO- AND MICROSCALE

The transition to a smaller scale requires the selection of an area, or group of areas of interest. This has been done considering the main criterion that, although no selection can cover all the particularities of Málaga’s built environment, the chosen areas should reflect interesting and typical environments of the city.

Five areas of interest for the analysis phase have been chosen, according to their interest and representativity, as well as three additional criteria:

- That they are representative of the chronological evolution of the city fabric,
- That they are spatially linked in some way,
- That they represent a variety of density types of environment.

The two first conditions are met by the fact that all five areas are placed along one of the historic radial routes of the city, which has guided an important part of the growth of Málaga over the last century and it still does.

The third criterion requires the analysis of two density variables - Floor Space Index (FSI) and Ground Space Index (GSI) - using GIS software and the information of block and buildings shape and height provided by the municipality and the Online Office of the Land Registry. In a later stage, these two variables are statistically clustered using SPSS, obtaining a map with three different density typologies.

Each of the areas are analysed in a similar way, but at the same time attending to their particularities. Part of the information is measurable and comparable among different areas, while other parts are specific for the area according to their characteristic features or come directly from observation.

The information and findings for each of the areas is presented in a homogeneous way, as shown in fig.27.
INTRODUCTION TO THE SITES

1:
Location of the area within the selection of five representative sites. Short description.

2:
Representative photographs of the area.

3:
Map of the area, with an indication of the main areas of activity.

COMPARATIVE CHARACTERIZATION AND QUANTIFICATION OF SURFACES

4:
Representative values of density (type, GSI and FSI), LST, NDVI and Albedo per site.

5:
Representation of relative surfaces:
-Private versus public,
-Buildings versus private unbuilt spaces,
-Pedestrian space versus space for traffic,
-Green areas: accessible versus not accessible.
PERCEPTUAL/SUBJECTIVE ANALYSIS

6:
Graphic representation of the outcomes of the site visits, made on the week of 6th to 12th February, 2017. It includes personal observations, as well as comments from the inhabitants.

IDENTIFICATION OF POTENTIALS

7:
Map of potentials, specific for each area, and description of the main features that have been observed in relation to a future design stage.
The generation of a Lands Surface Temperature (LST) map is the first step for understanding the general performance of the city in terms of UHI effect. The observation of this map and its comparison with other spatial features facilitates the establishment of links between temperature and other spatial features of the territory.

**GENERATION OF A LST MAP**

As a first step, the territory and Málaga’s configuration is interpreted based on a Land Surface Temperature (LST) map. In particular, the one that is analysed as part of this work corresponds to July, 9th, 2016 at 10:56 h, and is the result of a series of operations on the images taken by the satellite Landsat 8 on that day and time (USGS, 2016).

The temperature of the surface, including both the city and its surroundings, ranged on that day approximately from a minimum of 29.7ºC to a maximum of 38.0ºC. This means that there were differences of almost 9ºC, which occurred often in short distances, as it can be seen on the map (Fig. 28).

**THE NATURE OF THE UHI EFFECT IN MÁLAGA**

The definition of the UHI effect is based on the difference in temperature between the urban fabric and their rural surroundings (Oke, 1982). The observation of the Land Surface Temperature Map, however, does not allow a clear identification of this phenomenon in the case of Málaga. In this respect, although there are big differences in temperature across the city and its territory, their distribution does not respond to a concentric scheme. Instead, the higher proportion of blue (lower temperatures) seems to happen in the eastern half of the map, while the red areas (the hottest) have a greater presence towards the west. The reasons for this unexpected distribution can be found in the fact that the concept of “rural surrounding” in the case of Málaga is heterogeneous in nature.

The biggest difference between the eastern and the western part of the city is topography. The east is characterized by a marked topography, low accessibility, the presence of some single-family housing, wealth and a higher proportion of vegetation, which extends almost to the city centre (marked with (1) on the map, the Mount Gibralfaro, with its homonymous Arabic fortress, Fig. 28). The west, on the other hand, is defined by the Guadalhorce Valley and a more accessible topography. Here is where industries (either abandoned or in-use), agriculture and residential expansion takes place: an area of conflict in which vegetation is scarce. This might explain why some locations, like (2) on the map (Fig. 28), show some of the highest temperatures.

**PHYSICAL FEATURES DEFINING TEMPERATURE**

The LST map reflects some natural and artificial structures that are evident, but also reveals others that can be often overlooked. It talks about the way Málaga is placed in the territory and the way it relates with and responds to its surroundings, about potentials and dangers, past, present and future.

In the following pages, the LST map is juxtaposed with four different maps, showing different ways in which temperature can be related to space:

- LST and topography,
- LST and vegetation,
- LST and proximity to water,
- LST and land use.

![Fig. 28. LST map. Generated by the author using GIS software, based on images from the satellite Landsat 8 (09/07/2016, 10:56h)](image1)

![Fig. 29. Ortophoto of Málaga and surroundings. Source: Google Earth.](image2)

Scale 1:100,000

10 11 12

15km
RELATION BETWEEN LST AND TOPOGRAPHY

Although temperature drops down with height (Körner, 2007), in this case the effect of topography is indirect. Topography and slope difficult urbanization, and therefore high areas tend to be associated with single family houses and a higher presence of vegetation. Parameters like height, orientation and slope can define the temperature in areas of the city.

(Fig. 30 and 31)
Fig. 31. Map of topographic height. Generated by the author using GIS software, based on the Digital Elevation Model (MDT5) provided by the National Geographic Institute (Instituto Geográfico Nacional - IGN). Mean height of the ground within each urban block (as defined in Fig. 39, page 64) represented on the buildings layer.
Although it is indirectly related to topography, there are also big green areas within the city, either as public parks or within public boundaries, that have an important cooling effect. This can be seen on the LST map as well (marked as •, Fig. 32). The type and health of vegetation is important. As a counterpart, football fields made of artificial grass can be seen as hot spots. Fig. 33 shows the differences in the Normalized Difference Vegetation Index (NDVI) across Málaga. This index reflects the quantity and quality of vegetation.
Fig. 33. Vegetation index map. Generated by the author using GIS software, based on images obtained from the satellite Landsat 8 (09/07/2016, 10:56h). Mean Normalized Difference Vegetation Index (NDVI) of each urban block (as defined in Fig. 39, page 64) represented on the buildings layer.

Scale 1:100,000
Both inner water bodies and the sea have an important cooling effect. In the case of Málaga, rivers and streams have been excluded from the map (Fig. 35) due to their seasonal nature. The effect of the proximity to the Mediterranean Sea is especially significant along the western coast (Fig. 34).

**RELATION BETWEEN LST AND WATER**

Fig. 34. LST map. Generated by the author using GIS software, based on images obtained from the satellite Landsat 8 (09/07/2016, 10:56h). Mean LST of each urban block (as defined in Fig. 39, page 64) displayed on the buildings layer.

**Scale 1:100,000**

だれ0 10 11 12 15km
Fig. 35. Vicinity to water map. Generated by the author using GIS software, based on the information provided by the Municipality of Málaga on its Open data portal. For this analysis, only the Mediterranean Sea has been considered.

Scale 1:100,000

Distance to the sea (m)
- 8000 - 13000
- 4000 - 8000
- 2000 - 4000
- 1000 - 2000
- 500 - 1000
- 0 - 500
Industries are associated with extensive buildings with metal roofs that heat up rapidly. The industrial areas of the city appear to be hotter than any other built area (Fig. 36 and 37). As for low-density residential areas, they tend to be cooler.

Fig. 36. LST map. Generated by the author using GIS software, based on images obtained from the satellite Landsat 8 (09/07/2016, 10:56h). Mean LST of each urban block (as defined in Fig. 39, page 64) displayed on the buildings layer.

Scale 1:100,000
Fig. 37. Land Use map. Generated by author using GIS software, based on the information provided by the Municipality of Málaga on its Open data portal. For this analysis, only residential (low and medium/height density) and industrial uses have been considered.
CONCLUSIONS OF THE ANALYSIS OF TEMPERATURE AT THE METROPOLITAN SCALE

The analysis of temperature at the metropolitan scale showed that the following features of Málaga and its territory play an important role in determining the city’s temperature: topography (height, slope and orientation), proximity to water bodies, quantity and quality of vegetation and land use. These elements, which are in some cases structural, should be taken into consideration in any integral approach to the issues of the UHI effect.

-An immediate conclusion of the analysis is that the lack of vegetation in the surroundings of the city, especially towards the west, is resulting in extremely high temperatures along the city edge. The reforestation of some of these areas might result in an improved thermal behaviour, through the generation of a Park Cooling Island effect (PCI). This phenomenon explains the drop in temperature in big forests or parks, but also in their surroundings. However, any intervention in this direction should take into account possible conflicts with the industrial and agrarian uses of the land, as well as its formal role as the main area of expansion of the city.

-In line with the previous, within the city fabric there are several vacant lots which show a high surface temperature. These constitute areas with the potential of acquiring a “cooling” role and even being integrated with other natural systems, forming natural corridors.

-In the case of the industrial areas, it is required a specific approach that understands the characteristics of the building type that is associated to this land use. As it has been already mentioned, the extension of roofs and their material contribute greatly to heating up all industrial states. Especially in the case of the extensive industrial park to the west of the city, this heating effect is added to that of the lack of vegetation in the valley. An intervention on this building typology would focus on the roof surfaces, aiming for lighter colours or for the integration of green roofs, among other measures.

ASSESSMENT OF THE EFFECTS OF URBAN FORM ON TEMPERATURE

In addition to the previous features, urban form can also have a significant impact on the manifestation of the UHI effect.

-Within the urban fabric, significant differences in temperature have been observed. These differences, however, are generally smaller than those seen around the city. A deeper analysis in a smaller scale is required not only for understanding the possible causes of such temperature differences, but also for determining which features of the built environment are contributing to a good or bad response to high temperatures.

-In particular, the influence of density on the UHI effect can be particularly important:

-On the one hand, higher physical densities hinder the existence of green areas, soft surfaces or water bodies, which could contribute to lower the temperature of a particular area. It could be stated that, in general, highly dense fabrics require more paved surfaces. Additionally, the prospective incorporation of elements with a cooling function might find spatial limitations in dense environments.

-On the other hand, a higher social density means that more people are exposed to the negative consequences of the UHI effect, therefore contributing to a higher degree of vulnerability. Regarding a possible intervention, a greater concentration of inhabitants and the subsequent conflicts over the use of space might result in the rejection of measures.

The evaluation of the consequences of different types of density on the way the UHI effect is manifested requires the study of density through different parameters. In the next sections, physical density will be studied at a metropolitan scale using GSI and FSI. This will lead to the generation of a typology of densities and, finally, to the selection of a group of five representative areas for a more thorough analysis at a small scale.

[Right] Fig. 38. Parque del Norte. Source: author.
11.2 Density

**STUDY OF FSI/GSI**

As previously described, one of the criteria for selecting areas of interest is their morphological characteristics, specifically in relation to physical density.

There are two values that are especially useful for describing this feature: the Floor Space Index (FSI) and the Ground Space Index (GSI) (Berghauser Pont and Haupt, 2010).

The GSI is the ratio between the buildings’ footprint and the block area (Fig. 39 and 40). It represents the coverage, or relationship between built and unbuilt at ground level. By definition, it ranges from 0 to 1.

The FSI, on the other hand, is the ratio between the built-up area, considering all floors, and the block area (Fig. 39 and 41). It represents the built intensity of an area. In the case of Málaga, the maximum FSI for a block is 7.52.

Apart from the information regarding building shape and height, it is necessary to define an aggregation unit, which in this case is the urban block. The block has to include not only the parcel and the paved area around it, but also the proportional part of road. In the case of Málaga, the blocks have been determined by combining the administrative divisions of neighbourhoods (i) with a road network map (ii) (Fig. 39).

Fig. 39. Representation of the process followed in the definition of urban blocks. Source: author. Indication of the numerator and denominator used for the calculation of the GSI and FSI values. Source: Berghauser Pont and Haupt, 2010

Fig. 40. Ground Space Index (GSI) map of Málaga. Generated by the author using GIS software, based on the information provided by the Municipality of Málaga and the Online Office of the Land Registry. Information displayed on the buildings layer.

Fig. 41. Floor Space Index (FSI) map of Málaga. Generated by the author using GIS software, based on the information provided by the Municipality of Málaga and the Online Office of the Land Registry. Information displayed on the buildings layer.

Scale 1:100.000
GENERATION OF A DENSITY TYPOLOGY

As a way of allowing a more direct and intuitive interpretation of the FSI/GSI data, the information is clustered using SPSS, a statistical analysis software. The actual process is a two-step cluster analysis, which takes into account a group of variables (in this case two, FSI and GSI) and generates a typology, which represents in this case groups of urban blocks with similar characteristics (van der Hoeven and Wandl, 2015; Hausleitner and Berghauser Pont, 2017).

Despite of being a mathematical process by nature, the generation of clusters is at the same time fairly explorative. The inclusion/exclusion of particular variables, their order and, above all, the number of clusters that want to be obtained generate completely different results. There are, however, certain requirements in order to consider a typology to be valid, which include:

- That all blocks are covered by the typology,
- That the model of the clustering is, at least, fair,
- That all the variables used as inputs have a high predictor of importance, and
- That the ratio between the largest and smallest cluster is not too big in statistical terms. (Hausleitner and Berghauser Pont, 2017).

For the purpose of this work, an iterative process was followed: with a high number of clusters, the results were more accurate, but a low number of clusters allowed a more intuitive lecture of the physical density of the city. Finally, a map containing a reduced number of types (3) was considered for the visualization Málaga’s density, ensuring at the same time that the areas selected for the analysis phase represent a heterogeneity of conditions.

Each type represents a group of blocks with similar conditions: type #1 represents the lowest densities, which correspond to single-family housing and other dispersed buildings. Type #2 corresponds to industrial areas and medium-dense fabrics. Type #3, finally, represents the densest neighbourhoods: the city centre but also a big part of the housing built during the 60s and 70s, which are often distributed along corridors, as it can be seen on the map (Fig. 44).

The significance of this density typology is that it represents particular density environments, which result in different performances. In the case of the UHI effect, each environment is characterized by a different set of spatial features, which determines the extent to which it promotes higher temperatures and facilitates the adaptation of dwellers to heat.

The selection of areas for the analysis at the meso- and microscale should therefore take into account this typology, in order to guarantee the highest degree of representativeness.

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean FSI</th>
<th>Mean GSI</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>0.43</td>
<td>0.17</td>
<td>34.1%</td>
</tr>
<tr>
<td>#2</td>
<td>1.02</td>
<td>0.46</td>
<td>43.7%</td>
</tr>
<tr>
<td>#3</td>
<td>2.96</td>
<td>0.52</td>
<td>22.3%</td>
</tr>
</tbody>
</table>

Fig. 42. Mean FSI and GSI for each density type, and relative size of cluster.

Fig. 43. Spacemate diagram showing the GSI and FSI values of each block, coloured according to their belonging to each of the three density types. Elaborated by the author using SPSS software.

Fig. 44. Map of density typology. Generated by the author using SPSS, based on previous GSI and FSI maps. For the selection of areas for the analysis phase, please refer to the following page.

Scale 1:100.000
11.3 SITE SELECTION

CRITERIA FOR THE SELECTION OF AREAS

As previously explained, the transition to a smaller scale for the analysis requires the selection of a number of areas that can be representative of certain conditions. From the typology map, it can be seen that there are areas that show a much higher density than others, areas where the ability of citizens to regulate their thermal comfort is probably lower and, in general, where the issues of the Net/Self conflict become very evident. If the discrepancy between livability and sustainability has density as a determining variable, then choosing a group of locations in which this variable becomes extreme can be a logical way of predicting the conflict and a valid criterion for selecting an intervention site.

The approach at this point, however, is not to focus on those areas that represent the biggest issues, but to take a number of locations in which a wide variety of conditions take place. Not only in terms of different densities, but also taking into account other externalities, their chronology, their position within Málaga and their surroundings, among others.

Such an approach results in an analysis that represents a heterogeneity of conditions and a multiplicity of potentials, which could probably be transferred to other areas of the city at a later stage.

The analysis at the metropolitan scale shows that Málaga, and its territory, is characterized by a distinction between the east and the west. While the east has always been affected by its topographical nature, the west is defined by the valley and its uses, representing at the same time Málaga’s natural growth area (at least according to contemporary plans). It is also here where the impact of the UHI effect becomes more evident, as it can be seen on the Land Surface Temperature map. For all these reasons, the five areas selected for the site analysis correspond to this “half” of Málaga, showing at the same time a linear progression, from the city centre to the valley, which represents a chronological evolution.

These five areas are placed along a same corridor, which corresponds to one of the traditional routes between city and countryside that later defined Málaga’s growth. As in the case of other main corridors, and as it is shown on the typology map, some of the higher densities of the city (type #3) occur along this axis. At the same time, however, the other two density types are also represented along this route, specially towards the edge of the city, where the new developments are currently taking place. This offers an interesting overview on different morphological conditions, which also corresponds to a significant variation on the Land Surface Temperature.

Each of the areas, finally, offers a particular combination of conditions, not only environmental but also social and economic, that defines not only their current performance (in terms of sustainability and livability) but also their potentials. In the individual analysis of each of these locations, some parameters can be quantified and compared to others, but other characteristics are unique and need to be represented independently.

(left) Fig. 45. Selection of areas within the density typology map. Elaborated by the author.

(left) Fig. 46. Map of the five areas considered for analysis. Source: author.
La Trinidad, together with El Perchel, is one of the historic quarters of the city. Its origins date back to the Phoenician age, although it gained importance as a suburb outside of the walls of the city during the Muslim occupation, as the place where different types of industrial activities used to take place. During the late 19th century, La Trinidad became a working-class neighbourhood, the place of residence of many of the workers that laboured in the successful industry of that period. During this time, the relative crowdedness and unhygienic conditions of the neighbourhood were seen as an issue, and in consequence there were numerous attempts to regularize blocks, open wider streets and integrate the area with the rest of the city. Although some measures were implemented, La Trinidad could not evade its image as “stopper” to the growth of the city. The strong transformation of its border during the second half of the 20th century has only contributed to a further isolation of the place. This isolation, which is still present, gave La Trinidad its unique character but, on the other hand, is a stumbling block in any attempt to improve the social conditions of its inhabitants (OMAU, 2015).
Fig. 50: Map of La Trinidad. Current state.

Analysis:
- Area delimitation
- Commercial activity
- Public facility
- Public activity

Scale 1:4,000

Legend:
- 10
- 10,1
- 10,2
- 10,5 km
Gamarra and Haza del Campillo are two well-delimited neighbourhoods that are adjacent to each other. Although the main focus will be on Gamarra, as it presents more urgent issues and a higher social density than Haza del Campillo, it is interesting to consider both areas for analysis. Both neighbourhoods respond to unitary projects, however, the 24 years that separate their construction (Haza del Campillo, was built in 1944 and Gamarra in 1968) have propitiated multiple differences in image, structure and character.

Haza del Campillo is lower in density and can be perceived as a village that has been “trapped” in the middle of the city. Its design, in fact, tried to promote this idea by imposing a “traditional” appearance on an otherwise rational architecture, and also by generating well-defined streets and squares. As a result, this neighbourhood enjoys a good provision of public and qualified spaces, that are used not only by its inhabitants, but also by dwellers coming from other areas.

The contrast with Gamarra is evident, and can be described through the differences in building scale and their relation with the surrounding open space. In Gamarra, the unbuilt space is not the result of design but the negative space in between towers, a continuum that lacks of definition, hierarchy and other function other than parking. The higher density of the neighbourhood and the possibilities of temporary parking have resulted in a very vibrant commercial life.
Fig. 54. Map of Gamarra and Haza del Campillo
NUEVA MÁLAGA

Nueva Málaga is, in reality, the general denomination that is commonly applied to a group of neighbourhoods (like Nueva Málaga, Los Millones, Castillejos) that lie along the eastern border of Parque del Norte (“North Park”). This park is actually a “recent” incorporation to the district, and was previously a big vacant area with no specific function. Its location corresponds to the basin of Arroyo del Cuarto, a stream that runs currently underground and that crosses the city from north to south. Having a very strong longitudinal component and a certain topography, Parque del Norte includes different areas with specific functions and qualities.

Until the park was built, the western edge of the neighbourhood was conceived as a back side, and therefore today all the main commercial functions of the area tend to locate along the neighbourhood’s main axis (Magistrado Salvador Barbera street). The area presents a high level of density and a certain topographic component. Some residual spaces are often qualified as small gardens.
Fig. 58. Map of Nueva Málaga

Area delimitation
Commercial activity

Public facility
Public activity

Scale 1:4,000
0 0,1 0,2 0,5 km

10 10,1 10,2 10,5 km
Camino de Antequera designates an old area of expansion of the city, which developed along the axis formerly known as “road to Antequera”. Between the 20s and 40s, this was the location chosen by multiple wealthy families to build their villas, which in some cases enjoy today architectural protection. The whole area is formally designated as “garden city type”, which means that a certain densification is allowed with the condition (among others) that perimeter private gardens are maintained as a distinctive element.

Although a certain heterogeneity is already evident in terms of building heights, the neighbourhood is still perceived as low-density and lacks of any mix of uses within its borders. The presence of the MA-20 highway was solved by the addition of a roof, which offers continuity between the two halves of the neighbourhood.
Fig. 62. Map of Camino de Antequera.
Torre Atalaya belongs to the district of Teatinos, the area where most of the Málaga’s current urban expansion is taking place. The area is, in general, characterized by a complete development of urbanization but an uneven presence of buildings. It is, in any case, the district that stays in the public imagination as good urban environment and best possible building quality. The place to be for young families with children.

Torre Atalaya designates, in particular, a series of private communities that are homogeneous in appearance. The buildings are situated perpendicular to the main axis and enclose private common areas with gardens, paved platforms and swimming pools. The roads to the north and south of this neighbourhood are two main distributors of flows from the city to other areas of expansion. The treatment given to these avenues is very similar: great width, high provision of space for traffic and aseptic urbanization.
Fig. 66. Map of Torre Atalaya

Scale 1:4,000

- Area delimitation
- Commercial activity
- Public facility
- Public activity

0, 0,1, 0,2, 0,5km
12.2 COMPARATIVE CHARACTERIZATION

As previously explained, the selection of sites attempts to be a representative sample of different density conditions. In that regard, the definition of a density typology was useful for a first identification of density trends. Each of the sites represents, however, a unique distribution of built and unbuilt spaces, a singular combination of masses of different sizes, functions and qualities. The representation and juxtaposition of maps enables comparisons and provides a base for the understanding of the sites’ intrinsic differences.

In relation to the built form, the GSI and FSI values of each block continue to be a helpful indicator of physical density, and can therefore be studied and compared in detail. An additional set of useful indicators, which can be obtained and mapped via remote sensing, include the Normalized Difference Vegetation Index (NDVI), the albedo and the Land Surface Temperature (LST). The latest has been already represented at metropolitan level.

1. A certain correlation between the values of temperature for each urban block in two different moments of the year (mid summer and late autumn, in this case) reinforces the idea that it is the coincidence of multiple physical factors what determines, to great extent, the final LST value (Fig. 65). These physical factors can be related to the position of each of the blocks in relation to other natural or urban elements (for instance their proximity to water bodies, height or vicinity to industrial areas, as seen before) or can be linked to any characteristics of the fabrics themselves. In any case, the existence of a strong link between temperature and place, which is intrinsic to their nature, confirms the adequacy of mapping and comparing the LST values of each of the sites.

![Fig. 67. Example of heterogeneity at Camino de Antequera. Source: author.](left)

![Fig. 68. Linear regression analysis of the temperature of each urban block on two different days (July 9th and November 14th, 2016). Generated by the author based on LST maps, using SPSS software.](right)
Fig. 69. Comparative representation of the density typology, GSI and FSI for each of the five areas. Elaborated by the author as explained in pages 64 to 67.
Fig. 70. Comparative representation of the values of LST, NDVI and albedo for each of the five areas. Elaborated by the author using GIS software.
The comparative analysis of these characteristic indicators can lead to some initial conclusions:

- Regarding the density typology, the proportion of blocks that belong to the density type #3 (the densest) increases with the proximity to the city centre. These areas might have stronger limitations that are associated to higher physical densities.

- As for the GSI, the lowest values can be seen in Camino de Antequera (single-family housing) and Nueva Málaga and Gamarra (free-standing buildings). The highest values can be found in some areas of La Trinidad.

- In terms of the FSI, the highest values belong to Nueva Málaga and Gamarra, while Torre Atalaya and La Trinidad present the lowest ones.

The GSI and FSI values per block are represented in Fig. 71, according to their location within the five areas of analysis. The Spacemate graph easily depicts big distinctions among fabrics, which could lead to different design approaches.

- Regarding the areas’ surface temperature, it is also possible to identify a gradient from the city centre to the outskirts. This trend becomes already noticeable in some spots in Nueva Málaga and Camino de Antequera, and is fully evident in Torre Atalaya.

- The gradient in temperature is accompanied by (and partially explained by) higher levels of NDVI in the peripheral areas of the city.

Fig. 72 presents a summary of the mean values that are present in each of the sites. Being average values, they should be used as a way of identifying general differences among the five areas. In that respect, they are more related to a meso-scale understanding of the city, while the identification of concrete limitations and potentials still requires a deeper analysis of their materialisation in the micro-scale.

Fig. 71. GSI and FSI values per block for each of the five areas of study. Elaborated by the author based on previous data.
**Fig. 72.** Mean values of GSI, FSI (Sept. 2016), LST, NDVI and Albedo (July 7th, 2016) for each of the sites. Elaborated by the author based on previous data.

<table>
<thead>
<tr>
<th>Site</th>
<th>GSI</th>
<th>FSI</th>
<th>LST</th>
<th>NDVI</th>
<th>Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA TRINIDAD</td>
<td>0.56</td>
<td>1.64</td>
<td>35.87</td>
<td>0.086</td>
<td>0.176</td>
</tr>
<tr>
<td>GAMARRA</td>
<td>0.29</td>
<td>2.58</td>
<td>36.11</td>
<td>0.076</td>
<td>-0.170</td>
</tr>
<tr>
<td>HAZA DEL CAMPILLO</td>
<td>0.48</td>
<td>0.84</td>
<td>36.17</td>
<td>0.106</td>
<td>-0.178</td>
</tr>
<tr>
<td>NUEVA MALAGA</td>
<td>0.32</td>
<td>2.24</td>
<td>35.50</td>
<td>0.098</td>
<td>-0.156</td>
</tr>
<tr>
<td>CAMINO DE ANTEQUERA</td>
<td>0.31</td>
<td>1.10</td>
<td>35.73</td>
<td>0.114</td>
<td>-0.170</td>
</tr>
<tr>
<td>TORRE ATALAYA</td>
<td>0.19</td>
<td>1.01</td>
<td>34.87</td>
<td>0.131</td>
<td>-0.179</td>
</tr>
</tbody>
</table>
13.3 QUANTIFICATION OF SURFACES

As previously explained, the comparative analysis of density parameters provides an initial understanding on the main physical differences between fabrics. However, even within blocks of similar characteristics, there is space for multiple materialisations, which would result in complete different levels of NDVI, albedo or temperature, for instance. This goes in line with the idea that the physical characteristics of surfaces have a very strong influence in the extent to which the UHI effect manifests (van der Hoeven & Wandl, 2013). In other words, the quantification of surfaces provides the necessary information for understanding the urgencies, potentials and limitations that are present in each of the sites.

Beyond the physical characteristics of the surfaces, their use and especially their ownership regime can limit or boost certain type of interventions. While the measurement of GSI takes only into account the building shape, very often there are private areas inside or around buildings, which cannot have the same treatment as a completely public ground. The mapping of the private and public ground is therefore of great importance. Within the private realm, the distribution of built and unbuilt space is also relevant, because the later still has the potential of being intervened or materialised in different ways. Within the public realm, the main distinction is made between pedestrian areas and space for traffic. As indicated in the theoretical framework section, spaces for cars tend to heat rapidly, what makes this one of the physical factors that have a great influence on the UHI effect (page 43). The presence of vegetation is also relevant, and therefore is also included in the quantification of surfaces.

Finally, an indication of the amount of roofs and façades in each of the sites is added. This can be an interesting indicator, given the fact that some of the interventions to palliate the UHI effect can be projected on the roofs and façades on buildings. Likewise, the presence of a higher ratio of façades per surface unit tends results in a stronger UHI effect (van der Hoeven & Wandl, 2013) as it results in a higher amount of surface that is exposed to the surroundings and the sky, working both as a collector and a radiator. Additionally, areas with a high façade ratio are likely to have low sky-view factors, which also affects the UHI effect (see page 43) (Fig. 74)

![Fig. 74. Amount of roof and façade surface in each of the sites, as well as ratio between of façade and ground surface. Elaborated by the author using GIS software.](image)

<table>
<thead>
<tr>
<th></th>
<th>Roofs surface (m²)</th>
<th>Façade surface (m²)</th>
<th>Façade ratio (m²/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Trinidad</td>
<td>83784</td>
<td>145687</td>
<td>952</td>
</tr>
<tr>
<td>Gamarra</td>
<td>20131</td>
<td>84871</td>
<td>670</td>
</tr>
<tr>
<td>Haza Campillo</td>
<td>30850</td>
<td>47253</td>
<td>1238</td>
</tr>
<tr>
<td>Nueva Málaga</td>
<td>38454</td>
<td>147662</td>
<td>1240</td>
</tr>
<tr>
<td>C. de Antequera</td>
<td>109339</td>
<td>291374</td>
<td>833</td>
</tr>
<tr>
<td>Torre Atalaya</td>
<td>66091</td>
<td>148738</td>
<td>441</td>
</tr>
</tbody>
</table>

![Fig. 73. Interstitial garden at Nueva Málaga. Source: author.](image)
The quantification and comparison of public and private areas reveal important differences among the sites. Some of the main conclusions are:

- A higher proportion of public space can be found in Nueva Málaga and Gamarra. In the first case, this becomes logic as the extension of Parque del Norte is computed.

- The higher proportion of private space in La Trinidad goes in line with its higher GSI. This means that, in this area, most of the building plot tends to be occupied by buildings. On the other hand, Camino de Antequera and Torre Atalaya show low values of GSI but a high proportion of private spaces. It is in these sites where most private gardens can be found.

![Diagram of public and private areas in the sites](image-url)
The private realm can be understood as a space with the potential of being intervened. This makes it necessary to depict not only the built areas, but also the unbuilt private spaces.

- In Torre Atalaya the high proportion of private unbuilt space contrasts with the amount of space that is occupied by buildings. These unbuilt spaces have a semi-private function and concentrate in several large, partially enclosed gardens for their respective communities.

- In Camino de Antequera, the abundance of private gardens manifests as small private surfaces around the buildings. It is these spaces, with their fences, what defines the clear orthogonal structure of street, and not the buildings, which have heterogeneous shapes and positions.

- In Gamarra and Haza del Campillo, the presence of unbuilt private areas is almost testimonial. This can be seen as an absence of spaces of intermediate privacy. This tendency is also present in Nueva Málaga, although in that case the presence of schools and other facilities in the surroundings can be perceived in the map.

- Finally, most of the unbuilt private surface in La Trinidad corresponds to plots that are currently vacant and need still to be developed. That explains the irregular distribution of these surfaces, although it is possible to find “clusters” of available space in some parts of the neighbourhood, especially on its south-west area. In other cases, the unbuilt private spaces of La Trinidad correspond to private or semi-private courtyards.

Fig. 76. Comparative representation of the built and unbuilt surfaces in each of the sites. Elaborated by the author using the sites’ maps.
Within the public realm, the distinction between pedestrian areas and spaces for traffic has a significant impact in understanding urgencies and potentials. Some of the main conclusions that derive from the comparative analysis are:

- In all sites the space for traffic is abundant, and even in the case of La Trinidad, where most of the streets seem to be pedestrian, cars have access for parking purposes.

- The imbalance between traffic and pedestrian spaces is more evident in Gamarra, where the abundance of open space is mostly dedicated to traffic and parking functions.

- In Torre Atalaya the space for pedestrian use tends to be linear and wider. However, the quality of these pedestrian spaces make these surfaces uncomfortable.

**Fig. 77.** Comparative representation of the space dedicated to traffic and pedestrians in each of the sites. Elaborated by the author using the sites’ maps.
Regarding the amount of green areas, a distinction is made between accessible and not accessible surfaces. This acknowledges the fact that the positive impact of big vegetated areas can be perceived even outside the area’s boundaries (Kleerekoper, 2016).

- The lack of accessible green spaces is worrying in La Trinidad, Gamarra and Camino de Antequera. In the case of La Trinidad and Gamarra, this absence of green is not even compensated with private green.

- In Torre Atalaya, the amount of both accessible and not accessible green areas is high. This correlates with the highest mean NDVI value for the area, and a lower overall LST.

- In Camino de Antequera, the linear public space above the tunnel stands out as an area with a limited amount of green surface. Regarding the not accessible green, it becomes evident that not all private parcels have been qualified as gardens.

- The map of green accessible areas in Haza del Campillo shows an interesting sequence of public, qualified spaces that crosses the neighbourhood diagonally.

- One of the characteristics of Nueva Málaga is that, besides its proximity to a big park, there are small interstitial gardens distributed all around the fabric.

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**Fig. 78.** Comparative representation of the green (accessible and not accessible) surfaces in each of the sites. Elaborated by the author using the sites’ maps.
The final layer of information has to do with the concrete qualities of space. This are often subjective and related to the position of each of the areas in the common imagination, and subject of different interpretations according to the perspective (inhabitant or visitor). By means of site visits, direct observation and interviews it is possible to compose a collage of references, which together represent an approach to the different atmospheres of each site.

Fig. 79. Graphic representation of the outcomes of the site visits, made on the week of 6th to 12th February, 2017. It includes personal observations, as well as comments from the inhabitants.
The design of Haza del Campillo combines modernist principles with a strong vernacular language. Traditional elements of public space, like well-defined streets and squares, have been given great importance.

"Town square" - defined by its shape, its concentration of public functions (church, social centre) and concrete street elements (fountain).

HAZA DEL CAMPILLO

There are too many vacant lots, full of rubbish and rats."

"This is a nice place, although not in summer. These two vacant lots have been like this for too long."

Multiple commercial activity at ground level.

"This is a good neighbourhood to live in. There is a bit of everything and it is not far from the city centre. There are some parks in the vicinity."

Plaza Basconia acts as the centre of the neighbourhood, a space with an unequivocal function; the concentration and distribution of traffic in the search of a parking space.

The traditional "coralón" a building type in which family units are arranged around a common courtyard, which is normally carefully maintained and decorated.

GAMARRA

LA TRINIDAD
12.5 IDENTIFICATION OF POTENTIALS

LA TRINIDAD

Fig. 80: Main site potentials. Elaborated by the author.
La Trinidad is characterized by a relatively high GSI, if compared to other areas. However, currently a number of plots are vacant, and in general the rate of demolition/construction in this area of the city is high (which is also a characteristic that is present in the historical centre of Málaga). This vacant land has the potential of being transformed into small green areas, or to be built in a way that certain cooling functions can be incorporated into the building.

There are a few areas within the site in which people gather. Despite of their small scale, these areas have still a big potential for improvement, with the incorporation of shading elements or water, among other solutions.

“El corralón” is the traditional building type of the area, and is nowadays seen as a very outdated building type that does not meet current standards of livability. Its courtyards, however, can be seen as an inspiration for future buildings in the area: an important part of the social life of dwellers takes place within these inner spaces, which also help in keeping the houses cool and ventilated.
Fig. 81. Main site potentials. Elaborated by the author.
The design of Haza del Campillo included a series of transitions between public spaces of different sizes and functions. This structure of public areas is one of its main assets, that could be transferred to Gamarra as well. The interconnection of both neighbourhoods through public space would guarantee accessibility in both directions. This would be also beneficial for Gamarra’s strong commercial program.

Gamarra was designed with a good provision of open space between buildings. Most of it, however, is now dedicated to the circulation of vehicles and parking. Although it is understood that this is seen as an important function by dwellers and shop owners, it also constitutes a big potential for the transformation of part of this spaces into pedestrian surfaces.

The biggest open space of Gamarra, which includes a water fountain, is isolated and inaccessible. This area has the potential of being transformed into the neighbourhood’s new representative centre, a fresh and livable public space in connection with the rest of squares in Haza del Campillo.

The position of the buildings influences the way open space is seen in the neighbourhood, specifically in relation to shading and temperature. The two main corridors, which run north to south, receive more sunlight than the transversal ones, which due to the height of the buildings are almost permanently shadowed.
Fig. 82. Main site potentials. Elaborated by the author.
It is possible to observe different functions and atmospheres along Parque del Norte. This characteristic is seen as positive, as it allows a more domestic perception of the park by citizens. Its variety of spatial features also allows different degrees of adaptation to temperature. Such a heterogeneous character should therefore be maintained and enhanced.

The reduction or redistribution of traffic would allow the extension of the park towards the neighbourhood. Currently, some of its inner areas contain small gardens, which have a positive cooling effect.

The area presents a marked topography and has traditionally served as the riverbed of a stream (Arroyo del Cuarto), which is now underground. This situation represents a potential for the reintegration of (intermittent) water into the green system, which could result in a stronger cooling power and a higher livability in the area. The feasibility of this approach in such a dry context should be studied carefully.
Fig. 83. Main site potentials. Elaborated by the author.
The area of Camino de Antequera is defined by a mix of different building types: both single-family houses and multi-family buildings are represented. In the long term, the alteration of the area’s physical density is more feasible than in the other four cases.

In terms of ownership, most of the neighbourhood’s ground surface is private. There are multiple gardens, however, most of these are within property limits. All that vegetation has a cooling effect, however, it is not accessible green, and its positive effects on the general livability of the area is therefore diminished. The roof over the MA-20 highway constitutes a space with the potential of being transformed into a qualified public area.
TORRE ATALAYA

Fig. 84. Main site potentials. Elaborated by the author.
In this area, public space is identified as undetermined and vast. Its design and dimensions seems to be subordinated to the scale of the car. Compared to older multi-family neighbourhoods, the variety of public areas is poor and, in general, the provision of shade tends to be insufficient. The scale of these areas, however, constitutes a potential for the exploration of multiple approaches to thermal comfort.

The most livable spaces are within the private property. They normally include a variety of surfaces, trees and water, both as fountains and swimming pools. All these elements have a cooling effect that is visible in the LST map, and work as “oases” of livability. Their integration of these spaces into the public realm could be considered as a potential, although such an intervention should understand and consider the difficulties of working with privately owned spaces.
12.6 CONCLUSIONS

Morphology determines, to a great extent, the way an urban environment performs according to multiple aspects. Thermal comfort, and in particular the theory of the Urban Heat Island effect, is one of those lenses that allow us to have a particular view on specific features of a city. In the case of Málaga, the attention was put on density.

The five areas were selected with respect to their representativeness as different density environments. The outcome of their analysis shows that each of them contains a particular set of spatial features, problems and potentials that would hinder any attempt to look for universal solutions.

Any intervention on one of these areas, however, should try to balance the acknowledgement of their uniqueness with the need of transferability. In that respect, the identification of typical density environments facilitates the search for common features and connections.

The conclusions of the analysis at the meso- and microscale contrast with those of the analysis at a metropolitan level. In that case, the interpretation of the variations of temperature across the city calls for the adoption of a more systemic approach: the reforestation of the surroundings of the city or the attention to the general land use are two of the possibilities mentioned at this scale.

Designing for the UHI effect, therefore, requires a balance between the need for a structural vision and the understanding of the particularities of each area. The insertion of the different interventions at a neighbourhood scale within a system can strengthen their positive effects and facilitate the adoption of similar measures in other areas of the city.
Fig. 85. Street in La Trinidad. Source: author.
Fig. 86. Street in Gamarra. Source: author.

Fig. 87. Public square in Haza del Campillo. Source: author.
Fig. 88. Nueva Madíga from Parque del Norte. Source: author.
Fig. 89. Street in Camino de Antequera. Source: author
Fig. 90. Main avenue in Torre Atalaya. Source: author
The existing literature on the UHI effect refers to which physical elements of urban environments can be modified in order to gain a better thermal performance. Kleerekoper (2016), for instance, provides an inventory of possible interventions, which are different in nature and can be classified in four main categories: vegetation, water, urban geometry and material and colour.

Higuerra García (1997), on the other hand, states that any spatial intervention aiming for a certain bioclimatic effect can occur on different urban structures, not only the road network or the system of open spaces, but also at block, parcel or building level. When designing for a better response to the UHI effect, the aim is therefore not only the street system and the system of public spaces, but also the private realm.

Such a variety of physical elements and structures leads to multiple possibilities with respect to design. This multiplicity of approaches can be very well felt in the city, where often several cooling elements are combined in the same space in order to generate a perceivable cooling effect.

**EVOLUTION OF THERMAL ADAPTATION IN MÁLAGA: THE ROLE OF DESIGN**

The traditional Arabic architecture, which is present in Málaga in the palatial fortification of La Alcazaba, is characterized by the use of enclosed gardens, flowing water, dense vegetation and permeable façades in order to create a cool inner environment (Fig. 91). Here, the enclosure of the space provides protection from the external conditions and shade, while at the same time the combination of running water and irrigated plants contributes to a lower inner temperature due to evapotranspiration. This effect is naturally fostered and boosted through the facilitation of wind flows.

It is therefore through the combination of multiple design principles that an optimal qualification of spaces can be achieved. During centuries this effort belonged mainly to the private realm, especially through the creation of courtyards, which have been present not only in relevant buildings but also in the popular architecture. Courtyards are, in fact, one example of architectural element that has a strong potential for generating cool environments (Taleghani, 2014). With the emergence of bourgeoisie in the 19th century, new external spaces for social representation had to be
generated and designed, and started to appear as scattered squares and boulevards around the city. These spaces were as well qualified with vegetation and fountains, among other elements (Fig. 92). In the end, these spaces represent the concern of extending some of the qualities of inner spaces to the exterior, expanding the dimension of livability from the very private realm to the whole city. Still today, the provision of measures against heat is sometimes a main driver for the design of exterior urban spaces, as in the case of the recent renovation of Málaga’s waterfront (Fig. 93).

The appearance of rationalist urbanism that occurred in the 20th century lead to the elimination of any sort of transition between inner and outer spaces. In the open city urban model, the negative space of the free-standing buildings had to provide their inhabitants with all the qualities that are complementary to those of the domestic spaces, which, especially in the case of badly-isolated buildings, include thermally comfortable exterior spaces. The vast majority of neighbourhoods built during this period in Málaga failed to do so, and as a response, contemporary planning favours today the construction of enclosed gated communities, in which the inner semi-private spaces, which include gardens, some trees and always a swimming pool, seems to be an updated and over-scaled version of the Arabic garden.

Salvador Moreno Peralta, one of the three main authors of the urban plan of 1983, describes in his report “Del vacío a lo público: sombras y luces del urbanismo democrático” (“From void to public space: shadows and lights of the urbanism of democracy”, 2014) some of the challenges that urban planners and designers had to face over the last decades in Málaga. In this report, it is particularly interesting to focus on the similarities and contrasts between two different urban models: the pre-democratic and the democratic city. The first was characterized by an intense and uncontrolled urbanization and a complete abandonment of public space. In these neighbourhoods, which are mostly peripheral and mono-functional (Gamarra and Nueva Málaga are two examples), the spaces in-between buildings had urgently to be taken to the minimum standards of accessibility and function. The second model, or the “city of democracy”, was elaborated based on the empiric evaluation of the inherited city and is today is can be seen in contrast as diverse and
“formally brilliant” (as in Torre Atalaya). Surprisingly, despite these profound differences and according to the author, both models show an identical attitude towards urbanism, which he denominates “a lack of desire for design”. This attitude would explain the fact that the same pieces of urban furniture, playgrounds and palm trees can be found in every available space in the city, no matter their particular constraints or characteristics. As Moreno states, the result of this attitude has been “a vulgar, homogeneous, egalitarian and impersonal system of public spaces (...) to the point that even if we move from one to other [neighbourhood], we always feel to be in the same one. If before they looked identical in the lacerant coincidence of infraurbanization, now they do so in the decent but aseptic correctness of their urban treatment” (p. 10). This “lack of desire for design” also explains the current tendency to over-size open space in the areas of expansion of the city: a maximum parameter of density (60 to 75 dwellings per hectare) is set and applied without any reflection on the resulting qualities, leading to an inhospitable landscape of underused boulevards in the middle of a chequerboard of private condominiums.

This “unwillingness to design” defines most of Málaga. Not its centre, which acts as the only space of representation of the city and is continuously re-designed, centring all the attention of architects or urbanists. But the rest of the city, in its peripheral condition, suffers the consequences of a fast and disaffected urban design. This attitude explains its generally insufficient aesthetic quality, which was already mentioned in the “motivation” chapter of this work as one of the first, maybe too-obvious observations, but also other additional malfunctions and, certainly, the perceived (and proven) poor thermal behaviour of Málaga’s urban fabric. The proliferation of palm trees around the city demonstrates that “lack of care” and a complete disregard of the city’s particular needs, especially regarding the UHI effect, but also represents the essence of the sustainability/livability imbalance. In the end, palm trees are easy to plant and maintain and do not require much irrigation, therefore being a very sustainable option (more in the economic sustainability side), however, their impact on the livability of public space in the southern context is obviously negative.
The previous reflection on the role of design determines, to a great extent, the definition of the design framework. Based on the theory of the UHI effect, the goal is to find a balance between two different tendencies: on the one hand, the elaboration of a catalogue of solutions, or a toolbox, which could be applied to multiple fabrics around the city; on the other, the isolation of each of the sites and the generation of a particular response for their specific set of problems. The first is in risk of ignoring the constraints of each particular environment, becoming too homogeneous or impersonal and thus repeating the same mistakes described in the previous paragraph. The second overlooks the benefits of a certain transferability and the possibilities of defining a systemic approach.

The design framework consists, instead, on the generation of a metropolitan-scale system of vegetated corridors and the exploration of its different spatial manifestations in each site, according to their specific characteristics.

This system accommodates, by itself, some powerful cooling functions, such as the generation of a Park Cool Island effect (PCI) or the facilitation of wind infiltration from the sea. More importantly, however, it also enables the implementation of a city-scale water system, capable of purifying, storing and discharging water and using it for an enhanced cooling down of the city.

As in any system, and especially in the case of water, there is a certain hierarchy in the way its different elements are related, which also translates in the way they are presented. In this case it is important to notice, however, that these two levels of intervention are not two separated projects, but two different scales of an unitary vision, in which also the interventions in the small scale are important elements in the articulation of the city-scale system.

Each of the sub-interventions represent one exploration of how different UHI design principles can be developed in one specific context. The ultimate goal, however, is to achieve a higher and more balanced performance of urban spaces from the point of view of sustainability and livability. This implies that there is a duality in the way these sub-interventions need to be evaluated: on the one hand, it is required to know if each design would have a positive contribution to reducing the UHI effect in the area. This can be estimated by measuring the changes in the physical elements that affect the UHI effect, according to van der Hoeven and Wandl (2013) [see pages 42 to 45]. On the other hand, in order to evaluate if a greater sustainability/livability balance is reached, it is possible to evaluate the positive or negative changes in some selected indicators.
EVALUATION FRAMEWORK

Each of the interventions in the small scale is evaluated with respect to their impact in relation to the UHI effect and to their contribution to a higher and more balance sustainability and livability.

Regarding the UHI effect, the evaluation takes into account the eight physical elements of urban environments described in the theoretical framework (see pages 42 to 45):

- Vegetation: its value is positive if green surfaces are added, or if additional vegetation is added to existing green areas.
- Surface hardening index: its value is positive when the overall permeability of the ground increases (by means of additional vegetation or more permeable paving, for instance).
- Albedo: its value is positive when the new materials that are introduced have a higher albedo, as compared to the previous state.
- Space for traffic: its value is positive when the space dedicated to vehicles decreases.
- Building skin: its value is positive if the amount of façades and roofs decreases in the area.
- Open water bodies: its value is positive if the total area dedicated to superficial water is higher.
- Sky-view factor: its value is positive if there is a lower presence of physical elements blocking the view of the sky. These can include buildings (which block the access to the sky at certain angles) or lighter elements, such as trees or pergolas.
- Shadow: its value is positive when there is a higher presence of elements capable of casting shadows.

The evaluation of the impact on sustainability and livability is highly complex, as each of these two categories include several indicators. As an approximation, however, eight of the indicators presented in pages 32 to 35 have been selected for a similar evaluation:

Sustainability:

- Energy savings on long leisure travel: its value is positive when it is understood that the resulting intervention provides an attractive environment for leisure activities.
- Quality of urban ecosystems: its value is positive when the intervention results in a richer environment for multiple living beings (including flora and fauna).
- Presence of public services: its value is positive when the intervention incorporates functions that are of public use.
- Sense of community: its value is positive when the intervention generates a stronger identification with the neighbourhood.
- Social integration: its value is positive when the resulting qualities are expected to facilitate the interaction of different social groups.
- Likeliness of doing physical activity: its value is positive when a high level of environmental comfort is achieved.
- Availability and accessibility to public open space: its value is positive when different types of open public spaces are added to the public realm.
- General satisfaction with the neighbourhood: its value is positive when the intervention is expected to be seen by dwellers as a positive change.

All of the previous indicators, including those belonging to the UHI section, are evaluated according to the following scale (Fig. 94):

Fig. 94: Rating scale for the evaluation of the small-scale interventions. Elaborated by the author.
Fig. 95: Water fountain in Parque del Norte. Source: author.
14 DESIGN INTERVENTION

14.1 DESIGN OF A METROPOLITAN SYSTEM

The design of a system at a metropolitan level enables the implementation of different cooling principles, and could therefore be explained from different points of view. Due to its technical importance, however, it is interesting to use water as the starting guiding thread. The scheme of the water system (see next page, Fig. 96) also reflects the interconnection between different scales and elements of the private and public realms.

Water is constantly cited in the UHI literature as an element with a very strong cooling power (see theoretical framework). Due to Málaga’s water scarcity, however, using water as a general measure against the UHI effect is not feasible without a system capable of cleaning, storing and reusing water. From the point of view of the Urban Heat Island issue, the most relevant manifestation of this system is its use in public spaces (D), however, this would not be possible without the support on the rest of the water infrastructure, in charge of the collection, treatment, transportation, storage and discharge. The cooling power of water also extends to these additional elements of the system, either directly or indirectly, through the evapotranspiration processes that occur in the case of irrigated plants.

Fig. 95. Pedro Luis Alonso gardens. Source: author.
Fig. 96. Elements conforming the metropolitan system, according to their water function. Elaborated by the author.
A - GREYWATER COLLECTION

In order to guarantee a constant availability of water throughout the year, the collection of rainwater is combined with the collection of domestic greywater. It is important to notice that, in old buildings, both sewage collectors might not be separated. The addition of green roofs delays the discharge of rainwater into the system and helps to cool down the surroundings.

B - GREYWATER TREATMENT

A Vertical Flow Helophyte Filter can be used in order to eliminate most of the bacteria and pollutants from domestic greywater and runoff water. These filters use specific species of plants (such as marsh plants) with an extensive root system. It takes around three days to the water to be filtered and cleaned. It is possible to plan for big, centralized helophyte filters or for smaller solutions placed in streets or gardens.

C - INTEGRATION AT STREET LEVEL

Once water has been cleaned, it is possible to integrate its flow in the street system, taking into account their section and topographic conditions. Running water cools down the environment without the risks that are associated to still, superficial water bodies. The addition of vegetated strips helps to buffer runoff water in case of heavy rain and qualifies these urban spaces.

D - STORAGE AND USE IN PUBLIC SPACE

In order to assure the availability of water throughout the year, it is necessary to add a certain storage capacity to the system. In the proposed model, the situation of underground water tanks below public spaces allows the cyclic use of part of this water for their cooling down. This could be done in different ways: incorporating disperse water, as in the diagram, or also through superficial water bodies in which water is constantly renovated, minimizing water loses. These water tanks should be dimensioned accordingly, and allow the discharge of overflowing water into the system.

E - DISCHARGE INTO MAIN STREAM

The need of a system capable of discharging the excess of water represents a great opportunity for the qualification of green corridors, which are one of the key elements of the design at metropolitan level. The integration of discharge water streams in the surface adds meaning to these corridors and contributes to a greater urban quality. For the city, the combination of a greater discharge and buffering capacity improves the response to recurrent rain storms, avoiding flooding.

Cooling principles: higher surface permeability and evapotranspiration (green roofs)
Enhanced livability: improved visuals (green roofs).
Enhanced sustainability: lower overall water consumption, water management during peak discharge (buffering at rooftops).

Cooling principles: higher surface permeability and evapotranspiration.
Enhanced livability: qualification of urban spaces.
Enhanced sustainability: lower water pollution, biodiversity, water buffering.

Cooling principles: running water, higher surface permeability, shadow and evapotranspiration
Enhanced livability: qualification of urban spaces.
Enhanced sustainability: water management during peak discharge, biodiversity.

Cooling principles: dispersed or surface water, shadow, evapotranspiration.
Enhanced livability: qualification of urban spaces, street liveliness.
Enhanced sustainability: water management in peak discharge, increased overall accessibility to public spaces, biodiversity.

Cooling principles: running water, shadow, evapotranspiration, higher surface permeability.
Enhanced livability: qualification of urban spaces, higher air quality, higher likeliness of doing physical activity, lower traffic congestion.
Enhanced sustainability: water discharge, higher quality of urban ecosystems, support to biodiversity, increased accessibility to public spaces, social integration and awareness.
Due to their function within the water system, the design of the main corridors needs to respond, in the first place, to the logics of water discharge and possibilities of continuity across the city. Their location within urban boundaries must therefore consider topography, allowing water to flow without obstacles towards the sea.

At a metropolitan level, the design of these main corridors has been based on the existing (mostly underground) system of streams and main sewage collectors, which can be assumed to be already responding to topography (Fig. 97). Additionally, a remote sensing analysis of the hydrology of the territory has been conducted in GIS software, showing which the optimal stream lines and catchment areas are according to topography (Fig. 98).

The information provided by both maps can be combined in order to obtain a complete system of main and secondary streams, which can additionally be qualified as green corridors (Fig. 99). Altogether, this system provides support for many of the cooling principles that occur at a smaller scale, but also enhances the livability and sustainability performance of the city by itself.
The impact of the system of main corridors transcends its function within the water system and improves the performance of Málaga in different aspects:

- As an aggregation of vegetated surfaces, a great impact on the overall temperature across the city is expected. The Park Cool Island effect (PCI) designates the process by which big areas containing irrigated vegetation can cool down their surroundings, an effect that can extend several meters into their immediate environment. Additionally, more people would benefit from the proximity of qualified, well-sized green areas, which are currently scarce and mostly peripheral. (Fig. 100)

- As part of the water system, they allow a rapid discharge of water in the event of heavy rainfalls, but also, due to the increase on permeable surfaces, they provide a useful additional buffering capacity. (Fig. 101)

- As elements with a strong linear component, they provide connections between different urban ecosystems, which has a positive impact on biodiversity. Additionally, most of the corridors are oriented in the NW-SE direction, which facilitates the infiltration of cool wind flows from the sea in summer. (Fig. 102)

The way the system of main corridors is manifested at street level differs according to the characteristics of the fabric it crosses. Sectional drawings can reflect not only the technical possibilities of integration, but also the changes in quality from a pedestrian point of view (Fig. 103 and 104)
Fig. 103. Current section at Calle Ingeniero De la Torre Acosta. Elaborated by the author.

Fig. 104. Proposed corridor section at Calle Ingeniero De la Torre Acosta. Elaborated by the author.
DESIGN INTERVENTION

An approach in scale helps to understand the complexity of integrating such a system in the city fabric. The design of its main elements was done based on pre-existences and the territorial topographic conditions, however, within the city limits there are multiple spatial constraints that hinder its development.

The proposed system has a strong hierarchical component. The water-related functions define a system of main and secondary corridors. The first constitute the primary system of water discharge to the sea, while the second is in charge of transporting clean water between the main functions of the system.

The implementation of running water at street level is limited by the topographic conditions of each street. This means that, for instance, the transversal interconnection of corridors is often difficult to achieve with a water-related function. The presence of "qualified routes" interconnects corridors within the water system and areas of interest.

Fig. 105 and 106 show a possible development of the system in one section of the city, which comprises the five intervention sites. Each of their linear elements can be defined by a typical sectional drawing (Fig. 107). The final design of each of those elements, however, would depend on the local conditions of each place.

SYSTEM INTEGRATION IN THE CITY FABRIC

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[Right]

Fig. 107. Diagrammatic sections of the different elements that define the hierarchy of the metropolitan system. Elaborated by the author.
MAIN CORRIDORS
They provide the main discharge function within the water system, and add the benefits associated with green corridors and the PCI effect.

SECONDARY CORRIDORS
They respond to the integration of water transportation and retention at street level, interconnecting the main elements of the water system among them. The implementation of this type of section has to take into account topography and the basin delimitation.

QUALIFIED ROUTES
They interconnect functions of interest among them, also adding transversality to the main system of corridors in those cases in which, due to gravity, it is not possible to implement water elements. The addition of shade and soil permeability via vegetation provides a higher degree of thermal comfort.

POTENTIAL AREAS FOR WATER TREATMENT
They provide big unbuilt extensions in which centralized Vertical Flow Helophyte filters can be implemented. Their location takes into account the situation of highly dense neighbourhoods, in order to be able to collect their wastewater.
14.2 SYSTEM DEVELOPMENT IN THE SMALL SCALE

Despite the aim for unity and coherence in the form of a metropolitan system, the way such an infrastructure manifests in the city has to vary and adopt multiple forms, according to the particular characteristics of each area. In that respect, design in the small scale should not be simply understood as the development of interventions that can be "plugged" into the system, but the definition of the system itself. The generation of qualified public spaces at neighbourhood scale, for instance, proofs and provides the system with the necessary continuity. What seems to be just a line in a system scheme could actually be seen as a concatenation of explorations of how the same principles can be developed in different ways in each point of Málaga. At the same time, such an approach contrasts with the general impersonality and homogeneity of design in Málaga, which has led, in recent times, to many of the current deficiencies of the city, as explained previously.

In the following sub-chapter, the potentials of each of the sites with respect to the metropolitan vision are unfolded. This can be done through the definition of meaningful, qualified spaces in some cases, or through the study of possible alterations in the built form, in others. The particular characteristics of each of the sites, which were studied during the analysis phase, guides the exploration of potentials to some particular elements of areas of each of the fabrics.
A SUMMER SQUARE
LA TRINIDAD

Fig. 108. Spaces for intervention in the fabric of La Trinidad. Elaborated by the author.

A NEW CORBALÓN
A SUMMER SQUARE
One of the main consequences of La Trinidad’s relatively high GSI is the absence of qualified public spaces. Plaza de San Pablo (Fig. 110) is the only open space of a certain size within the neighbourhood, a spot for the contemplation of the church and meeting point of thousands of inhabitants in the event of a procession (Fig. 111). Due to its function, this square is tremendously unfriendly for any pedestrian: hard, paved surfaces, absence of any urban furniture other than five benches and a group of palm trees in one corner.

One of the urgencies of the neighbourhood is, therefore, the inclusion of a space capable of counterbalancing the physical features of Plaza de San Pablo by offering a cooler environment. Such space could be understood as a “summer square”, as opposed to the existing one, which seems to be appealing to pedestrians during the winter months. The coincidence of multiple vacant lots along Calle Carril (one of the traditional routes of internal communication in Málaga) provides an opportunity for the introduction of such a space (Fig. 112). Simultaneously, it helps to define and consolidate one of the corridors that form the metropolitan system, which was identified in the remote sensing analysis of the city’s hydrology as a possible stream line (Fig. 98, page 126).

Fig. 110. Plaza de San Pablo. Source: Google maps.

Fig. 111. “Misa del Alba” in Plaza de San Pablo. Source: Hugo Cortés, Diario sur.

Fig. 112. Current state of the area of intervention. Source: Google Earth.
DESIGN INTERVENTION

TRANSFORMATION OF MULTIPLE PLOTS
The generation of a unitary design for a public space is possible due to the coincidence of multiple vacant lots in one part of the neighbourhood’s fabric.

RESPONSE TO PUBLIC FUNCTIONS
The design of the public space responds to the function of its borders, providing space for rest and encounter between the elderly and the youth, and play areas.

SPECIAL QUALIFICATION OF THE BORDER
A border pergola encloses the square, offering vegetated, shaded space to both the inner public space and the street, as well as an identifiable image.

ADDITION OF VEGETATION
Being the lack of vegetation one of the neighbourhood’s main weaknesses, the priority is to define as much surface as possible as green.

CREATION OF PEDESTRIAN AREAS
The design of the pathways facilitates the access to the social program, the public functions and the transversal permeability of the space.

INCORPORATION OF WATER
An open water body is the main cooling element in the space created between the two facilities, which becomes a principal meeting place.

Fig. 113. Design guidelines according to the priorities of the site. Elaborated by author.
Fig. 114. Design plan. Elaborated by the author.

1. Housing for the elderly (under construction)
2. Additional facility for the community (proposed)
3. Playground
Permeable pavement
Public activities
Bushes in front of private uses
Low vegetation in front of public functions
Trees placed according to direction of shade
Facility’s entrance towards public fountain
The priority is to provide the maximum amount of vegetated surfaces, with the necessary addition of shading trees. This would constitute the main difference in comparison with any other public space in the neighbourhood, and a strong differentiating factor.

The paved surfaces, despite their orthogonal layout, take into account the transversal and longitudinal flows, facilitating the access to and from the public functions situated along the border of the public space.

Three main elements define the design:

- A water fountain, situated at the common corner of the two facilities, provides an additional cooling factor and a pleasant outdoor extension of their public function.

- A children’s playground, which can solve, at least partially, the lack of spaces for children in the area. In this case, the addition of a certain topography transforms the playground into a challenging and appealing installation.

- A border pergola, which demarcates the external boundary of the square while at the same time offering a great permeability in the access. It provides shade to passers-by but also delivers multiple sitting areas. Additionally, it supports the growth of deciduous climbing plants.

### UHI EVALUATION

| VEGETATION | ++ |
| SURFACE HARDENING INDEX | ++ |
| ALBEDO | - |
| SPACE FOR TRAFFIC | - |
| BUILDING SKIN | - |
| OPEN WATER BODIES | - |
| SKY-VIEW FACTOR | + |
| SHADOW | ++ |

### SUSTAINABILITY/LIVABILITY EVALUATION

Energy saving on long leisure travel (S)

| ++ |

Quality of urban ecosystems (S)

| ++ |

Presence of public services (S)

| ++ |

Sense of community (S)

| + |

Social integration (S)

| + |

Likelihood of doing physical activity (L)

| + |

Availability and accessibility to public open space (L)

| ++ |

General satisfaction with the neighbourhood (L)

| ++ |

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Fig. 115. Perspective view of the design intervention. Elaborated by the author.

Fig. 116. UHI and sustainability/livability evaluation of the design intervention, according to different indicators. Elaborated by the author.
Fig. 118. Sectional drawing S2. Elaborated by the author.
A NEW CORRALÓN
The “corralón” (Fig. 120) is the traditional building type of La Trinidad. In its early days (second half of the 19th century, a period of great industrialization in the city), multiple buildings like this hosted thousands of workers and their families. Dwellers on the corralones used to share spaces for some domestic functions (like kitchens and bathroom) and make a strong use of the buildings’ common space.

Today, only a few of these buildings are still in place. It is possible to identify three main factors that would explain this situation. In the first place, property speculation since the last half of the 20th century lead to a fast destruction of a big part of this legacy. The location of this neighbourhood, adjacent to the city centre, boosted this process. In the second place, this building type is conceived, in the public imagination, as a source of marginality and as a model that does not meet the current minimum standards of housing. Finally, the existing regulations for the neighbourhood, in particular the Special Plan for Internal Reform (PEPRI Trinidad-Perchel), firstly developed in the 70s, have not included any strong incentives for the conservation or generation of upgraded corralones. Only in those cases where multiple building plots were acquired and developed by a single promoter could similar building types be developed, however, the common functions associated to the central courtyard are rarely present.

In the last years, certain efforts have been made to promote a more positive image of these corralones, both as a way of strengthening the sense of belonging in the neighbourhood and as a way of attracting public attention to this relatively deprived area.
FORM OPERATIONS

The design goal is, in this case, to promote the generation of inner courtyards within blocks, so that, in the long term, the addition of multiple small individual courtyards could result in a “corralón-like” common space. This space would incorporate multiple qualifying elements with cooling functions. The courtyard itself, as an architectural element, has a long tradition in vernacular architecture as it provides shade and shelter from external negative conditions.

The focus is, therefore, on the regulations that allow for certain building forms to be developed. The proposed guidelines would maintain the rules that ensure an external homogeneity (mandatory height, façade alignment and sloping roof). The combination of these restrictions with a maximum FSI results in the accumulation of built mass towards the front of the plot, while in the back area, incentives should be provided for the incorporation of elements with a cooling function.

CURRENT REGULATIONS

- Mandatory façade alignment and height, as per adjacent buildings.
- Mandatory sloping roof, with ceramic tiles.
- For structural courtyards, when required, minimum dimensions of 3x3 meters.

PROPOSED REGULATIONS

- Mandatory façade alignment and height, as per adjacent buildings.
- Mandatory sloping roof towards the front side, with high albedo ceramic tiles.
- Maximum FSI of 1.75*.
- 30% of GSI dedicated to a cooling element (vegetation, pergola or water).

*For a 2 stories-high façade, which is the most common in the area. Value to be determined as per height.
At the block level, the proposed modifications would gradually result in the accumulation of private unbuilt space towards the middle of the block. In the medium term, these private spaces could still be understood as independent from each other. Even in such a case, however, the accumulation of cooling elements in a continuous space would have a positive impact in temperature, as compared to the 3x3m isolated courtyards.

In the long term, however, the modification of multiple plots could be seen as an opportunity for generating an inner common space, that could be accessible from all buildings and also directly from the exterior. Such a space would act as a modern “corralón”, a space of common use and multiple qualities, just as heterogeneous as its perimeter.
Fig. 124 and 125 show two possible outcomes on the same block, at different stages. In the first, the currently available plots have been built according to the proposed regulations. The resulting backyards are treated as individual private spaces and incorporate different cooling elements. The second perspective shows a possible long-term outcome, in which the combination of individual courtyards result in a bigger, shared space that is directly accessible from outside, and therefore can also be understood as a distributor of flows towards the buildings. The accumulation of elements with a cooling function (water, vegetation and shading elements), together with the courtyard’s irregular shape, results in a heterogeneous space with multiple spatial qualities.
**UHI EVALUATION**

**VEGETATION**

**SURFACE HARDENING INDEX**

**ALBEDO**

**SPACE FOR TRAFFIC**

**BUILDING SKIN**

**OPEN WATER BODIES**

**SKY-VIEW FACTOR**

**SHADOW**

**SUSTAINABILITY/LIVABILITY EVALUATION**

Energy saving on long leisure travel (S)

Quality of urban ecosystems (S)

Presence of public services (S)

Sense of community (S)

Social integration (S)

Likeliness of doing physical activity (L)

Availability and accessibility to public open space (L)

General satisfaction with the neighbourhood (L)

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Fig. 125. Perspective view of the design intervention, as per its long-term state (see page 145). Elaborated by the author.

Fig. 126. UHI and sustainability/livability evaluation of the design intervention, according to different indicators. Elaborated by the author.

1. Direct access from the exterior
2. Buildings can be configured with an internal gallery for access and distribution

---

*DESIGN INTERVENTION 147*
Fig. 127. Spaces for intervention in the fabrics of Gamarra and Haza del Campillo. Elaborated by the author.

Scale 1:4,000

GAMARRA & HAZA DEL CAMPILLO

A SEQUENCE OF SPACES
One of the main characteristics of Haza del Campillo is the careful composition of public spaces, designed as a sequence of enclosed public spaces of different characteristics, linked by a continuous pathway. The neighbourhood’s main public functions, like the church, are situated around those public spaces (Fig. 129 and 130). Each place is discovered at a time, providing pedestrians with an enriching spatial experience.

Gamarra, in comparison, offers a higher proportion of unbuilt space (due to its lower GSI) that is not defined nor qualified in any distinctive way. The adjacency of both neighbourhoods provides an opportunity for the extension of the already referred pedestrian route to the south. This requires both the qualification of a newly-created axis and the demarcation of concrete spaces in between buildings (Fig. 131). The presence of a stream line which crosses the neighbourhood offers a good opportunity for the integration of water in one of those defined spaces. By means of such an intervention, a higher spatial qualification can be achieved in an area with a very high population density and with an absence of human scale.
DESIGN PRINCIPLES

EXTENSION OF PEDESTRIAN SPACE
Elimination of parking space and expansion of the space designated for pedestrians.

IDENTIFICATION OF FUNCTIONS
Consideration of public facilities and commercial, which should also occur along the pedestrian path.

HABILITATION OF PARKING SPACE
Demarcation of an extensive and qualified parking area, which would compensate the loss of parking space and support the commercial projection of the neighbourhood.

SEQUENCE OF PUBLIC SPACES
Definition of areas with a specific function, placed along a qualified path. This principle replicates the concatenation of public spaces that occurs in Haza del Campillo.

QUALIFICATION OF PEDESTRIAN ROUTE
Implementation of a quasi-continuous element which enables the application of cooling measures and provides an identifiable image and guidance.

INCORPORATION OF WATER
Qualification of the neighbourhood’s central space by means of an accessible water fountain, which can be connected to the metropolitan water system.

Fig. 132. Design guidelines according to the priorities of the site. Elaborated by the author.
Fig. 133. Design plan. Elaborated by the author.
Commercial activity
1. General use of permeable pavement
2. Different pavement around fountain for demarcation
3. Heterogeneous shading through alternation of pergolas
4. Increased height to demarcate the central space
5. Increased height to adapt to commercial plinth
6. Visual and physical connection between supermarket and public space
**DESIGN DESCRIPTION**

The two main goals of the intervention, from a purely spatial point of view, are the qualification of a pedestrian route and the enclosure or definition of certain spaces. This can be done by a continuous pergola, with the additional benefits of the provision of a support for additional cooling elements (vegetation and dispersed water) as well as the definition of a strong, recognizable image.

The varying height of the pergola responds to the height of the public plinth to its borders, but also tries to demarcate spaces with a special function, as in the case of the water fountain. This fountain is not only the geometric centre of the neighbourhood, but also has the potential for being the main space of social representation and public life. The special qualities brought by the presence of disperse water try to enhance and confirm the role of this space for the whole neighbourhood.

One of the main positive characteristics of Gamarra is its strong commercial life, which is highly supported by the generous availability of parking spots. This intervention, however, implies an expansion of the pedestrian surface and therefore requires the removal of some traffic and parking space. The implementation of a parking area to the south of the neighbourhood tries to compensate this fact, as a way to assure that the commercial activity of Gamarra is not affected. The emergence of the pergola at the south end of the route, right in between two buildings with a public function and next to the proposed parking area, is intended to be seen as an invitation for the access to the neighbourhood, in a way that can be easily identifiable.

Altogether, therefore, the intervention tries to combine different cooling principles (dispersed water, deciduous climbing plants, shade) in a unitary, easily-identifiable element. By doing so, it is possible to enhance the qualities of a newly-created sequence of spaces, that would be used by both locals and visitors.

**UHI EVALUATION**

<table>
<thead>
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<tr>
<td><strong>ALBEDO</strong></td>
<td>-</td>
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<tr>
<td><strong>SPACE FOR TRAFFIC</strong></td>
<td>++</td>
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<td><strong>BUILDING SKIN</strong></td>
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<td><strong>OPEN WATER BODIES</strong></td>
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<td><strong>SKY-VIEW FACTOR</strong></td>
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<td><strong>SHADOW</strong></td>
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**SUSTAINABILITY/LIVABILITY EVALUATION**

<table>
<thead>
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<th>Indicator</th>
<th>Value</th>
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<tr>
<td>Energy saving on long leisure travel (S)</td>
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<tr>
<td>Quality of urban ecosystems (S)</td>
<td>+</td>
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<tr>
<td>Presence of public services (S)</td>
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<tr>
<td>Availability and accessibility to public open space (L)</td>
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<tr>
<td>General satisfaction with the neighbourhood (L)</td>
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Fig. 137. Sectional drawing S2. Elaborated by the author.
Fig. 138. Spaces for intervention in Nueva Málaga’s fabric. Elaborated by the author.

Scale 1:4,000

NUEVA MÁLAGA & PARQUE DEL NORTE

A PARK ON THE ROOF
A PARK ON THE ROOF
The implementation of a new main corridor in the vicinity of Nueva Málaga implies that Parque del Norte becomes one section of one of the city’s structural elements, and would also result in “re-discovery” of Arroyo del Cuarto, which runs currently underground. Although, in the past, urban streams were seen as a source of flooding problems and marginality (Fig. 140), and therefore removed from the city’s surface, their re-incorporation into Málaga’s landscape would be seen today as an element with a positive impact in terms of urban quality. In the concrete case of Nueva Málaga, therefore, the development of this corridor results in the qualification of one of its boundaries.

One of the functions associated with the proposed metropolitan corridors is the creation of a Park Cooling Island effect (PCI), which means that, by means of extensive vegetation, a significant temperature drop is expected not only in the area, but also in its surroundings. In the case of Nueva Málaga, however, this positive effect in the corridor’s vicinity can be hindered by a certain “barrier effect”, caused by the neighbourhood’s high levels of physical density. A right balance between “Self” and “Net” means that any positive qualities derived from design should reach as many dwellers as possible. In this context, therefore, the goal is to extend or “filter” the qualities of the metropolitan corridor to the interior of the neighbourhood.
INCORPORATION OF WATER
“Re-discovery” of Arroyo del Cuarto, as it is brought back to the surface as part of one of Málaga’s new metropolitan corridors.

EXTENSION OF THE GREEN COVER
Incorporation of a green roof, which results in an increased vegetated surface and allows the preservation of the parking functions.

INCORPORATION OF ACTIVITIES
Addition of spaces for commercial or social activities towards the corridor, compensating the existing accumulation of functions along the neighbourhood’s central axis.

DETOUR OF TRAFFIC
Elimination of road traffic as a way of giving space for a closer integration of the neighbourhood’s boundary with the corridor.

CONTINUITY OF FLOWS
Facilitation of transversal pedestrian flows, bridging the existing topographic unevenness on a segregated level.

FACILITATION OF WIND FLOWS
The lower levels of the residential towers are reconfigured, so that the allow access from multiple points but also facilitates the flow of wind from the park to the neighbourhood.

Fig. 142. Design guidelines according to the priorities of the site. Elaborated by the author.
DESIGN QUALITIES

Fig. 143. Sectional drawing of the intervention. Elaborated by the author.
Commercial activity
1. Incorporation of bridges for transversal permeability
2. Delimitation of spaces for activities, accessible and visible from the park
3. Addition of vertical natural lighting
4. Elimination of walls at ground level
5. Addition of new access routes to dwellings
**DESIGN DESCRIPTION**

The main element of the proposal is a green roof, that extends from Magistrado Salvador Barbera street to the park, where it becomes a stepped stand. It is possible, therefore, to describe the project according to its two different levels, each of which offer different qualities and functions.

On the ground level, there is a continuity from the park into the roofed area, which ensures the accessibility to the residential buildings. The roof’s stepped perimeter “breaks” in certain points, allowing not only a pedestrian transversal access but also the generation of wind flows from the park. In that respect, these openings in the roof’s border are aligned with the inner courtyard of the taller buildings, which, by means of the chimney-effect, can facilitate the infiltration of air from the park to the interior of the neighbourhood. The generation of such airflows also requires the elimination of some of the buildings’ walls on the ground floor and, in general, a series of modifications that would guarantee a certain degree of permeability in all directions, while at the same time respecting the required privacy of some of the areas. While the main function below the roof is parking space, areas for the inclusion of commercial or public functions are incorporated, in a way that they can be seen and accessed from the park.

On the first level, the project is understood as a facilitator of pedestrian flows between the interior of the neighbourhood and the park, in both directions. The addition of a new level also generates new opportunities for the addition of new commercial or social functions on the new “ground level” that is created. From a material point of view, the extension of the park’s green cover towards the neighbourhood’s fabric brings two main benefits. On the one hand, it helps to infiltrate the qualities associated to green areas into the compact fabric of Nueva Málaga, on the other, it strengthens the park’s PCI effect and therefore contributes to increase the temperature drop.

**UHI EVALUATION**

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**SUSTAINABILITY/LIVABILITY EVALUATION**

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<tr>
<td>General satisfaction with the neighbourhood (L)</td>
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Fig. 146. Spaces for intervention in Camino de Antequera's fabric. Elaborated by the author.

Scale 1:4,000

CAMINO DE ANTEQUERA

AN OPEN FRONT YARD
AN OPEN FRONT YARD
The area around Camino de Antequera is designated in the current urban plan as a “city garden ordinance”. This means all buildings should stand in isolation and be surrounded by gardens in all directions. The transition from the private unbuilt space to the exterior is always a fence, and altogether (fences and the vegetation that exceeds the fence’s height) compose what the plan defines as the characteristic image, or landscape, of the area.

The regulations associated to this type of fabric also allow a certain rise in the built intensity, as it is understood that, due to their position (formerly peripheral but nowadays completely embedded in the city) these areas are subject of some densification. While the search for a higher urban density might be seen as adequate, there is, however, a clash with the aesthetic values that want to be maintained by preserving the private gardens. In multi-family, three or four stories buildings, these front private spaces do not have any specific function, and are often not qualified with vegetation. There is, therefore, a disconnection between a certain “romanticism” of the neighbourhood’s inherited aesthetic values and its current needs in terms of growth.

The aim is, therefore, to explore modifications in the current regulations, so that the expected increase in density can be accommodated while, at the same time, the qualities that are associated to this type of fabrics can be re-defined in a more beneficial way.
CURRENT REGULATIONS:

$$FSI_{\text{max}} = 0.83$$  
$$GSI_{\text{max}} = 0.40$$  
Maximum height = 3 stories  
Minimum distance to plot boundary = 3 meters

PROPOSED REGULATIONS:

Equal, however, if the front 3-meter-wide strip is given for public use, the following regulations can apply:

$$FSI_{\text{max}} = 1.13$$  
$$GSI_{\text{max}} = 0.40$$  
Maximum height = 4 stories  
Minimum distance to plot boundary = 3 meters. The front façade can be aligned with the fence after the setback.
The aesthetic values of the area, which define its traditional character, are based on the demarcation of streets by vegetation. These values can be maintained if part of these frontal green areas are incorporated to the public realm, so that they can directly benefit pedestrian life and acquire a new relevance.

The existing regulations establish a mandatory minimum distance from buildings to the plot’s borders, and maximum levels of coverage and building intensity. The proposal can be seen as an optional “fence setback” at the plot’s front side, which would be compensated by allowing an increase in FSI (Fig. 150). The new value, 1.13, is the result of adding an extra floor to the volume that can be currently obtained if applying the minimum possible GSI and the maximum possible FSI to a given plot. This means that, by ceding the use of the front 3 meters to the public, a substantial increase in built surface can be expected.

The gradual implementation of these new regulations would result in a changing street profile. While some of the plots would preserve their front gardens, others would progressively increase their density and cede part of their private space to the public realm. The increase in street width would allow a progressive qualification at pedestrian level: addition of vegetation, benches and other kinds of urban furniture could find a place in this new street profile.

The impact of this proposal is double: on the one hand, it protects the traditional garden type in those cases where its function and quality are really present. In the cases where is not (normally, where the higher values of FSI are present or expected at plot level) it provides incentives to “release” these important surfaces for public use. On the other hand, it results in an increased accessibility to the already-existing cooling functions of vegetation. In other words, an NDVI snapshot of the area would remain identical, but the qualities that derive from the “garden type” would be shared by many others.

Fig. 151. Representation of the changing street profile that is expected after the application of the new regulations. In yellow, areas that are incorporated to the public realm. Elaborated by the author.
Fig. 152 and 153 show two possible outcomes on the same street, with variations according to the position of the vegetated strip.

In the case of Fig. 152, the strip is situated towards the border of the road. This could result in a more indirect pedestrian path, in the cases where multiple fence alignments coincide. However, it provides several benefits:

- Visual enclosure of the street from its centreline;
- Higher protection of pedestrians from traffic;
- Higher accessibility to commerces at ground level,

Among others.

Fig. 152. Perspective view of one possible design outcome. Elaborated by the author.

Fig. 153 on the other hand, shows a possible variation in which the straightness of the pedestrian pathway is respected. Additionally, higher levels of privacy can be achieved on the ground floor where commercial uses are not implemented.

In any case, it becomes clear that there are multiple possibilities regarding an higher qualification of the neighbourhood’s public realm. This qualification can adopt several forms, but aims to reveal some of the existing values of the area, which are understood as defining and traditional, to the street level. In this way, the neighbourhood’s need of growth can be accommodated in a way that its inherited character is respected and preserved.

1. Incorporation of sitting areas with facing benches
2. Incorporation of sitting areas with individual benches, for privacy reasons
3. Occasional use of paved surfaces for easier access to commerces
### UHI Evaluation

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<td>Shadow</td>
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### Sustainability/Livability Evaluation

| Energy saving on long leisure travel (S) | = |
| Quality of urban ecosystems (S) | + |
| Presence of public services (S) | = |
| Sense of community (S) | + |
| Social integration (S) | = |
| Likelihood of doing physical activity (L) | + |
| Availability and accessibility to public open space (L) | + |
| General satisfaction with the neighbourhood (L) | ++ |

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**Fig. 153.** Perspective view of a second possible design outcome. Elaborated by the author.

**Fig. 154.** UHI and sustainability/livability evaluation of the design intervention, according to different indicators. Elaborated by the author.
Fig. 155. Spaces for intervention in Torre Atalaya’s fabric and surroundings. Elaborated by the author.

Scale 1:4,000

TORRE ATALAYA

A FOREST IN BETWEEN

A NEW CITY IN THE MAKING
6

A FOREST IN BETWEEN
Torre Atalaya symbolises the a double opportunity. On the one hand, it belongs to a distinctive urban model in which the manifestation of the proposed metropolitan system can adopt unique forms. It is, from a purely morphological point of view, an interesting case, different from all the previous ones. On the other hand, however, Torre Atalaya also represents an opportunity for challenging Málaga’s current urban expansion model. While all previous sites were purely urban, Torre Atalaya, and the district of Teatinos lie on the rural-urban interface, and are, in a way, the forward line of a process of urbanization that will soon extend deep into the Guadalhorce valley.

For this neighbourhood, therefore, two different levels of intervention are envisioned, one being subsequent or complementary to the other. The first one seeks to explore the way in which the metropolitan system can be developed within the public realm. It takes into account the main issues of the area in terms of public space, which derive from its scale and its treatment as an over-dimensioned traffic machine. The second level of intervention will explore possible ways of breaking the limits between the open private space of the communities and the exterior.

Regarding the first level of intervention, the position of Torre Atalaya in the transition between natural and urban environments constitutes an opportunity for defining the corridor’s multiple functions, like the retention and storage of water, or its integration within a narrower street, but also relation to the required addition of vegetation. In this particular case, however, it is the perpendicular axes to the corridors that offer a greater potential for qualification, and thus are explored as an urban linear park, which can add meaning to an otherwise completely inhospitable exterior space.
DESIGN PRINCIPLES

INTEGRATION OF WATER FUNCTIONS
Due to its topographic and peripheral position, the presence of water in the area is higher than in more urban contexts.

ADDITION OF VEGETATION
The reforestation of the neighbourhood’s boundary and the perpendicular axis seek to create a PCI effect.

INCORPORATION OF ACTIVITIES
The integration of activities within the urban park is achieved through the demarcation of specific areas among trees.

EXTENSION OF PEDESTRIAN SPACE
Some residual spaces, which were the result of prioritising vehicular flows, are incorporated back as pedestrian areas.

GENERATION OF A PEDESTRIAN PATH
In a smaller scale, the newly added urban park incorporates pedestrian flows in an organic way.

Fig. 158. Design guidelines according to the priorities of the site. Elaborated by the author.

Fig. 159. Proposed design plan. Elaborated by the author.

RB Water retention basin
WT Water treatment area
PG Public ground

Scale 1:4,000 10 10,1 10,2 10,5km
A NEW CITY IN THE MAKING
The second level of intervention in Torre Atalaya seeks to challenge the current model for Málaga’s expansion, by exploring different possible alterations within the urban block.

On the one hand, the availability of unbuilt space, both within and outside private boundaries, can be seen as an opportunity for exploring an additional densification of Torre Atalaya. Currently, density plays a crucial role in defining the area’s growth, as a strict limitation of dwellings per hectare is being applied in new developments, regardless of the qualities that are finally achieved. The combination of these maximum levels of density and a big block size incentivizes the appearance of closed communities.

Within the blocks perimeter, two smaller plots are designated as public function [Fig. 161]. The proposal incorporates on them an additional residential function, which would automatically increase the area’s density. Towards the previously created urban park, it is also possible to extend the built surface, thus creating new spaces for commercial activities and adding scale in the transition between park and block (see next page).

On the other hand, it is possible to envision the rupture of the block’s perimeter, leading to the superposition of a new inner orthogonal order of public spaces and streets. In this way, the clear distinction between a qualified interior and the inhospitable exterior, which is one of the area’s main characteristics at block level, would become less evident. The qualities previously inserted in the urban park can infiltrate into the block, and be shared by dwellers and visitors. Altogether, it propitiates a redefinition of urbanity in the context new developments, which could serve as an example of future adaptations or as an inspiration for the development of new expansion models.
FORM OPERATIONS

Fig. 162. Explorations of alterations within the urban block: densification and superposition of a new order of public spaces. Elaborated by the author.

[Right]
Fig. 163. UHI and sustainability/livability evaluation of the design intervention, according to different indicators. Elaborated by the author.

Fig. 164. Perspective view on the transition between the proposed urban park (as defined in the intervention number 7) and its extension beyond the block’s boundaries, including an additional densification. Elaborated by the author.
UHI EVALUATION

VEGETATION
SURFACE HARDENING INDEX
ALBEDO
SPACE FOR TRAFFIC
BUILDING SKIN
OPEN WATER BODIES
SKY-VIEW FACTOR
SHADOW

SUSTAINABILITY/LIVABILITY EVALUATION

Energy saving on long leisure travel (S)
Quality of urban ecosystems (S)
Presence of public services (S)
Sense of community (S)
Social integration (S)
Likeliness of doing physical activity (L)
Availability and accessibility to public open space (L)
General satisfaction with the neighbourhood (L)

1. Commercial/public functions
2. Use of water for the definition of areas of activity
3. Use of circles as formal motif for other design elements
4. Meandering path for continuity with the park
14.3 DESIGN CONCLUSIONS

The transition from the metropolitan to the local scale reveals the importance of design in enabling the implementation of the metropolitan concept. It also strengthens the relevance of context in determining the particular manifestation of the system’s principles, and the way its physical components (water, vegetation, etcetera) can be integrated. As stated during the development of the design framework, only through good design it is possible to give meaning to any intervention in an existing fabric and to reach the necessary acceptance.

At a metropolitan level, the role of design is to interpret the general structure of the city and its position regarding other physical elements (such as topography, existing streams or open areas in continuity) in order to determine the best possible location for the different parts that compose the system. With this regard, the use of additional analytical methods, or the generation of more accurate typologies can be useful for identifying potentials.

At a local scale, design demonstrates its true potential as enabler of the metropolitan system. The technical aspects of the design at a metropolitan scale need to find a compromise with local constraints and potentials. The same spatial principles (water, shade, vegetation, permeability) can be presented and integrated multiple forms, and in that respect, the seven small-scale interventions previously presented demonstrate the great variety of approaches that can be envisioned (Fig. 165).
Fig. 165. Visual summary of the variety of design approaches present in the previous seven interventions. Source: author.
During the development of the design approach in the small scale, the attention to the specific characteristics of each of the sites resulted in very particular design interventions. These show particular ways in which the metropolitan system manifests according to the physical characteristics of each of the fabrics, but also depending on the relative position of that area within the system.

The possibilities of transferability, therefore, should not only be analysed in relation to the parameters of density (GSI or FSI) but also incorporate other variables, which reflect the relation of each area within the system:

-The distance of each area to the main system corridors reflects the extent to which the surface water functions of the system can be incorporated at street level. Additionally, a higher proximity to these corridors derives into an increased amount of vegetation, that should also be accommodated. In order to determine these needs, the relative position with respect to the system of corridors can be expressed both as an increased NDVI or as an indication of the vicinity to the systems’ stream lines (Fig. 167).

- The relative position of each area in relation to the sea and the topography also determines the nature of their priorities. Those areas that are more distant to the sea can play an important role in relation to water buffering and retention, in accordance with the limitations set by their topography. The importance of this function gradually disappears as the system approaches its discharge points. Additionally, proximity to water and height lowers the urgency of applying heat adaptation measures, as these are two factors that tend to result in lower relative temperatures (Fig. 167).

The incorporation of these variables, which are different in nature, results in a comprehensive consideration of both local and systemic conditions. This constitutes the basis for determining the degree of transferability of one specific design approach to other areas to the city. In that respect, the generation of a second typology can facilitate the visualization of such possibilities.
GENERATION OF A TYPOLOGY

The proposed “transferability typology” is, as in the case of any other typology, the result of an explorative process. In each of the iterations, a number of the indicators presented in Fig. 167 were considered, generating different representations of transferability as a balanced combination of local and systemic conditions. The final typology incorporates three of these indicators:

- **GSI** (Fig. 168). While FSI is a better representation of social density, GSI provides a better indication of the spatial possibilities of intervention. Ultimately, the proportion of built/unbuilt space at ground level is the biggest limitation to the incorporation of spatial elements with a cooling function.

- **Distance to stream lines** (Fig. 169). This variable provides an unequivocal indication of the “horizontal” position of each block within the system. The selection of this indicator over the NDVI prioritises the consideration of the water-related functions of the system and focuses on those areas in which the presence of vegetation needs to be intensified the most. It is important to notice that this indicator is based on prospective stream lines, taken from the proposal for a metropolitan system. In the current situation, most of the city’s urban stream lines are situated underground. Those could, however, also be considered for the generation of a different typology.

- **Height** (Fig. 170). This variable provides an indication of the “vertical” position of the blocks in relation to the system. The consideration of height reflects issues and potentials in relation to the retention and buffering of water, reflects the heterogeneous nature of Málaga’s topography (especially evident in the east/west contrast) and is indirectly connected to the type of fabric and the amount of vegetation that is present in each area.

The generation of the typology followed the process described on page 66. The definition of six different clusters was selected as the best representation of the potential for transferability (Fig. 171, next page).
Fig. 171. Map of the resultant transferability typology. Elaborated by the author using GIS and SPSS software, based on previous data.

Fig. 172. Mean values for each transferability type, and relative size of cluster. Elaborated by the author.

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean GSI</th>
<th>Mean distance to stream [meters]</th>
<th>Mean height (meters)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>0,55</td>
<td>144,08</td>
<td>16,44</td>
<td>28,5%</td>
</tr>
<tr>
<td>#2</td>
<td>0,52</td>
<td>479,89</td>
<td>23,17</td>
<td>14,9%</td>
</tr>
<tr>
<td>#3</td>
<td>0,25</td>
<td>82,82</td>
<td>24,09</td>
<td>28,3%</td>
</tr>
<tr>
<td>#4</td>
<td>0,20</td>
<td>471,88</td>
<td>32,80</td>
<td>12,4%</td>
</tr>
<tr>
<td>#5</td>
<td>0,43</td>
<td>98,98</td>
<td>83,60</td>
<td>8,0%</td>
</tr>
<tr>
<td>#6</td>
<td>0,17</td>
<td>205,28</td>
<td>126,72</td>
<td>8,0%</td>
</tr>
</tbody>
</table>
**TYPE #1**

Represents areas with high levels of GSI and high proximity to the water system. Achieving a satisfactory integration of the system at fabric level requires the consideration of imaginative solutions, that often may imply alterations in the urban form or the insertion of cooling elements within the private realm.

**TYPE #2**

Designates areas that present high levels of GSI but that cannot be easily integrated in the system of corridors, due to their distance to the main stream lines. They are, however, often located in the vicinity of other green areas, or in close proximity to the sea. This type possibly represents the areas with a higher priority of intervention, however, a concrete evaluation of each case is required in order to determine the level of urgency.

**TYPE #3**

Represents the fabrics with the highest potential of integration in the metropolitan system, both due to their proximity to the stream lines and a relatively lower GSI. This means that, in these areas, it is easier to conceive the generation of a PCI effect through extensive vegetation, as well as the implementation of spaces for the retention and treatment of water. The higher availability of unbuilt areas also facilitates the integration of water in the public space.

**TYPE #4**

As in the case of type #2, designates areas that are distant to the main elements of the metropolitan system. A relatively lower GSI means that the integration of qualified routes and spaces should always be possible, but that a certain priority should be given to the generation of shaded areas, either through the addition of vegetation of by other means.

**TYPE #5**

Represents areas with a relatively high GSI, high proximity to the system corridors and situated at a higher altitude. These areas, therefore, offer interesting opportunities regarding the buffering of rain water and the integration of the system in their fabrics. However, the high proportion of built space may hinder the possibilities of intervention.

**TYPE #6**

As in the case of type #5, it designates areas with a strong topographic component. These fabrics tend to be more dispersed and situated far from the main stream lines, however, they often show a high presence of vegetation. For these reasons, the priority lies in building a good response to heavy rains, rather than in the adaptation to heat. The integration of natural corridors within these fabrics is relatively straightforward.
Until now, the LST map was used as an additional layer of information, in a descriptive way. This means that, for this work’s sake, the priority was to ensure that a good representation of fabrics was selected for analysis, and not necessarily to focus on the areas that show a higher temperature. At this stage, however, the combined lecture of the LST map (Fig. 174) and the transferability typology (Fig. 175) can result on a new type of reflections, which have to do with potentials and priorities.

First of all, there is a direct correlation between areas showing a lower temperature and a high proportion of the blocks belonging to types 5 and 6 (1). This is a completely logic correlation, given the fact that a strong relationship was identified between topographic height and temperature (pages 54 and 55), and that topography is one of the three indicators that define the typology. The priorities associated with these two types are related to the retention and storage of water, which are important functions regarding the functioning of the whole system. For a good retention of water, these areas should include a good amount of vegetation, however, in most cases that level of vegetation is already present. From a purely thermal point of view, therefore, these areas do not constitute a strong priority other than the integration of its water-related functions.

At the other end of the temperature spectrum, there is also a coincidence between the areas that present a higher temperature and blocks belonging to type 1 (2). This type is characterized by a good proximity to stream lines but higher levels of GSI. This means that, in those areas that present more urgencies in terms of temperature, the integration of measures for thermal adaptation is more challenging, due to spatial constraints. Most of these areas are, in fact, industrial states, where the possibilities of intervention may differ from the ones in residential neighbourhoods. In any case, these constitute the areas with the highest priority.

Interestingly, even within the urban core (where the LST map shows more moderate temperatures), areas belonging to type 1 also show a slightly higher temperature than the surroundings (3). This corroborates the statement that density plays a significant role in defining temperature differences in the small scale. On the other hand, the areas that belong to type 3, which are characterized by a lower GSI, show currently lower temperatures.

Finally, it is possible to observe how some of the areas that are located away from the system’s main corridors, and therefore belong to types 2 and 4, are currently enjoying good levels of temperature due to their proximity to extensive green areas (4). This is explained by the absence of the indicators of vegetation in the generation of the typology, which prioritises the relation of the blocks with the water functions of the system. Types 2 and 4 were, however, defined as ambiguous, and it was stated that a concrete evaluation of their needs was required for every specific case. The incorporation of NDVI as a fourth variable to the typology could also amend this deficiency.

From an operational point of view, the transferability typology identifies areas with a similar GSI and relation to the water system. It is based, therefore, on the relative location of blocks and their form, and not directly on temperature. Even then, it is possible to identify correlations with the current levels of temperature in the city. This opens new possibilities regarding the incorporation of temperature as a variable for the generation of a new typology, in which the identification of priorities would be direct.
APPLICABILITY OF THE TYPOLOGY

The main goal of the transferability typology is to offer a first indication of the potentials of intervention, making it possible to transfer some design principles from one area in the city to others. In this respect, when two sectors of Málaga share a type, it means that the level of integration of the metropolitan system within the fabric is similar, as well as the functions that the area should accommodate. In addition, comparable cooling and spatial design principles can be applied.

The generation of fast design tests in a completely different area of Málaga, in the particular context of one of the main corridors of the system, is a suitable method for exploring the extent to which such a typology is valid.

Fig. 176. Area of interest for the generation of design tests, with an indication of the transferability type that is associated to each block. Elaborated by the author.
The area of intervention belongs to types #5 and #6, which provides an indication of the importance of topography in shaping design. In this particular intervention, it is possible to find a way of incorporating the necessary water buffering functions, as well as an extension of the vegetated cover. The integration of the corridor becomes easier towards the bank that belongs to type #6, due to its lower GSI.
The presence of type #3 demarcates the transition towards a more consolidated fabric. At the same time, however, a relatively low GSI allows the incorporation of the water and green functions of the corridor to the public life of the neighbourhood. A similar intervention as the one applied in Parque del Norte (intervention #4, pages 160 to 165) would allow the extension of the qualities associated to the corridor to the interior of the fabric.

Fig. 179. Bird's eye view of the current state of the area of intervention. Source: Google Earth.

Fig. 180. Proposed approach to the intervention. Elaborated by the author.
In Mangas Verdes, the higher relative GSI that is associated to type #1 defines the possibilities of intervention. In such a fabric, the incorporation of cooling functions requires imaginative and precise design solutions. The insertion of water in the public space, in the form of channels or fountains, and the addition of other shading elements are possible design alternatives in this type of fabric. The incorporation of the private realm is also present in this design, and establishes a clear connection with the interventions in La Trinidad (pages 134 to 141).
THE ROLE OF DENSITY

Part of the primary motivations of this work lied on a series of observation of Málaga’s fabric. Among them, the realisation that, in its heterogeneity, some big differences in density could be leading to an uneven performance of the city in multiple aspects. During the development of a theoretical framework, density (both in its physical and social definition) was effectively linked to an increased manifestation of the negative aspects of the UHI effect. This statement led to the generation of a typology, which helped to define different types of density and five representative areas of interest, in which it could be possible to explore the extent to which density was playing a role in the issue. Two main indicators, FSI and GSI were specifically chosen for the generation of this typology.

Once the design stage has been defined, it is possible to reflect on those first intuitions and draw some conclusions on the real role of density in relation to the UHI effect. First of all, not every intervention required an modification of physical density, a fact that can be seen as an positive indication of the adaptability of many of Málaga’s fabrics. In those cases in which it was required to intervene in urban form, the proposals reflect notable alterations in GSI, while the values of FSI tend to be similar (Fig. 184). This can be seen, in the context of the UHI effect, as an indication of the preeminence of GSI in defining physical limitations and potentials, while FSI could be more easily related to the problems that derive from a higher social density, such as higher levels of vulnerability and conflict.

The alterations in density displayed in Fig. 183 also indicate the non-existence of an “ideal” density value: while in some cases, the resulting density is lower, in other it is evidently higher. The alterations of density at block level can be significant, as seen in the graph, to the extent of making a particular block shift from one density type to another. The concept of “good density” is therefore multiple, depending on the specific characteristics of each of the fabrics and their relation with different metropolitan systems. The unit of aggregation is also important: for instance, it is possible to think on applying a lower density to a certain block in order to obtain some qualities, however, in general this should be done in a way that the values of density at neighbourhood level remain relatively high. The operations in one block, therefore, are not always transferable to any other, as they have implications not only within block limits, but also in its surroundings. In general, using the urban block as the aggregation unit for the calculation of density provides a great level of detail, but these very specific values should always be taken into account in relation to their vicinity. Interventions like the ones envisioned for La Trinidad (Fig. 183, 1 and 2) or Camino de Antequera (3), for instance,
Fig. 183 (cont.). Diagrams of alterations in density presented in this work. Elaborated by the author.

Fig. 184. Alterations in density according to their GSI and FSI values, and density type. Elaborated by the author based on previous data.
are adequate in the context of a very homogeneous fabric in which the GSI values are relatively high. In the case of Nueva Málaga (4), on the other hand, the addition of built space at ground level is only possible because of its relative position with respect to the park. A similar intervention could not be envisioned in Gamarra, where the conditions of the surroundings would be completely disadvantageous. In the case of Nueva Málaga, additionally, the benefits of the intervention become more evident for those blocks that are beyond the limits of the project. Even in the smallest level of aggregation, therefore, density should not be taken as an isolated value. Each specific context, and the particular relation of each fabric with the system, establishes concrete needs and potentials that need to be unveiled through design.

Density, therefore, plays a relevant role in relation to the UHI effect, and can be subject of different types of alterations regarding a better thermal performance of Málaga’s built environment. Beyond the UHI effect, however, it is crucial to remember the implications of density regarding sustainability and livability. The relation between these three dimensions defined this work’s problem statement, and was seen as the main cause of the sustainability/livability imbalance. Although it is believed that a higher level of concordance between these two dimensions has been achieved by means of design, it is also true that density seems to have played a more indirect role in achieving this equilibrium. The main factor defining the design’s impact on the issue lies in its definition as a metropolitan system with particular spatial manifestations in each area. While the first condition is more directly associated with an increased sustainability, the second can be seen as the driver for a higher livability in each particular context. In both cases, density helps to define potentials and limitations. At metropolitan scale, for instance, the functioning of the water system relies on those areas with a higher density, which can provide good amounts of domestic grey water. In the case of the areas with a lower density, which tend to be peripheral, they provide sufficient space for the buffering and treatment of this water. These factors, among others, can define the extent of the system’s impact regarding sustainability. And on the livability side, as previously explained, the particular manifestation of this system in each fabric is also highly dependent on density.

LIMITATIONS OF DENSITY REGARDING TRANSFERABILITY

One additional conclusion to the study of the transferability typology, which includes GSI as one of its variables, is that the degree of transferability of interventions is only partial. The comparison of two different interventions (Fig. 185 and 186) can picture this idea. Both of the areas (in the case of Fig. 186, the fabric standing on the left side of the corridor) belong to the same transferability type (#5) and have similar GSI values. However, the possibilities of transferring the concept of “integrated urban forest in between blocks” from the first to the second are limited. This indicates that, just as important as the density value, the way urban form is configured and distributed has also a relevant impact in conditioning design. The incorporation of this concept as an analytical tool can be fruitful.
"THE NET" AND "THE SELF"

The imbalance between sustainability and livability, which constitutes the core of this work’s problem statement, is partly derived from the uneven performance of fabrics in respect to their density. There is, therefore, a strong morphological component behind this particular issue. From a more abstract perspective, however, the discrepancy between sustainability and livability is also a representation of the conflict between “the Net” and “the Self”, as explained in the theoretical framework, and is therefore embodied in our human dual condition, both as individual and collective entities.

For this reason, the achievement of this work’s title, a “sustainable Self” and “livable Net” might probably sound like a chimera. Certainly the issues derived from this duality will always be present in our urban environments, but, by means of research and design, it is crucial to reduce its presence to more anecdotal manifestations. As previously stated, the relevance of the imbalance between sustainability and livability is nowadays crucial. The purpose of this work has been to show one possible way to palliate its impact.

However, the design proposal, as a physical artefact (a metropolitan-scale system with different spatial manifestations according to smaller-scale particularities) is, by itself, unable to guarantee the achievement of a more sustainable and livable city. A metropolitan corridor cannot lead to a higher sustainability unless it is conceived and designed according to the needs of the whole (the Net), while its manifestation in a smaller scale cannot result in a more livable environment unless it understand and respect the specific constraints of each of the areas, without being imposed or creating new problems, which is a reflection of the Self. Only when this duality is assimilated since the design stage can the resulting intervention help in achieving a “sustainable Self” and “livable Net”.

Fig. 187. Diagram of the relation between Density, Sustainability and Livability with respect to the “Net/Self” perspective. Source: author.
MÁLAGA'S EXPANSION MODEL

This work has mainly focused on the qualities and characteristics of the existing fabric. However, the inclusion of Torre Atalaya in the group of sites has been also an opportunity for challenging Málaga’s current urban expansion model, which could be described as the combination of a stricter maximum value for density and the stimulation of a certain building type (enclosed communities).

In the pre-democratic Málaga, the main limitations to a balanced sustainability and livability are derived from a certain shortage of open spaces. In the current expansion model this characteristic has reversed, but the allocation of the most qualified spaces to a semi-private function has defined a completely new problematic, which is based on accessibility rather than availability. The multiplication of such semi-private spaces is a triumph of one specific “Self” (the middle class, relatively young couple that want to raise their children in a safe environment) over the theoretical advocacy for the common good (“the Net”) of the planning figures, which is not resulting in a more livable and sustainable city, as it has been described in this work.

The revision of the high over-representation of this building type in the areas of expansion of the city should be accompanied by the incorporation of the proposed metropolitan system to the urban plans. Undoubtedly, the integration of the water functions and the system of corridors can be easily achieved if they are considered as an important structuring element from the beginning. Even more as the city continues to expands towards the Guadalhorce valley, an area in which the importance of a good water management is even higher. The consideration of these guidelines, in the end, may reverse the current tendency, present in the urban plans, to consider Málaga’s areas of expansion as a tabula rasa (Fig. 188).

Fig. 188. Málaga’s area of expansion, as currently planned. Source: PGOU 2011
The generation of a metropolitan infrastructure is a design approach that could be applied in multiple contexts, due to the fact that it does not only provide immediate benefits to the UHI effect, but also helps to increase the levels of sustainability and livability and balance them. In that sense, the generation of such a system in Málaga implied certain technical difficulties due to its climate conditions, but would be easier to apply in those places with the availability of water is higher.

LIMITATIONS

The design of this work relies on the feasibility of the water system. Without it, the inclusion of water as a cooling element in design would be infeasible and unsustainable, given the fact that drinking water would have to be used.

However, in the scenario of technical limitations to the implementation of the water functions of the system, there are still benefits deriving from the introduction of the rest of the elements, as it is the case with the addition of vegetation. In that case, it would be required to select species according to their levels of water consumption, so that the do not require to be irrigated.

The proposed design require a considerable investment, due to its scale and to the incorporation of multiple functions. The immediate benefits that would follow its implementation might be seen as reduced, and this perception might hinder the political acceptance of such a proposal. The water-related functions of the system, in particular those aiming for the retention and management of rainwater, might be seen as more attractive from an investment point of view, due to the recurrent flood-related problems experienced in Málaga. The UHI effect, on the other hand, is probably not seen by many (even among residents) as a completely urgent issue.

A design that is able to incorporate multiple benefits is more likely to be accepted by the community, and be thus seen as a more interesting investment.

Further possibilities related to research can be found in multiple stages of this work:

- Regarding the design of the system of corridors at a metropolitan scale, the method followed in this work included the study of hydrology via remote sensing and the mapping of the existing underground discharge lines. It could be possible, however, to incorporate the study of street widths across the city as a strong complementary tool, which could even be linked to the hydrology map in order to generate a new typology. Such a typology would indicate the best areas for the implementation of a corridor, and would constitute a previous step to the transferability typology, or could be combined with other indicators (such as GSI and height) in order to generate a completely new approach. The possibilities of such a method should be explored further.

- In terms of the water-related functions of the system, there are still multiple technical constraints that should be researched, in order to confirm the extent to which such a system would be feasible in every context.

- The evaluation of the positive impact of the interventions in relation to the UHI effect has been based on the quantification of changes in multiple spatial elements (such as increased albedo, vegetation or higher permeability). Such an evaluation framework, however, offer certain limitations, like the fact that all spatial alterations are given the same importance and assigned subjective values. The development and integration of a more comprehensive method would allow a more precise evaluation of the positive impact of design in relation to the UHI effect. An additional field for further research, therefore, lies in the exploration of possible alternatives for evaluation and their effective integration in the design process.

- Finally, from a more strategic point of view, further research can be conducted on the principles and guidelines that should be incorporated into Málaga’s existing planning figures. This would not only allow the development of interventions within the existing fabric, but also define an alternative vision for Málaga’s current expansion model. Some of the existing methods used in this work for understanding existing fabrics (such as the generation of typologies) could be adapted for the evaluation of needs in unurbanized areas.
The initial scope of this Master Thesis is very broad, as the focus is on how livable or sustainable cities can be in the presence of certain conditions. Sustainability and livability are two dimensions of urban environments that have been presented in this Thesis as in a continuous conflict, although the diffuse nature of the two terms makes it difficult to identify these conflicts immediately. The recognition of temperature and the UHI effect as one particular representation of this imbalance served for the purpose of bringing the problem statement to manageable terms, but also provided different spatial solutions that are known to be effective towards thermal adaptation.

The UHI effect is a well-documented and researched phenomenon. The solutions that are often proposed for counteracting this effect are also known to be effective, and can be combined in multiple ways. There was a certain risk, therefore, that the relationship between research and design in this Thesis had been reduced to a unidirectional one: there is a certain UHI effect in Málaga and some typical spatial interventions are known to be effective against it, therefore, they should be combined and applied in different or innovative ways in various places in the city. Such an approach would be technically efficient, but was seen as a missed opportunity for establishing a bidirectional relationship between research and design: one in which design also retrofits research, allowing the for the discovery of hidden potentials and the incorporation of unforeseen theory. This idea, which lies closer to the “research by design” concept, was, at least from my point of view, partially present in the Thesis. For instance, the discovery that there were certain technical limitations to the implementation of water in any small scale intervention lead to the need of further research on the topic of water management, which then made clear that only through the incorporation of a metropolitan-scale system would the goal of reaching a higher sustainability/ livability balance be taken to its full potential. In a way, this iterative relationship between research and design allowed for the identification of the system-approach as the first priority, supported the incorporation of multiple scales and modified the constraints to which the UHI design principles could be developed.

It is interesting to analyse the adequacy of Málaga as a valid case study by reflecting on some of the keywords that define this Master Thesis.

Density has been one aspect of urban environments that has defined the nature of the work, linking the intangibility of terms like “sustainability” and “livability” to the actual city form and justifying the insertion of this research in the Urban Fabrics research group. It can be stated that the levels of density in Málaga, despite of being certainly diverse across the city, are not representative of the great differences in density that can be found in urban environments around the world. Surely, a thorough research on “the imbalance between sustainability and livability in the presence of certain levels of density” would require the study of the implications of extreme density levels on these dimensions, but such a task (which would certainly deliver interesting results) would exceed the requirements of a Master Graduation Project. In the end, the selection of a graduation theme was site-based, and derived from my personal observations on different urban qualities across a city that I know to a great extent. Even within a city that could be considered to be moderate in terms of density, small morphological variations have a great impact in the way it performs, and these variations are certainly worth being studied.

Regarding temperature and the Urban Heat Island effect, the location of Málaga in the southern European context justifies by itself the adequacy of Málaga as case study, in spite of the fact that the study of its Land surface Temperature did not show an actual Urban Heat Island effect happening. In the scenario of rising temperatures and aging population, the study of this phenomenon in a context like Málaga’s is certainly adequate.

As for the selection of smaller intervention sites, it was done according to the criterion that they had to represent different morphological (density) conditions. For this reason they however do not reflect the greatest temperature variations, or represent those areas with higher LST values. This would have been an interesting complementary approach to the work, and should been taken into account as a recommendation for future elaborations on the topic.
REFLECTION OF THE SELECTED METHODS

The research group Design of the Urban Fabric has a strong morphological approach to the study of urban environments. For the elaboration of a theoretical background, this means that it encourages the study of the interrelations between different aspects of urban form and the performances or qualities that derive from them. In other words, there is a bidirectional reflection of how different tangible and intangible aspects of urban environments are interrelated. This Master Thesis tries to do that, by always relating the sustainability/livability performance of urban fabrics in relation to their density.

During the elaboration of the Thesis different methods were used. At this point, it is possible to reflect on their adequacy, based on their contribution to the final results. In particular, it is interesting to focus on the three main stages of the work, namely the formation of a theoretical framework, the analysis and the design intervention, because each of them required a series of methods that were completely different in nature.

Regarding the formation of a theoretical background, one of the main contributions of this Master Thesis is the application of the “Self and Net” perspective to the notions of livability and sustainability in urban environments. This process, far from being anecdotal, constitutes by itself the elaboration of a new method which is capable of identifying conflicts from a theoretical point of view. Without this particular step, the transition from the abstract to the concrete dimensions of the work would have been unfounded. It also can serve as a useful method for further research in the topic.

Regarding the analysis stage, it is noteworthy that a big part of the analyses were conducted using remote sensing, which means that they were done by processing georeferenced data in GIS software. These include the study of density, the generation of Land Surface Temperature maps, the study of Málaga’s hydrology, the study of the vicinity to green areas or water, among others. Indirectly, also the generation of a density typology, in which the selection of intervention sites is based, was done using this type of data and the tools provided by GIS. In the end, a big part of the decisions made in this work have been based on this type of information, which offers great potentials but also limitations. For instance, the use of such methods is highly dependent on the availability of georeferenced data, which is often provided at all. While in The Netherlands there is a great amount of open data that can be used for any kind of study, other countries do not have yet a tradition of making certain information accessible to the general public. This affects and often limits the transferability of the methodology of this work to other contexts.

Another limitation has to do with the degree of resolution of the available data. The images provided by the satellite Landsat 8, for instance, which were used for the generation of the Land Surface Temperature Map, had a maximum resolution that allowed the distinction of differences in temperature at block level, but could not give information related to microclimatic conditions. The fact that this particular satellite always flies over Málaga at 10:56 am, instead of in the afternoon/evening, also means that the temperature data does not show the real extension of the UHI effect in the city, which is stronger after the sun has been heating up the surfaces of the city for some hours. In the end, however, this relative inaccuracy of the temperature data did not affect the subsequent steps: as it has been mentioned, the intervention sites were selected according to their density conditions and the design of a metropolitan system is intended to bring similar qualities across the city. Similar limitations occurred in the case of other datasets and analyses.

Finally, regarding the design stage, the decision of generating a multi-scalar system has proven to be coherent with two main constraints: on the one hand, that whatever design was finally produced had to respond to the abstract dimension of the problem statement, that is, result in a higher sustainability/livability balance; on the other, that it could not be the result of the application of a toolbox, nor the sum of different isolated interventions.
THE RELATIONSHIP BETWEEN THE PROJECT AND THE WIDER SOCIAL CONTEXT

As described during the Thesis, sustainability has been given traditionally three dimensions: economic, social and environmental. And in response to the sustainability/livability confrontation, also some indicators of livability seem to belong to one or other dimension. The fact that temperature and the UHI effect have been selected in this work as representative of this confrontation has probably drawn most of the attention to the environmental side, and the subsequent design interventions have mostly been based on environmental principles. Social factors have been there nevertheless, shaping the spatial interventions in one way or the other according to local conditions, although the importance of these factors in defining the design intervention could have been higher, at times. For instance in La Trinidad, which is a neighbourhood with higher unemployment rates and different social issues, the interviews with locals showed no real interest of the inhabitants on the environmental qualities of their neighbourhood but on social issues. “Having a job”, for instance, was a very common response to the question “what do you think this neighbourhood is lacking”.

The most important implication of this appreciation is that Málaga’s population might not see the issues presented in this work as really urgent, even though they have been stated to be socially relevant (as a result of an aging population and rising temperatures). This could be a crucial obstacle for the actual realization of such a design: most inhabitants might consider the quality of their environment to be already sufficient, and would probably not support any investment in this vein. Even more, when this investment implies drastic changes in their surroundings, which could lead to a certain degree of nimbyism.

In the end, all these issues are representations of the sustainability/livability confrontation, but acknowledging it does not automatically solve the problem. While the appreciation on the livability of one area is probably not shared by many, due to its subjective nature, the issues on sustainability seem still to be distant from the perceived urgencies of the city. And, in general, environmental issues seem to be less urgent than the social ones. If this project had to be applied in reality, it would certainly need to be based on awareness and communication.
Sustainability and livability are two concepts that can be used to describe the performance of urban environments. They are both heterogeneous, as they comprise multiple indicators, an also opposed in nature. This appreciation comes from a double perspective: from a theoretical point of view, each of them represents one of the two opposed dimensions of human existence, “the Self” and “the Net”. From an empirical perspective, it is observed that certain urban forms tend to be more livable as they become unsustainable, and vice versa. The main agent of change for this phenomenon is density, both in its physical and social sense. This tendency to the imbalance defines a problem area that needs to be addressed from an academic point of view.

In Málaga, this imbalance is manifested in different ways throughout its urban fabric, according to its morphological characteristics. Temperature is, due to the city’s geographic position, a relevant concept that represents a connection between sustainability and livability and that is dependent on density. Denser urban environments tend to contribute less to global warming, however, due to different social and physical features, they normally provide a lower degree of thermal comfort to their inhabitants. This fact is explained by the Urban Heat island effect, which is an inherently urban phenomenon, by which urban areas tend to be warmer than their rural surroundings. By narrowing the scope of the problem down to this matter, the essence of the imbalance between “the Net” and “the Self” is maintained, while becoming concrete and more manageable.

The study of Málaga’s superficial temperature shows great differences between different areas of the city. These can be partially explained by territorial features, such as topography, vicinity to the sea or to big green areas, or general land use. Within the city limits, the way the urban fabric responds to temperature is also heterogeneous, and depends on their morphological characteristics. Based on the measurement of the city’s Ground Space Index (GSI) and Floor Space Index (FSI), as well as the generation of a density typology, it is possible to identify areas with common or different morphological characteristics, in order to study and anticipate their weaknesses and potentials with respect to thermal adaptation.

In Málaga, the study of five different sites confirms the need for a customized approach to design. The reach of the benefits of any spatial intervention, however, increase when the scope of the design is metropolitan and systemic. The combination of both intentions result in a design approach that is multi-scalar and unitary, but manifests at the same time in a different way in each point of the city.

In the design intervention, the inclusion of a water management function provides the system with a greater coherence. By means of this water system, it is possible to reuse domestic grey-water and runoff water for achieving a greater cooling power in different places of the city, therefore helping to improve urban quality in the small scale. At the same time, this approach also responds to the metropolitan lecture on the UHI effect, by which the biggest differences in temperature are determined by the city’s internal structure and its relation with various natural systems.

By means of design explorations, the spatial principles that are associated with a better response to the UHI effect, such as the addition of vegetation, the presence of water, shade, etcetera, can be unfolded in different ways according to the particular characteristics of each area. The definition of design in the small scale builds on the metropolitan system, but also helps to prove and define its continuity across different fabrics and scales.

The resulting design is not only the response to a particular phenomenon (the UHI effect) but an attempt to achieving a more balanced livability and sustainability, by means of focusing on one particular manifestation of that imbalance. As such, it needs to be evaluated according to its contribution to a better thermal adaptation, but also according to its impact on other indicators of sustainability and livability.

Ultimately, the goal of achieving a “sustainable Self” and a “livable Net” requires, first of all, a real understanding of the opposed nature of both dimensions and of the effects of city form in the extent to which this contradiction is manifested. Building on that idea, design can become the process by which a greater compromise between the self and the Net is achieved.
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