# Smart Urban Green Spaces: Designing Resilient, Community-Centric Environments in De Hoogte

**Bachelor's Thesis BSc Spatial Planning and Design**

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## The Short And Sweet Summary If You Do Not Have Time To Read The Whole Thing

The present thesis explores the principles of smart technologies implemented within the framework of urban green spaces in the De Hoogte district in Groningen, Netherlands. In this respect, the mechanism of research-by-design is implemented as an instrument for innovations in the management of urban green spaces. This complex position concerning some of the most significant urban challenges, such as climate change, urban densification, and the urban heat island effect, delivers positive insight into the duality of the impact of urbanization on public health and environmental sustainability. Theories related to the duality of urbanization by Kuddus et al. (2020) and Zhang et al. (2023) and the benefits of smart city innovations by Andreev (2023) and Valencia & Castañeda (2018) underpin this research. Innovative technologies such as IoT-enabled waste management, intelligently controlled irrigation systems, and adaptive lighting show promise in managing urban green areas. Each of them offers real-time data, resource optimization, and community engagement in one way through accessible environmental information. The three design scenarios put forward are green space enhancement, strategic realignment of road networks, and the creation of the central park. The induction of all three scenarios mentioned above with innovative technologies significantly enhanced their functionality, sustainability, and accessibility into such propositions that make it possible to produce a more livable urban environment where social meetings and community engagements become a common trait among people. Based on the observations made here, it becomes recommendable that striking a balance between ecological, social, and technological

exposures is possible. However, while being the extensive beneficiary of smart technologies, they must be controlled to elude over-dependence on them and action to supplement ecology-based approaches. The recommendations presented in the thesis indicate lines of policy implications and urban design practice that endorse the creation of tolerant, inclusive, and environmentally sustainable urban green spaces.

# Contents

# 1. Hold Up, What Is Happening In Our Urban Jungles?

The dimensions of climate change are bringing challenges to the 21st-century human ecosystem, society, economy, and the urban environment. Among these, metropolitan regions are very vulnerable: the rising pressures call for strategic planning and focused interventions. The urban heat island (UHI) worsens, thus innovative, sustainable urban development plans must urgently reduce temperature increases and the urban heat island effect (Chapman et al., 2019; Tan et al., 2009; McCarthy et al., 2011). This not only amplifies the challenges that come along with denser human habitats but also signifies the implications of quality living and human comfort in urban settings (Zhao, 2018).

The idea of a smart city is one of the possibilities that can put technology and innovation into practice to generate sustainable, efficient, and inclusive urban places (Parubochaya et al., 2020; Valencia & Castañeda, 2018). This further underscores the need for transformation considering the projections from the United Nations (2018), with data indicating that 55% of the global population lives in urban regions, projected to rise to 68% by the year 2050. Smart cities can lead to quality living conditions, quality urban services, and even mitigating environmental and social threats by turning urban spaces into sustainable and resilient models (Dudycz & Piątkowski, 2018; Kumar & Rattan, 2020).

This is a rationale-based study in that it tends to address the emergent multifaceted challenges of climate change in urban areas and how smart cities could help mitigate these challenges. Based on theory, the value of the research will be to the literature review based on the sustainable development of cities and on the smart city initiative, concerning adaptation to climate change. From a societal perspective, the findings of this research shall inform policies, urban designs, and community mobilization toward the best ways a city can be made inclusive, resilient, and sustainable for the achievement of the United Nations Sustainable Development Goal 11 (SDG11).

By exploring the intersection of urban vulnerabilities and smart city solutions, this research sheds light on local solutions to global challenges. The development of urban neighborhoods is being done in various parts of this world to adapt to climate change; this would significantly contribute towards safeguarding our shared environment. This is a step towards the action to evade the adverse effects of human actions to be secure in achieving a very safe future for later generations.

The core purpose of this research is to review and propose new design principles that make use of smart technologies for sustainable management of urban greenspaces. The design principles are guided by the design cycle, which helps to emphasize, ideate, and evaluate the potential ideas in real-life scenarios. Therefore, the research will examine the challenges to maintaining and improving urban green spaces, among these being the degradation of an ecological nature, restricted public access, and problems caused by urbanization. Anchored in the context of smart cities, the purpose is to unravel how smart technologies can provide solutions with a focus on maintenance. These may be pivotal for the sustainable upkeep and revitalization of these spaces. In this regard, the outcome of this research seeks to make a valuable contribution toward deepening the understanding of the relationship between urban green spaces and smart technologies, suggesting a pathway for urban environments to become more resilient and livable. This dual focus is motivated on one side by the urgent need to mitigate the adverse impacts of climate change in urban areas and, on the other, by the potential of smart cities to offer innovative solutions that improve ecological health and enhance the quality of life for city residents.

Therefore, this study will investigate the following research question:

*How smart technologies can assist with the maintenance of innovative design scenarios to improve urban green spaces in densely populated areas?*

Moreover, to my knowledge, no research has been done yet on this specific topic, making the research itself unique and worth investigating.

# 2. From Theory To Tree: Understanding The Roots Of Smart Urban Greens

## 2.1 So, We Are Building Up … But What About Trees?

Urbanization is a double-edged sword with two sides, one that promotes environmental sustainability and the other that poses a challenge. It has put pressure on urban green spaces, increasing the loss due to rapid urban expansion. In most cases, it has been the cause of the loss of biodiversity and public space available for recreation (Stipanović et al., 2022). Green spaces, however, are critical because they mitigate the Urban Heat Islands, a phenomenon where the temperature is warm in urban regions compared to the rural areas, hence the effects of global warming are magnified (McCarthy et al., 2011).

Urban densification, a necessity in contemporary planning, impacts society, the economy, and the environment. The negatives of overcrowding and stressing of infrastructure result, which have to be balanced with the positives that some efficient use of land and less energy consumption results (Berghauser Pont et al., 2021). These motivations can be stated to be arresting dilemmas of sprawl and environmental degradation (Berghauser Pont et al., 2021). Challenges include maintaining green spaces to preserve ecological balance and quality of life (Berghauser Pont et al., 2021).

Further complicating this fact is one mentioned earlier: that there exists a mismatch between the scientific evidence of densification impacts on the one hand and the motives driving urban planning on the other. For example, in Swedish planning practice, it is much more optimistic that higher density will be a contributing factor to sustainable urban development than what could be directly supported by empirical studies. This optimism shines through most clearly in the perceived positive impacts on everything from everyday social interaction to public facilities, despite all evidence against it (Berghauser Pont et al., 2021).

Kuddus, Tynan, & McBryde (2020) argue that urbanization is a kind of two-faced process: on the one hand, it creates the condition for economic and technological growth, and on the other hand, it further aggravates public health problems, particularly those of the urban poor. In this regard, they highlight that the concentration of people in urban localities multiplies the vulnerability to communicable diseases, poor nutrition, and pollution-related health issues (Kuddus et al., 2020). Adding on to this discussion, Zhang et al. (2023) studied how urbanization may affect public health in the period from 2000 to 2018 in 175 countries This study finds positive correlations between urbanization and especially different econometric models, in turn, alleviates and improves living standards and reduces mortality rates and enhances life expectancy. However, the benefits of urbanization are less pronounced in countries with higher living standards (Zhang et al., 2023).

Beenackers et al. (2024) deconstruct the nuances of urban densification and mental health in the Netherlands using a causal loop diagram, which experts use to explore the relationship between these two factors in even greater detail. They have mapped out six subsystems that provide a model for how densification impacts mental health The related subsystems include impacts of neighborhood stress and recovery, impacts of housing affordability, impacts of social structures, impacts of a sense of place and perceived safety, mobility and physical activity, and positive feedback loop from mental health to densification. Their research indicates that higher population density can intensify environmental stress and diminish green spaces, negatively affecting mental health. This adverse impact is especially significant for low-income populations, who are more susceptible to these changes (Beenackers et al., 2024)

## 2.2 So, Cities Are Smart Now? When Did That Happen?

According to these authors, smart cities aim to transform the urban lifestyle into a more dynamic, effective, and sustainable way of life. Andreev (2023) commented that cities are also active systems that have drivers of digital innovations. On a similar side, Valencia & Castañeda (2018) also discussed various ways through which innovative technologies can enhance effectiveness and sustainability within urban cities. Such technologies are beneficial in arranging resources more effectively, improving participation of the people within the digital economy, & finally supporting the overall process of urban development.

As Dudycz & Piątkowski (2018) have shown in their analysis, smart technologies play an important role in enhancing urban governance. It is exactly the changes in public transportation realized under the influence of smart mobility solutions. The authors give very specific examples in London, San Francisco, and Singapore, where friendly user transport applications brought about real-time traffic management, huge efficiency, and access to their public transport systems. Urban transit becomes accessible to a larger demographic group, especially the elderly and the physically disabled (Dudycz & Piątkowski, 2018). Such smart mobility solutions encourage a higher rate of public participation in urban governance by allowing people to rely on and use public transport more often. In this way, the increased contact of the citizens with urban infrastructures and the increase in participation of the citizens in most of the city planning procedures could prove that smart technologies help to experience more involved and participatory urban life (Dudycz & Piątkowski, 2018).

Kumar & Rattan (2020) continue from the establishment of traditional cities to smart ones, pointing out how advanced technologies serve to enhance or increase the standard of living in a town. The authors use Seoul and Singapore as prime examples of innovative city development. The Seoul Smart City project began in the year 2014. Since then, it has been a sustainable and advanced information and communication technology city and competitive. The city has employed various intelligent technologies to push public services and the management of urban planning toward progress and to create a high-tech environment. Some salient features of Seoul's smart city project include the creation of one all-encompassing urban data platform to help deploy IoT sensors to monitor the city's infrastructure in real time and integrate AI for managing traffic and reducing congestion in the city. The other example, discussed by Kumar & Rattan (2020), is Singapore, which, meanwhile, has addressed challenges related to limited land resources and rapid population growth. Since its independence in 1965, Singapore has expanded its land area by about 23% through land reclamation. Answering the food security needs, the city-state has turned to vertical farming, leveraging innovation in agriculture to conserve space. Besides, the smart city infrastructure of Singapore showcases sustainable urban solutions such as efficient water management systems, smart grids, and green building technologies to achieve improved livability, environmental sustainability, and resource efficiency.

### 2.3 Are Robots Running Our Parks Now?

Over the years, smart technologies have been discussed in urban development contexts to properly manage and sustain green spaces. Neirotti et al. (2014) highlighted the potential of integrating Information and Communication Technologies (ICTs) to enhance the efficient use of natural resources in urban areas. The technologies are applied in controlling public lighting and water, whose objectives are to lessen the amount of energy and encourage sustainability maintenance in parks in urban areas (Neirotti et al., 2014).

Furthermore, the study examines potential improvements in ecological monitoring and management through the use of different equipment, including sensors and data systems (Deak

Sjöman et al., 2022). These allow, respectively, to know in detail the dynamics of the environment in the green spaces, facilitating the optimization of the use of resources and increasing the attractiveness for recreation in the environments. Furthermore, they encourage integrated management in all subsections for nature and human activity-based urban ecosystem components (Deak Sjöman et al., 2022). Making this clear, Twahirwa et al. (2022) note that this might be achieved through the use of the Vehicular Internet of Things (V-IoT) in the monitoring of metropolitan environments. For example, the establishment of sensors in public buses that monitor air quality will result in instant crucial information for the proper management of pollution levels in urban centers while maintaining the health of green areas (Twahirwa et al., 2022).

The impact of smart technologies on community engagement in urban green spaces is a significant area of research. Worthington & Kershaw (2023) move the issue a notch higher by examining how such technology can enhance the experience of tourists, hence luring them to visit the green space more often. It can also offer better incentives for public involvement in the far more effective conservation of green spaces by providing the most up-to-date information on park usage and environmental conditions. According to Worthington & Kershaw (2023), It makes the urban parks more dynamic in this process, responding to the needs of the community.

There is a unique way of enhancing the operational efficiency in urban green park management. The multilayered smart framework technology, explained by Zhang & Li (2015), is grouped under four levels: sense, network, support, and application, all working jointly toward the management of urban parks. This system comprises spatial information technology, smart sensing, the Internet of Things (IoT), and cloud computing. The developed system reflects the use of different sensor nodes at various locations within the park premises to facilitate real-time data acquisition and sustained monitoring throughout the park's operating hours. In such an environment, real-time monitoring helps maintain cleanliness and the health of the vegetation and visitor distribution. Fast response to maintenance issues that might arise is easily enabled by such level monitoring to help improve the user experience, as stated by Zhang & Li (2015). In addition, for example, smart watering systems have been made a way to read soil moisture and weather conditions through sensors that help conserve water and prevent wastage as stated by Bedi et al. (2020). According to Ababneh (2023), intelligent lighting systems dim or brighten depending on occupancy and availability of natural light to optimize energy consumption. Technologies such as the above provide material on which planners and managers can base proactive decisions concerning maintenance because environmental conditions can be monitored in real time and analyzed. It also requires community engagement to ensure that the needs of the locals are provided for in the urban green space and good governance to enhance sustainability, according to Ababneh (2023).

The chapter then goes ahead and investigates the direct impacts of such technological innovations on day-to-day users' interactions in such spaces to look at ways in which smartness influences perceptions of what green space is for its users.

### 2.4 Got Tech? How Smart Sensors & Green Spaces Are Changing Urban Chill Spots

Incorporating green spaces into urban settings has emerged as a significant trend aimed at fostering sustainable and livable cities, as well as offering diverse benefits spanning ecology and society (Rachmawati, 2019; Russo & Escobedo, 2022). According to Abankwa & Quaofio (2020), amenities in the space greatly impact the user experience in urban green areas. A couple of factors identify the amenity perception by the users, from the lighting and seating that were available at the point of use to naturalness and maintenance, including the availability of toilets. This tends to chase away visitors from poorly maintained sections and those that are dirty; hence the whole experience and impression of green spaces are negative (Abankwa & Quaofio, 2020).

In the same breath, Chen et al. (2021) review existing research on the impact of urban green spaces on mental health. Urban green spaces enhance the well-being of urban areas and their inhabitants, promoting improved health and fostering social cohesion (Hartig et al., 2014; Hunter et al., 2019). Chen et al. (2021) find that green spaces positively affect residents through three main pathways: environmental improvements, physical activity, and social cohesion. Specifically, green spaces can improve air quality, reduce noise, and provide calming visual stimuli, which all help to reduce stress, as well as green spaces increase neighborhood satisfaction and foster a sense of community, making people feel more secure and content (Chen et al., 2021). The presence and quality of UGS are linked to lower levels of mental stress and improved mood, as well as accessibility, safety, and amenities of green spaces further influence their use and the associated health benefits (Lee et al., 2015).

In line with this understanding, the incorporation of technology into urban green spaces enhances the user experience and general satisfaction very effectively. According to Jia & Wu (2020), one of the remarkable advancements in the field is the proposal of a multi-dimensional assessment model using RE—3DSG sensors - the model was applied in a real-life case, optimizing green space in Wuchang District, Wuhan, China. The system has two main components: Net Ecosystem Service (Net ES) and Green Volume Ratio (GVR). The Net ES part focuses on measuring environmental benefits like air purification, carbon sequestration, noise reduction, runoff control, cooling, and recreation. Jia & Wu (2020) note that to gather this data, different types of sensors are used: gas sensors for air quality, chemical sensors for carbon levels, sound sensors for noise, humidity sensors for water management, temperature sensors for cooling needs, and recreation sensors for how people use green spaces. The GVR sensors evaluate the three-dimensional structure of urban green spaces by looking at the leaf area index (LAI). This helps to understand the density and layout of vegetation, which is important for city planning and maintaining ecological health (Jia & Wu, 2020).

### 2.5 A Short Literature Wrap-Up

Urban green spaces are increasingly valued for improving urban living through smart management techniques. Research highlights several features suitable for management within a smart-city framework. Neirotti et al. (2014) discuss the role of ICTs in promoting the efficient use of natural resources. Important attributes include environmental monitoring with sensors measuring air quality, noise levels, and temperature, providing real-time data to control pollution and mitigate the urban heat island effect (Jia & Wu, 2020). Smart irrigation systems using soil moisture sensors and weather forecasts optimize water usage, minimizing waste and ensuring sustainable upkeep of green areas (Bedi et al., 2020). Intelligent lighting systems adjusting to occupancy and natural light availability improve energy efficiency and safety in parks (Ababneh, 2023).

Additionally, various sensors track plant health and biodiversity, aiding in maintaining ecological balance and the long-term viability of urban green spaces (Deak Sjöman et al., 2022). Technologies that offer real-time information on park usage, facilities, and environmental conditions can enhance the visitor experience and encourage more frequent use of these spaces (Worthington & Kershaw, 2023).

However, the existing literature identifies several significant gaps. Many studies focus on specific technologies without presenting a comprehensive model combining various smart solutions into a unified system (Neirotti et al., 2014; Ababneh, 2023). This limits understanding of how these technologies can collaborate to optimize urban green space management. Additionally, there is insufficient discussion on incorporating different user groups' needs and preferences into smart green space solutions (Worthington & Kershaw, 2023). Effective management should consider diverse user experiences to improve accessibility and satisfaction. Moreover, the economic and social impacts of implementing smart technologies in green spaces are under-researched. Further studies are needed to conduct cost-benefit analyses, examine potential low-income community displacement, and develop strategies to ensure equitable access to these enhanced spaces (Zhang & Li, 2015).

### 2.6 So We Have a Plan? Let's Figure This Out!

The following conceptual model, as shown in Figure 1, is derived from the literature review to increase the depth of the understanding of the complexities in urban green spaces (UGS) under conditions of modern urbanization problems and technological interventions. The model shows how urban planning and smart technologies affect the sustainability and functionality of urban green spaces.

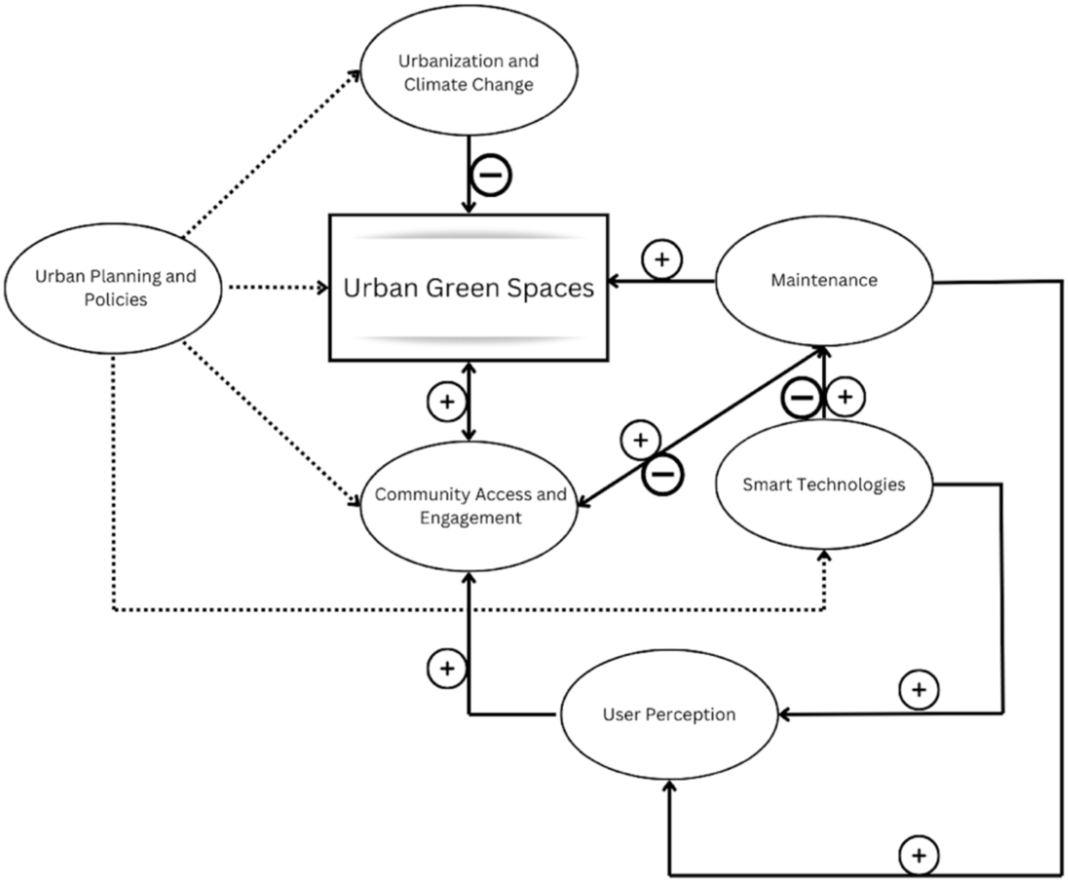


Figure 1. *Conceptual model* (own image, 2024)

Describing a conceptual model highlights the direct and indirect influence on the understanding of relationships between elements of urban green space (UGS) and maintenance as a central factor within an urban ecosystem. The model acknowledges a direct, negative influence of urbanization and climate change (UCC) on UGS, depicting this relationship as a simple arrow from UCC to UGS to symbolize degradation.

Smart technologies (ST) impact this model by providing both advantages and potential disadvantages to UGS maintenance. Positively, they enhance maintenance efficiency, resilience, and effectiveness, which in turn improves UGS management and user satisfaction. This influence is represented by an arrow from ST to maintenance. However, potential negative impacts include overreliance or improper application, which could complicate maintenance efforts by emphasizing efficiency over ecological sensitivity.

Maintenance positively influences UGS, ensuring that green spaces are healthy, accessible, and beneficial for urban communities. This relationship is represented by an arrow pointing from 'maintenance' to 'UGS'. Furthermore, the model includes a bidirectional, nuanced relationship between community access and engagement (CAE) and maintenance, reflecting mutual benefits and challenges: well-maintained green spaces are crucial for community welfare, and active community participation ensures sustainable maintenance.

'User Perception' is central, influencing and being influenced by UGS, maintenance, and ST. It affects and is affected by the effectiveness of maintenance and the application of smart technologies, and it directly influences community access and engagement.

Urban policy and planning (UPP) play a critical indirect role through governance, strategic frameworks, and regulations, influencing UGS, ST, maintenance, and CAE. UPP shapes the operational landscape for these elements, ensuring that smart technologies are integrated, supporting effective maintenance strategies, and ensuring equitable access for the community. The model highlights the supportive nature of urban policies and planning as crucial for the successful integration and adoption of smart technologies in the maintenance of urban green spaces.

### 2.7 What If We Could Tech-up Our Green Spaces?

Several design-oriented expectations are developed in a research-by-design methodology within my thesis, laying out a complex but innovative intervention to enhance urban green spaces. This is mainly different from the conventional hypothesis testing approach, more suitable to an exploratory and iterative research design process that is inherently flexible and reactive to emerging insights and conditions. Central to this approach is an anticipation that the integration of smart technologies within urban green spaces can greatly improve their management, resilience, and user experience. This imagines community access and engagement in planning and designing from its very inception to have green spaces that are not only much more appropriate and valued but rather serve as active platforms for social innovation and learning. Through inclusive design and planning, the expectation is to craft urban green spaces that are universally accessible and foster deeper collective ownership and stewardship of the environment. Along this line, the research will hope to offer pliable urban policy frames that uphold integration with smart technologies and further equity in community access, with an objective of policy recommendations for strategic action that would catalyze green spaces to turn into centers of innovation, engagement, and education.

## 3. How I Tried To Make Sense Of All This Green Tech Stuff

This thesis uses a research-by-design methodology, which was selected for its ability to integrate theoretical understanding with real-world design applications successfully. This method allows for the iterative development and testing of ideas through design practice, making it perfect for tackling complicated urban design concerns. A more important reason for choosing this particular approach is that in today's world, many issues are very complex, and the issue on how smart technologies can impact the maintenance of urban green spaces in the specific urban context is not an exemption. Climate change, migration, economics, and social processes are examples of problems that don't have final solutions (Roggema, 2016). These problems need to be managed and directed continuously to improve the future. These are known as wicked problems (Rittel et al., 1973). There isn't one single way to define these issues. Solutions are often framed in terms of "more-or-less," where planners and managers strive to achieve reasonable, yet ever-changing balances between competing interests and values (Roggema, 2016). We can't fully understand these problems until a solution is accepted (Norton, 2002). Regular thinking isn't enough to solve these persistent issues - they need counterintuitive thinking and new knowledge. Design is a good approach for these types of problems because it allows for creative jumps in thinking and solving problems (De Jonge, 2009). This approach is also important for the topic of this thesis.

The methodology is accompanied by consultations with domain experts and an extensive review of global case studies. Due to limitations on direct data collection via smart technologies and taking into account that the average resident has limited knowledge about the topic of smart technologies to make it a primary data collection, this research relies primarily on secondary data to assess their potential impact on urban green spaces.

This research combines theoretical exploration with practical insights based on selected existing smart technology applications. Primary sources include academic literature, industry reports, and policy documents, along with a set of spatial analysis tools employed for developing design proposals: ArcGIS, SketchUp, Adobe Illustrator, and Adobe Photoshop.

Also, every ethical consideration shall be ensured. These include informed consent, privacy, and voluntary participation. Representativity will also be ensured for all community segments. The secondary data used will be cited well to adhere to the copyright and data usage policies.

For this research, the De Hoogte neighborhood in Groningen, Netherlands, was selected based on several different aspects: demographic diversity, its form, and its amount of green. The site, 400m x 400m, is represented in Figure 2. According to literature, for instance, Yang Zhang (2017), De Hoogte is positively correlated with the health and well-being of its inhabitants with increasing levels of urban green. This high level of variety in socio-economic and demographic composition, coupled with the openness of this community towards technological innovations, has rendered the neighborhood an ideal case study to delve into the aspects of intelligent technology incorporation into green spaces. But, indeed, with the physical deterrents in the way of access to green spaces in De Hoogte, ample space is covered with green, which suggests the efficiency of everyday from-the-box management strategies. The demographic population of this area speaks more about a community open to technological innovations, which is in tune with the emphasis put on community involvement highlighted by Zhang (2017).

The design cycle, as depicted in Figure 3, will be followed throughout my design journey of the thesis. It comprises different steps that evolve from an initial design concept to a final product. While other designers may approach problems differently, some primary steps have been widely recognized. These steps - Emphasise, Ideate, Prototype Evaluate - collectively known as the design cycle form the basis of the design process. Table 1 shows a briefing summary of each step taken.

| **Emphasise** | **Ideate** |
| --- | --- |
| **What is it?** The empathize phase focuses on understanding the needs, experiences, and challenges of the people who will use the urban green spaces.<br><br>**How is it used?** In this phase, I conducted comprehensive analyses of existing literature and engaged directly with potential stakeholders to gather insights.<br><br>**What happened in this phase?** By reviewing academic research and best practices, I identified key issues and user preferences related to urban green spaces and smart technologies. | **What is it?** The ideation phase is about generating a wide range of ideas and potential solutions based on the insights gathered during the empathize phase.<br><br>**How is it used?** I utilized brainstorming sessions and design software like Adobe Illustrator and Photoshop to create visual representations of these ideas.<br><br>**What happened in this phase?** Multiple design concepts were developed, exploring various ways to integrate smart technologies into urban green spaces. These concepts were sketched and digitally modeled to visualize |

| | |
|---|---|
| | their feasibility and impact. |
| **Prototype**<br><br>**What is it?** Prototyping involves creating tangible models of the most promising design concepts.<br><br>**How is it used?** I used tools like SketchUp and ArcGIS to build detailed prototypes that could be tested and refined.<br><br>**What happened in this phase?** Selected design ideas were transformed into detailed prototypes, allowing for spatial analysis and practical testing. These prototypes provided a concrete basis for evaluating the design solutions' effectiveness and practicality. | **Evaluate**<br><br>**What is it**? The evaluation phase assesses the prototypes based on feedback from experts (if the option was possible) and self-assesment.<br><br>**How is it used?** I tested the design on how realistically it would be possible to implement such design principle into real life scenario, taking into account technical and social aspects.<br><br>**What happened in this phase?** Prototypes were presented to experts and, where possible, to community members. Feedback on usability, effectiveness, and overall impact was collected and analyzed to identify strengths and areas for improvement. |

Table 1. *Summary of each step taken in the design cycle* (own table, 2024)

Figure 2. *Chosen Plot In The De Hoogte Neighborhood* (own image, 2024)

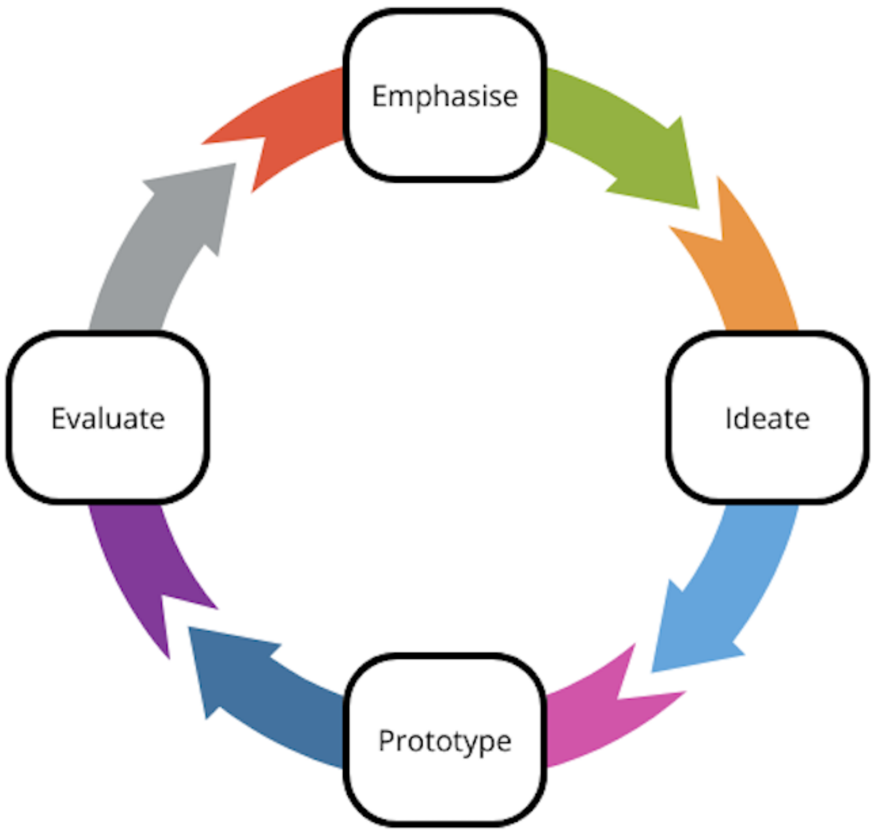


Figure 3. *The Design Cycle* (own image, 2024)

Finally, the applied approach is expected to narrow the gap between academic knowledge and practical application, and the design recommendations derived will support, among other things, the management and sustainability of urban green areas in dense cities.

# 4. What I Found Out: It's Complicated But Cool

This chapter elaborates on the detailed findings from the site analysis in De Hoogte. Site analysis forms an essential stage of the general research process to inform design decisions. The analysis phase will systematically assess existing conditions, challenges, and opportunities in the neighborhood to set the stage for development toward effective and contextually relevant design interventions. The broader research context of this process is pivotal. After completing the literature review, the overall understanding of what smart technologies entail has been granted. Now it is time to look at how cities worldwide are implementing theory into practice and try to incorporate their solutions into the urban context of the De Hoogte neighborhood.

We will temporarily shift our focus from smart technologies to thoroughly examining the underlying context and existing conditions in De Hoogte. The first step in my research brought to light the fact that a critical aspect would be visiting the place to grasp the feel of the place with my own eyes. I have been with Tijmen Hordijk, one of the most renowned historians of urban planning in this part of the Netherlands, and the director of Wijkmakers, checking the area, one of the oldest examples of post-war architectural and urbanistic planning and architecture in Groningen. It has been an enlightening visit, made so by Mr. Hordijk, who showed and discussed some key points to do with the design and socio-spatial characteristics of this. Very broad roads characterize the neighborhood, rented housing is run by housing construction associations, and social houses are run by the government. The residential community has fallen in love with their living space – they are very attentive to what is going on in the area and when I was walking around and taking pictures, some people came up to me and asked for my purpose here. Also, the use of space is quite interesting – commercial spaces are mixed with residential ones. This gives the semblance of a small town residing in the capital city. This visit has helped me frame the history and social fabric of the neighborhood.

This is part of my findings, wherein I elaborate on the process employed to arrive at the values of FSI that would help in evaluating the probable densification and integration of green spaces. For accuracy, the procedure has been covered in the following successive stages : first, digitizing the land area selected using a high-resolution satellite image helped in defining the boundaries precisely; then, the total area is calculated so that the development scope is understood. I then clipped the building layer within the digitized land area and isolated the structures. I made a new field in the attribute table of the GIS software for FSI recording and computed the FSI using the formula FSI = TOTAL FLOOR AREA/TOTAL LAND AREA for each building. Thus, the land area usage was quantified explicitly. Finally, I exported the FSI values into the map for further analysis and sharing, Figure 4. Although FSI values indicate where integration of green space is possible, other factors much more important to a site will drive the decision ultimately of where the best green spaces are placed and how effective they are. Factors that are discussed in the following paragrapgh - site analysis.

Analysis of the site considered herein was done using secondary data from open sources such as ArcGIS and Weatherspark to briefly describe the environmental issues and situation in the area of study, which is necessary information for strategic urban planning and incorporation of green spaces. Data visualizations were created in Adobe Illustrator. For example, noise levels over 70 dB were recorded, indicating significant noise pollution that can affect human health, necessitating strategic noise abatement in urban planning. Analysis of thermal conditions revealed a substantial UHI effect, suggesting the need for green infrastructure to mitigate temperature differences and improve urban microclimates. Accessibility analysis indicated that the linkages that existed between residential neighborhoods and green spaces were very poor, an indication of barriers to access and the health and social benefits accruing from their use. The land-use pattern was majorly residential, commercial, and service areas, with substantial open green areas that were underutilized; this is a call to the redevelopment of such areas for better usability and aesthetics in support of urban resilience and sustainability.


Figure 4. *The map indicating the FSI values of the buildings located on the site* (own image, 2024)

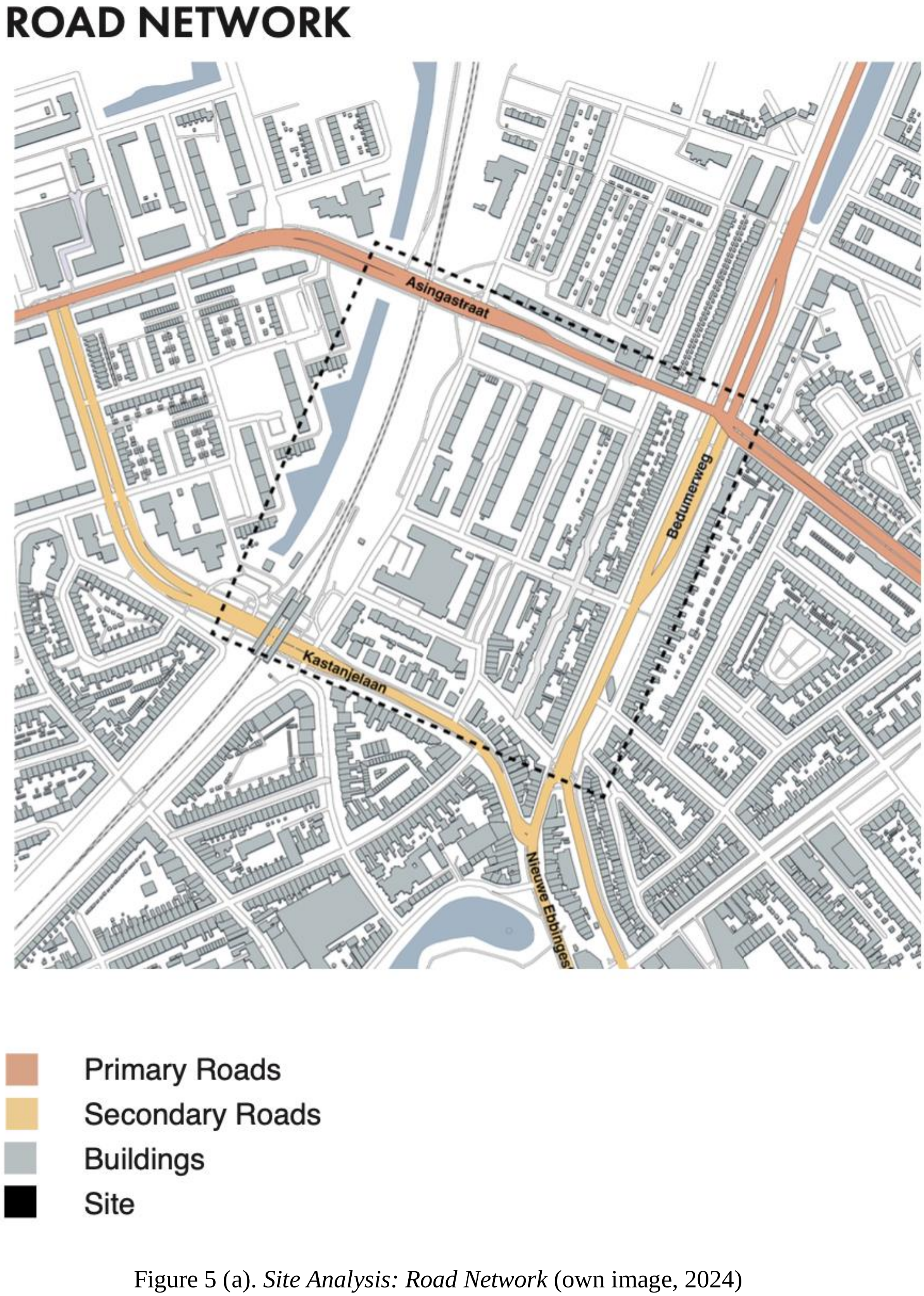


Figure 5 (a). *Site Analysis: Road Network* (own image, 2024)

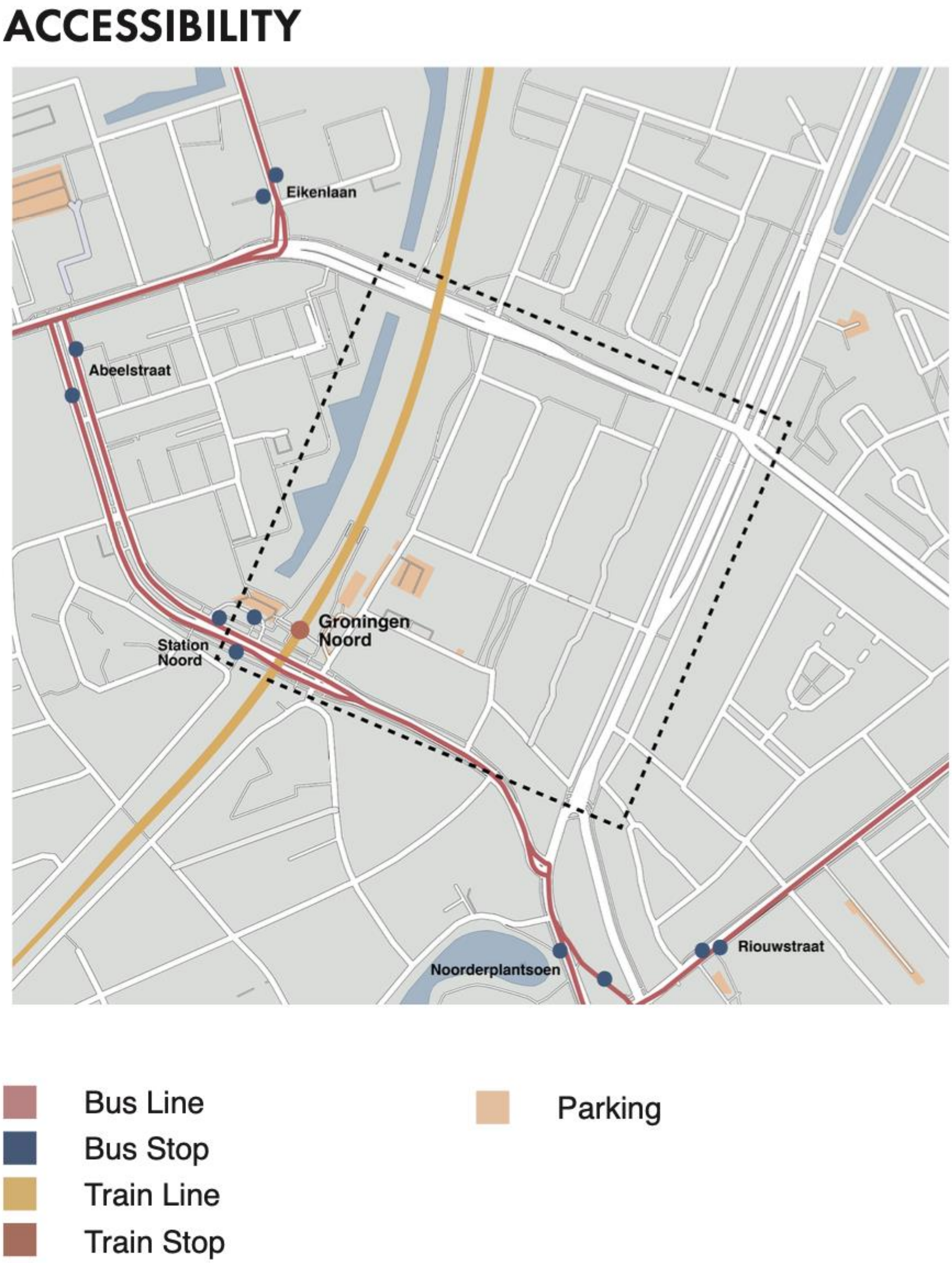


Figure 5 (b). *Site Analysis: Accessibility* (own image, 2024)


Figure 5 (c). *Site Analysis: Land Use* (own image, 2024)


Figure 5 (d). *Site Analysis: Land Use* (own image, 2024)


Figure 5 (e). *Site Analysis: Socio-Economical Factors* (own image, 2024)

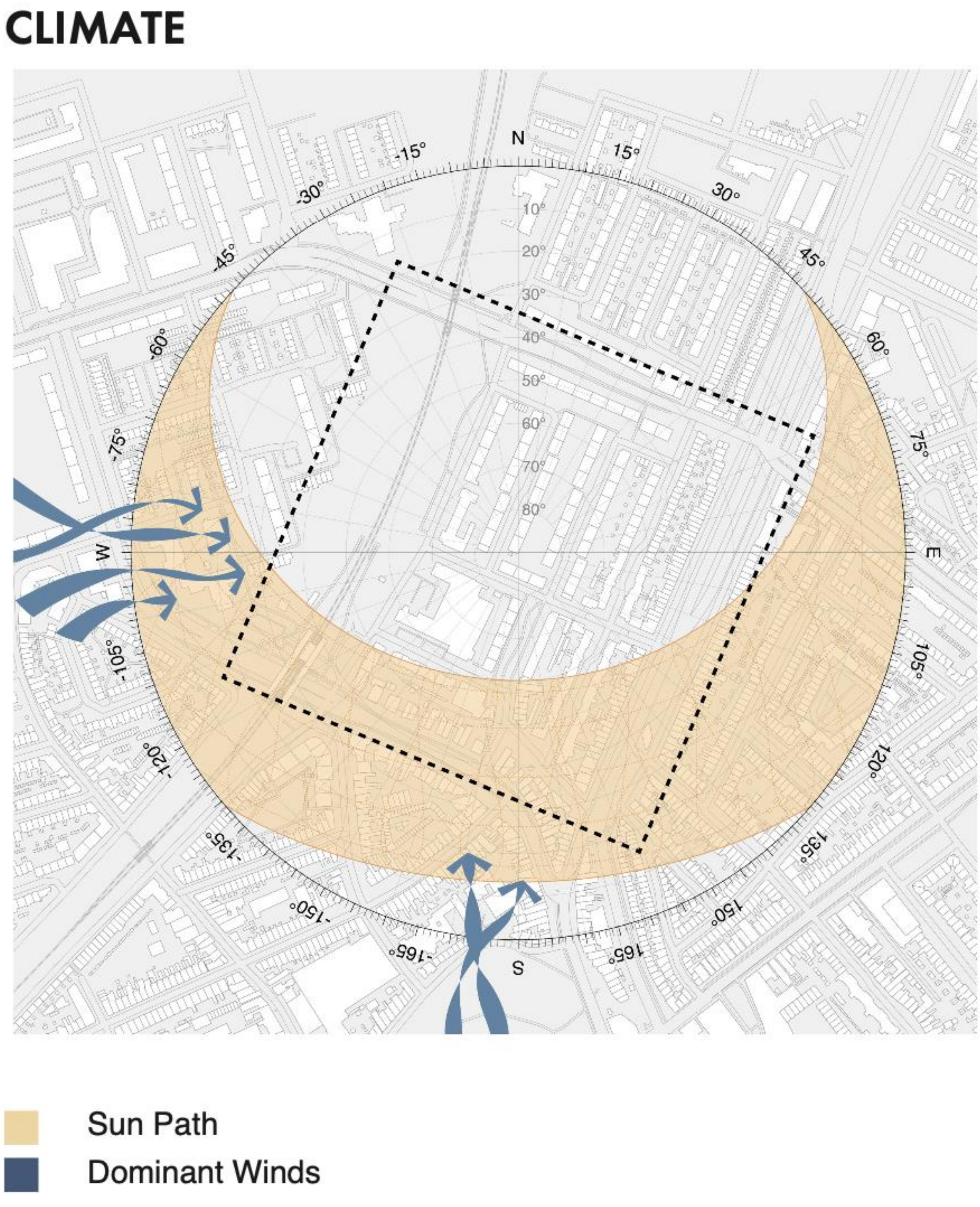


Figure 5 (f). *Site Analysis: Climate* (own image, 2024)

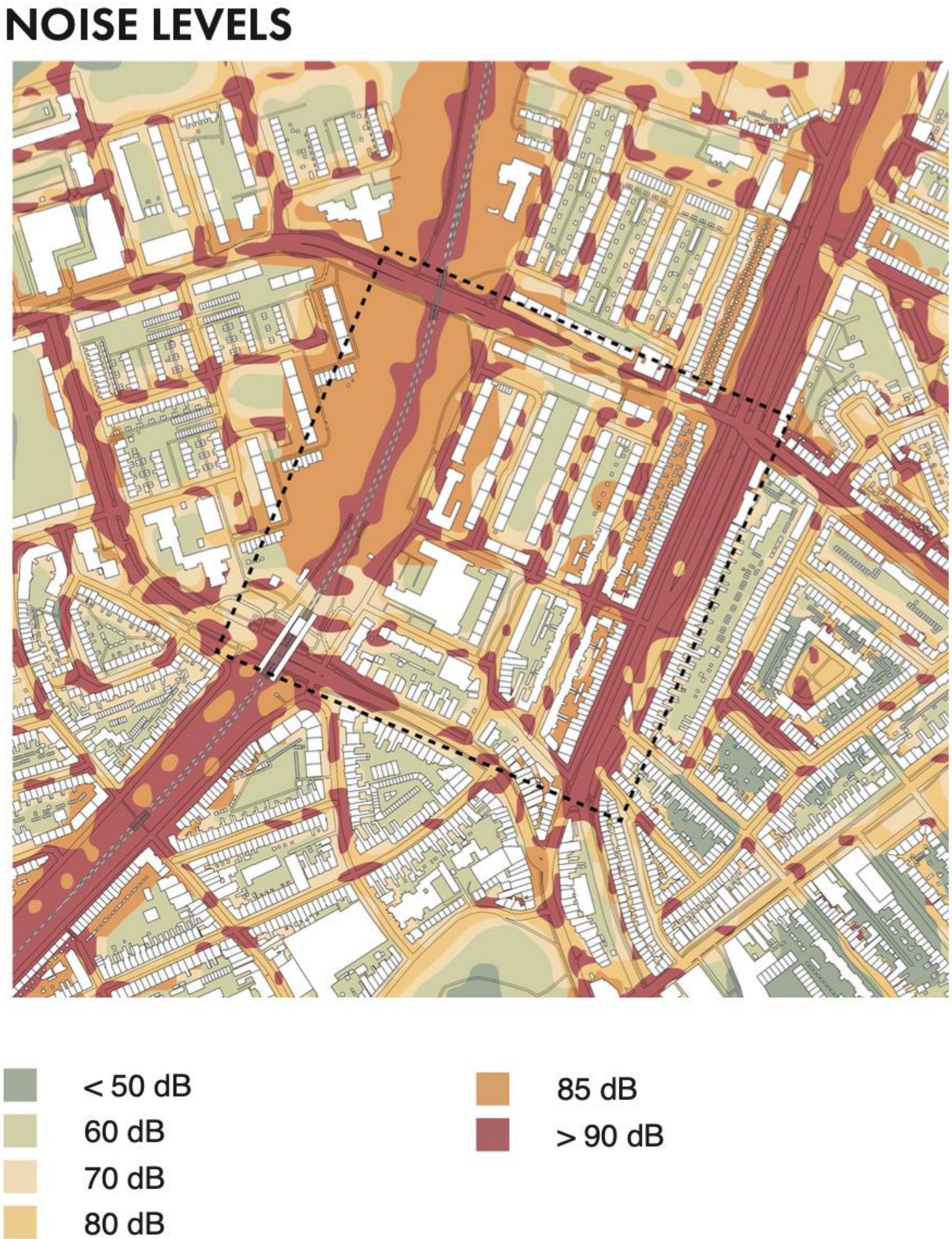


Figure 5 (g). *Site Analysis: Noise Levels* (own image, 2024)


Figure 5 (g). *Site Analysis: Heat Island Effect* (own image, 2024)

The visit to the site with Tijmen Hordijk brought deep insight into the urban fabric and socio-spatial dynamics of the area; it provided much more than basic exploratory studies and data analysis. More than anything, this site visit is essential in underlining how the community is genuinely active and appreciates their living environment, where spaces for commerce and houses come together, giving life to something truly unique, like a town in the city. These insights are vital for designing urban green spaces that meet the community's needs and preferences.

In addition to the site visit, I selectively consulted with Martin Klooster, who is a project leader at Gemeente Groningen and has immense experience in energy and greening projects across Groningen, including De Hoogte. His insights shaped the definition of the policies, organizational frameworks, and community involvement that the development of successful projects in De Hoogte should exploit. Mr. Klooster explained: "Each very much has within it three parts: the Garden Village de Hoogte, Selwerderwijk, and Cortinghborg Residential Area, which all have different kinds of needs and problems, obviously in terms of sustainability and the incorporation of green space".

Klooster said: "It is important to embed in these green space projects the wider urban development frameworks that are again led by the Mobility Vision and the Public Space Guidelines in response to the challenge to provide more green space and reduce the dominance of car use in the urban environment by attractive public spaces for stays—with more green than grey. These would be integrated so that green space projects aligned with the general functionality of the urban area for greater safety and livability.".

The consultations stressed the importance of a spatial framework at the district level, which extends to traffic and green areas, and this would enable one to identify opportunities for establishing green linkages, along with the inclusion of sustainability within the urban design. Realization of such initiatives is only possible through effective collaboration and cooperation, resource allocation, and genuine participation. Innovative methods, along with meetings that deliver the message to the residents, are both supportive of building trust among the residents and aligning their decisions toward the goals of the project, as well as a feeling of unity in a harmonious purpose.

These findings directly impacted the strategic development and further refining of the green design within De Hoogte. They were those that led to the three design scenarios given here. The key reason for these different design proposals was to maximize the space for urban living and improve the quality of life. Several brainstorming sessions were conducted independently to draw sketches, as illustrated in Figure 6. These activities should make the designed solutions well-informed, context-sensitive, and supported with expert input and community needs, making them more effective and sustainable solutions for urban green spaces.

By including these elements, I aim to create design solutions that are practical, sustainable, and beneficial to the community, ensuring that the project aligns with both expert recommendations and the community's needs.

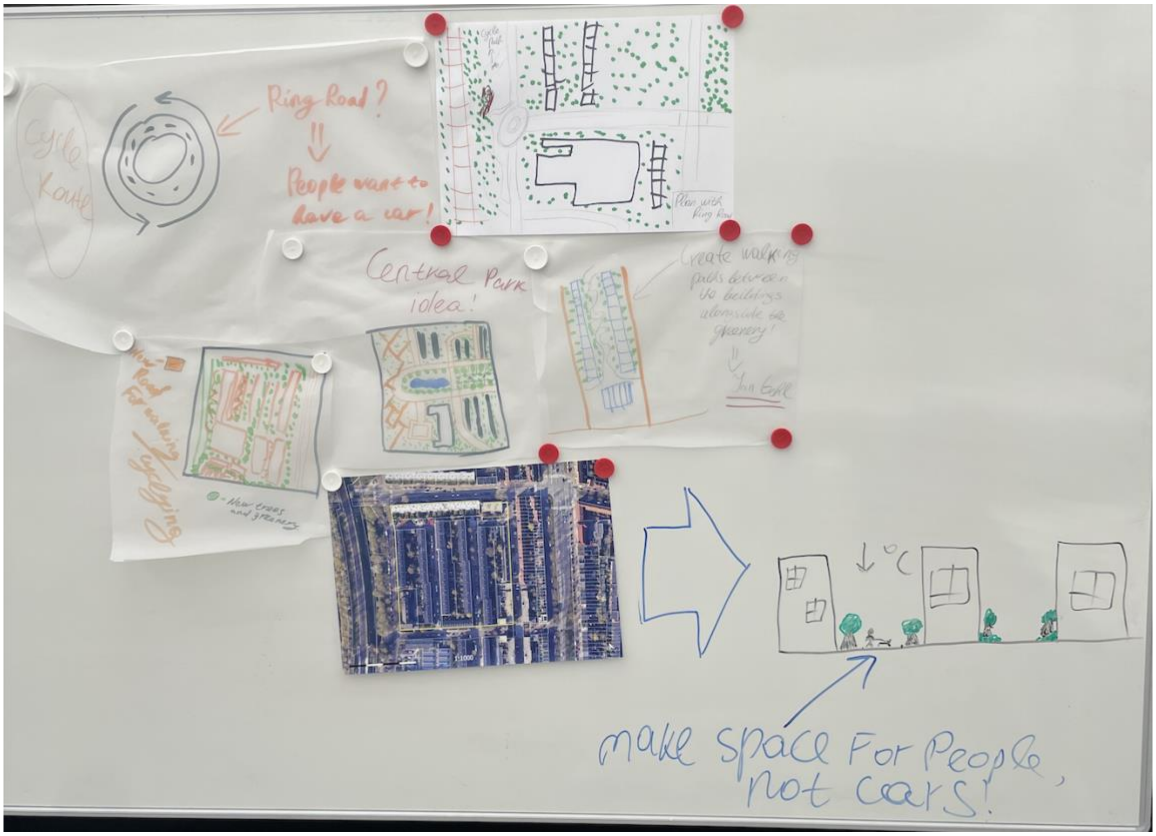


Figure 6. *Brainstorm sessions on possible solutions* (own image, 2024)

And here are the scenarios themselves:

**Option 1: Retain the Existing Plan Enhanced with Green Space Utilization:** This option, as illustrated in Figure 7(a), preserves the existing plan by keeping the current urban structure and adding green spaces to the maximum extent possible. This scenario supports the community's connection to their environment by enhancing existing underutilized green areas, which were identified through FSI analysis as having lower density. This approach aligns with Gehl's perspective on the importance of walking and being present in the public environment, reinforcing pedestrian pathways and accessibility to these enhanced green zones. As Gehl points out, "Walking is primarily a mode of transportation, a means of moving from place to place, but it also offers an informal and straightforward opportunity for being present in the public space" (Gehl, 2011, p. 133).


Figure 7(a). *Design Option 1* (own image, 2024)

**Option 2: Strategic Re-alignment of Road Networks, Demolition of Select Buildings:** The fact that the site analysis has identified noise pollution from the Bedumerweg highway and calls for a buffer zone to be created suggests strategic realignment of the road networks and removing a strip of buildings. It will create a good green belt between the highway and the residence area, which will address those sound levels that exceed 70 dB and, therefore, improve the living conditions and acoustic comfort for the residents. In addition, the design of this area opens new opportunities for community interaction and recreational spaces on the green buffer. The design can be seen in Figure 7(b).


Figure 7(b). *Design Option 2* (own image, 2024)

**Option 3: Creation of a Central Park or Garden:** Since the community and the land use patterns require central public spaces, a large central park or garden is proposed by clearing a wide strip of land in the middle of the community. It will offer a key foundation for social well-being and environmental sustainability; with this green heart, it will offer community activities, recreation, and engagements with nature. The central park will also become a natural cooling area that counters the great urban heat island (UHI) effect that prevails in the area (see Figure 7(c)).


Figure 7(c). *Design Option 3* (own image, 2024)

Coming back to smart technologies, the question “did the author forget about them completely?” probably arose several times while reading this chapter. Short answer for this question: no. The designs were created incorporating the statement I made in the introduction part of this chapter - look at worldwide examples and imagine how is it possible to incorporate it in the urban context of De Hoogte. The examples, for which scenario they are used and how they are used are summarized in Table 2.

| **Design Scenario** | **Smart Technology Example** | **Description of Technology** | **Application to Scenario and Location** |
| --- | --- | --- | --- |
| *Scenario 1: Retain the Existing Plan Enhanced with Green Space Utilization* | Melbourne Urban Forest | The Melbourne Urban Forest Visual is an interactive online tool to monitor and manage the forest of the urban environment. It contains information on tree health, species, and canopy cover that can be used to inform evidence- | **Application**: In Scenario 1, this technology can be used in monitoring the addition of the new green spaces. Sensors are applied within the increased green areas to monitor tree health and canopy cover for the green |

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| | | based decisions regarding tree maintenance and planting. | infrastructures to remain healthy and robust in function. It gives the urban planners and their residents an understanding of the benefits and needs of their urban forest with real-time data and visualizations. It engages the community and assists in the sustainability of urban green spaces in the long run. **Location**: Throughout the enhanced green spaces and along pedestrian |

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| | | | pathways to track tree health and canopy cover. |
| | IoT-Enabled Waste Management in Singapore | A smart system that uses IoT sensors to optimize waste collection. | **Application**: Install waste sensors in the new green spaces to ensure efficient waste collection and maintain cleanliness. **Location**: Distribute sensors in high-traffic green areas and near benches and recreational zones. |
| | Amsterdam Smart Lighting | Smart lighting system that adjusts based on occupancy and natural light. | **Application**: Improve lighting efficiency and safety in pedestrian pathways and green |

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| | | | zones. **Location**: Along main pathways, entry points, and recreational areas within the green spaces. |
| *Scenario 2: Strategic Re-alignment of Road Networks, Demolition of Select Buildings* | Smart Town Traffic Management System Using LoRa and Machine Learning | In the system, there would be the application of LoRa technology and machine learning algorithms; therefore, this system will collect information about the traffic and use machine learning with predictive modeling for effective and efficient road traffic | **Application**: It can help control and reduce traffic noise in Scenario 2 by maximizing the traffic flow. Traffic regulation of traffic management using sensors on Bedumerweg and Asingastraat is implemented to make the traffic effective and silent |

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| | | management. | around settlements.<br>The system improves the traffic conditions since it adapts to real-time data, predicts the problems in the traffic, and seeks solutions that can reduce traffic jamming. It helps to enhance general urban mobility and reduce the impacts of traffic on the environment.<br>**Location**:<br>Along Bedumerweg and Asingastraat, managing traffic flow and reducing noise pollution near residential areas. |

| | | | |
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| | IoT-Enabled Waste Management in Singapore | A smart system that uses IoT sensors to optimize waste collection. | **Application**: Maintain cleanliness in the newly created green belt. **Location**: In the green belt area between the highway and residential zones, particularly in high-traffic areas for recreation. |
| | Amsterdam Smart Lighting | Smart lighting system that adjusts based on occupancy and natural light. | **Application**: Enhance safety and usability of the green belt with adaptive lighting. **Location**: Along the pathways and recreational areas in the green |

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| | | | belt to ensure well-lit and safe environments. |
| *Scenario 3: Creation of a Central Park or Garden* | Barcelona Smart Irrigation System | This involves using an automatic intelligent irrigation system that applies soil moisture sensors as well as advanced data analytics in a bid to provide the optimum water conditions needed for crops. This is accurate monitoring of the soil conditions; it may do irrigation accordingly on a needs basis. | **Application**: It can be applied to the central park in Case 3. This is to conserve water and have healthier plants. Sensors detect high-density planting areas and the moisture in the soil for an optimizing irrigation system. Water wastage is reduced. Maintenance costs go down. The greenery is healthier. All this - and more - happens |

| | | | |
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| | | | with in-situ sensors combined with remote control to ensure plants receive irrigation as per the proper level of requirement.<br>**Location**: Throughout the central park, particularly in areas with high-density planting to monitor and optimize irrigation. |
| | IoT-Enabled Waste Management in Singapore | A smart system that uses IoT sensors to optimize waste collection. | **Application**: Ensure the central park remains clean and inviting for visitors.<br>**Location**: Distribute waste |

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| | | | sensors near high-traffic areas such as playgrounds, seating areas, and entrances. |
| | Amsterdam Smart Lighting | Smart lighting system that adjusts based on occupancy and natural light. | **Application**: Enhance safety and ambiance in the central park, making it more inviting for community activities and recreation. **Location**: Throughout the central park, focusing on pathways, gathering areas, and entrances. |

Table 2. *Detailed Application of Smart Technologies to Design Scenarios* (own table, 2024)

The table above presents applications of various intelligent technologies in the different design scenarios proposed for De Hoogte. Each design scenario is suitable and beneficial for particular applications of intelligent technologies for increasing maintenance, functionality, sustainability, and user experience of green areas in urban environments. As can be seen, there are 2 repetetive tehcnologies for each scenario - smart lightning (Amsterdam Smart city, 2016) and IoT- enbaled waste management (BNL, 2024) - as they could be accomponied to main technologies for each design scenario. Now, the in-depth description of each main technology of each design scenario will be presented.

For Scenario 1, I have stumbed upon the project by City of Melbourne (n.d). Melbourne has set a benchmark in urban forestry with its Melbourne Urban Forest Visual online system. This interactive system, which maps and manages the urban forest in real-time, monitors tree health around the city as well as tree species and canopy cover. This online platform helps Melbourne to monitor its targets to increase its urban canopy to 40% by 2040. Integration of several data sources makes it easier to use the platform in informed decision-making strategies on its maintenance and planting. The data includes, but is not limited to, tree species, age, health, as well as the different benefits they offer like carbon sequestration and cooling effects. With this kind of approach, urban forest management becomes efficient in a sustainable manner that enhances the cities' resiliency in climate change. For instance, against the backdrop of urban green space management in De Hoogte, the Melbourne Urban Forest Visual may be used as a prototype to monitor and manage such green spaces. That would include placing some sensors to monitor health and canopy cover so that green infrastructure is resilient and lush properly. This approach enhances the aesthetic and ecological value of urban green space in a way that also engages the community with the process of urban greening by making data accessible and transparent.

For Scenario 2, main idea revolved the Smart Town Traffic Management system, which employs LoRa and machine learning techniques. Project was found in IEEE Future Directions article (2018). Seung Byum Seo and Dhananjay Singh have developed it in the ReSENSE Lab. The architecture of LPWAN integrated with machine learning for optimum traffic flow, reducing congestion and hence offering a better driving experience, is described in this article. This is meant for intelligent towns, which are much smaller than smart cities, where high-quality service has to be provided in a small area. The system employs LoRa technology, which has gained a reputation because of its long-range, low-power nature for sustained traffic monitoring. The most recent data of traffic patterns are gathered by smart sensors and sent to a LoRa cloud platform. The platform uses logistic regression-a machine learning algorithm to analyze the data and forecast the condition of traffic. This 'forecasting ability' enables adaptive traffic management, which entails real-time traffic signal control, intelligent parking management, and routing for emergency services. It will include but not be limited to the increase in vehicles being on the road but giving off reduced emissions since the routes are optimized, a decrease in stress for drivers by preventing as much congestion, and bettering the public safety by privileging emergency vehicles, which use the surveillance data to deter crimes. The system can also be helpful to respond to public services and urban planning. It can give valuable data from traffic analysts to municipal management. A similar system applied on a scale of De Hoogte would sharply reduce traffic noise, with improved livelihood since the traffic shall flow without massive congestion and the buffer zones have the same reduced. There would be sensors installed on significant roads collecting data to manage the traffic for efficiency and hence reducing congestion and noise pollution. The overview of the system can be seen as Figure 9.

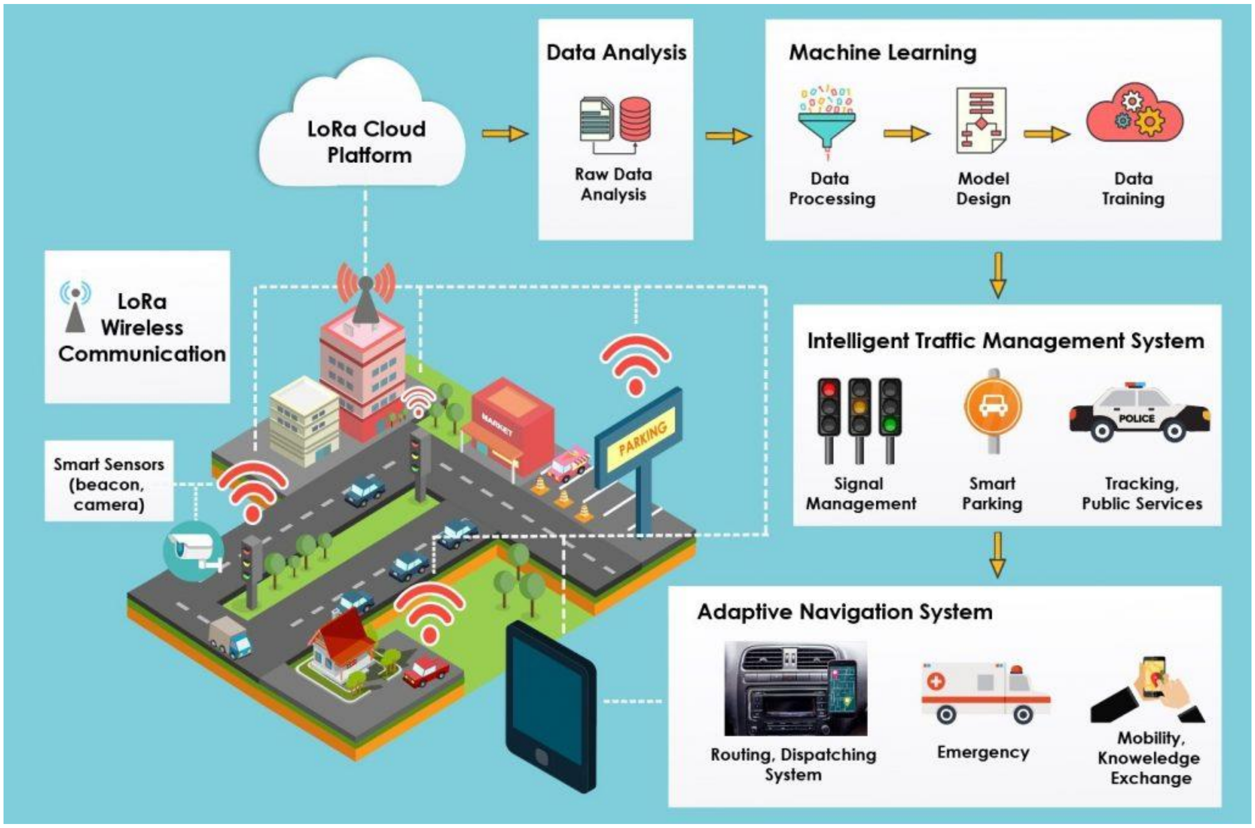


Figure 9. *System Overview of LoRa based Intelligent Traffic Management System*.

*https://cmte.ieee.org/futuredirections/tech-policy-ethics/2018articles/smart-town-traffic-management-system-using-lora-and-machine-learning-mechanism/*

For Scenario 3, the main inspiration was a project, known as intelligent water irrigation system (SIS) at Poblenou Park Centre, developed by the Barcelona Council in collaboration with Starlab and Libelium, The project was found on official Libelium website (2016). These in-situ probes permit remote checking of soil moisture with Libelium technology for the irrigation system to manage the water network properly. Before the project commenced, an assessment of the needs of each park area was carried out. The management of Smart Irrigation is regulated and supervised by using multiple soil moisture sensors that measure humidity and water flow at strategic points. It has as its core the Waspmote Sensor Platform, interfacing with various sensor probes commercially available, which guarantees flexibility in the use of enclosures, gaskets, and waterproofing, along with long-life batteries with one year of autonomy. The ZigBee transmits data from the Waspmote Sensor Platform to the Meshlium Gateway, which then sends it to the cloud via the 3G. That data can be viewed in real-time through the platform developed by the Barcelona Council and Wonderware, that operates on computers, smartphones, and tablets. The gardeners use such devices to process irrigation in the proper manner, in which the electronic valves that control the flow of water are controlled. This intelligent irrigation system in place will optimize the use of water, reduce dramatically some 25% of the municipal water bill, and allow conservation of the water resource. It positively affects environmental sustainability and daily life by taking real-time measures. This is part of the most important Smart City projects being developed in Barcelona: the application of technology related to the Internet of Things in the effective development of urban management. The illustration on how the technology works and looks in real-life can be seen as Figures 10 and 11.

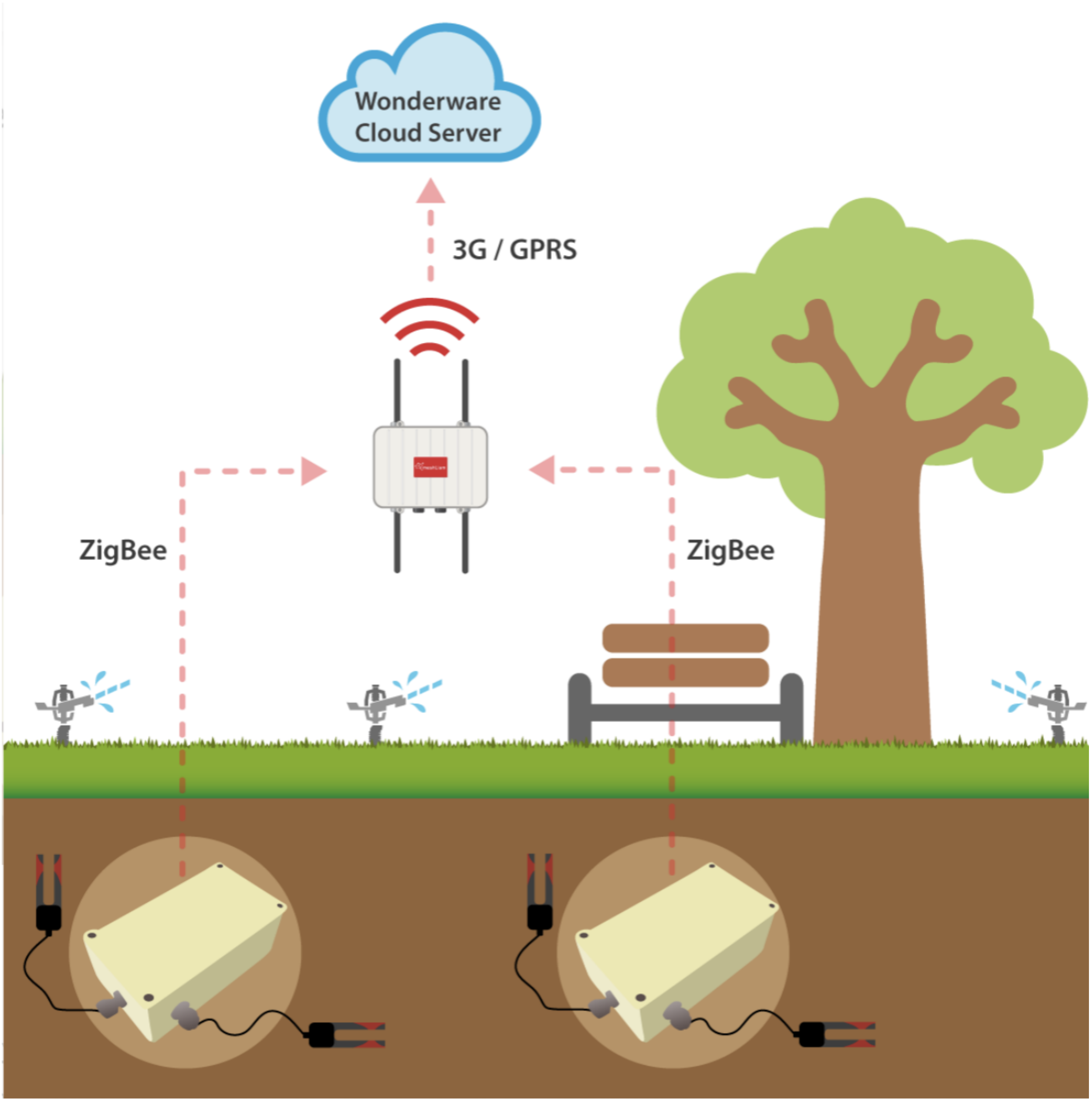


Figure 10. *Smart Irrigation System.* *https://www.libelium.com/libeliumworld/success-stories/saving-water-with-smart-irrigation-system-in-barcelona/*

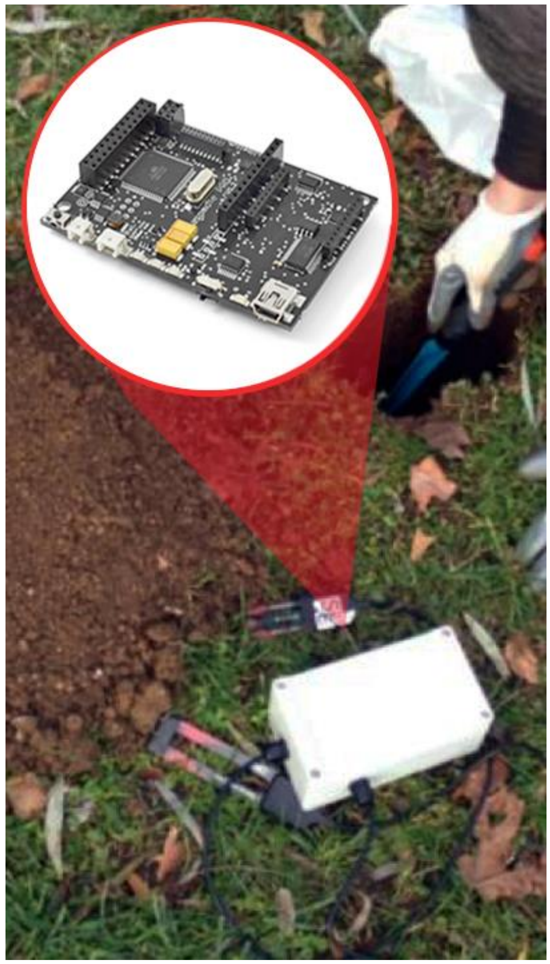

Figure 11. *Real life picture of SIS.* *https://www.libelium.com/libeliumworld/success-stories/saving-water-with-smart-irrigation-system-in-barcelona/*

# 5. The End Of The Trail: What We Learned From Trees Talking Tech

This thesis explores the intersection of urbanization, smart technologies, and green space management to elaborate how cities can effectively deploy innovative technologies within their urban green spaces. This research is built on the background theory on urban densification theories, smart city frameworks, and the role of green spaces in urban milieus. Though urbanization quickens economic and technological development, it builds immense pressure on green spaces with a direct consequence of reduced biodiversity and growing problems to the public's health. Theories by Kuddus, Tynan, & McBryde (2020) and Zhang et al. (2023) were very crucial in developing the framework of the dual nature of urbanization and its effects on public health. In the meantime, Andreev 2023, and Valencia & Castañeda 2018, ideas on the way smart cities can be benefited using digital innovations and insights into better ways of urban life.

The application of such smart technologies, as described by Neirotti et al. 2014 and Zhang & Li, 2015 shows how developments in ICTs and innovative frameworks can help improve the management and governance of urban green spaces. These have been essential theories in the comprehension of how technological interventions can help minimize some of the adverse effects that characterize urbanization, allowing for more effective ecological monitoring and also providing a platform for greater community involvement.

Finally, this thesis concludes closely related to the data from literature review, case studies, and site analysis. Information that came out of it is that, since urban densification occurs over green spaces, it usually happens at the expense of Urban Heat Island mitigation and, by extension, the quality of life of its people. The works of McCarthy et al. (2011) and Berghauser Pont et al. (2021) were critical in establishing environmental and social consequences due to urban densification. This empirically came in the form of facts regarding site analysis on the current conditions and the potential for implementing intelligent green space within the De Hoogte neighborhood, Groningen. As noted, this was done through expert analysis and consultation to identify the actual conditions and secondary data from sources such as ArcGIS and Weatherspark, among others, on the environmental challenges and opportunities in the chosen study area. This is integrated into developing related design scenarios and strategic uses of intelligent technologies in green space management.

It is realistic to generalize these findings into other urban settings with the same, or nearly the same, problems. Like this city today, many urban areas worldwide are caught in an increased densification and endeavoring to ensure that there is greenery as well. Technology and strategies described herein, such as smart irrigation systems, IoT enabled the waste management system, and adaptive lighting system, give solutions which are scalable and can be transferred to other urban settings easily.

For instance, the success of intelligent urban forestry in Melbourne and ReSENSE Lab's use of LoRa and machine learning concerning traffic management should be able to emulate theories across other cities. The overall principles or those relating to integrating intelligent technologies to extend functionality across green spaces, enhance sustainability, and engaging communities are transferrable beyond the context of De Hoogte generally. Reflecting on experiences during the entire research process, it became clear that integrating innovative technologies into urban green spaces is a complex goal but achievable nonetheless. The research-by-design methodology is adequate to navigate through this complex path to design this integration of urban design and innovative technologies. Such an iterative process permits flexible solutions to emerge, context-dependent solutions dealing with theoretical and practical aspects of the problem, with such a relevant circular approach.

One critical reflection is the need for a holistic approach that considers ecological, social, and technological dimensions. While smart technologies offer significant benefits, their implementation must be carefully managed to avoid overreliance and ensure they complement rather than dominate ecological considerations. Additionally, genuine community engagement is essential for the success of such initiatives.

I remember one significant point revealed from the case study of De Hoogte: participation by residents, both during the planning and design stages, is essential to meet their demands but, simultaneously, to satisfy their requirements and preferences regarding green spaces. Unfortunately, residents participation remained in the scope of consulation of experts, who worked with the community for long period of time. Could this be regarded as resident's opinion? Depends, but I believe the experts love this community as much as local residents love it.

Also, limitations brought in by reliance on secondary data and the management to deploy intelligent technologies in resource-constrained settings were significant. Direct data collection and pilot projects to test and refine the proposed solutions would help future research.

What makes the scenarios more plausible in this thesis is that they are designed and tailored to easily integrate into already existing urban infrastructures while making use of already proven intelligent technologies. On that note, each scenario takes into proper consideration the very peculiar characteristics of the De Hoogte neighborhood together with all its diversity of people, its physical layout, and current green spaces. Thus, from the gathering of empirical data to listening and consulting experts, the suggested solutions are individually fitted for the prevailing needs and conditions of the area.

For instance, the Scenario 1's "Everything stays" enhances the current green spaces without abrupt alteration in the urban structure. Thus, it is a low-cost and high-effect strategy. While Scenario 2's "Road network B" has some specific environmental issues, namely noise pollution, simultaneously, creates buffered green areas. And also, Scenario 3's "Central Park" fulfills the identified lack of need for a greater public space in the community, again with social interaction on environmentally driven features.

After completing the whole design procedure and analysis, the question on whether smart technologies enable more eased management than without them did arise many times. So what is the asnwer? My answer is yes, compared to traditional means, innovative technologies undoubtedly make it a lot easier to manage urban green spaces. For example, IoT-enabled waste management, intelligent irrigation systems, and adaptive lighting systems have all the advantages of providing real-time data and, thus, automation that has the best and most efficient management as a guarantee.

For example, smart irrigation systems make use of sensors to monitor soil moisture and weather conditions to optimize water usage, which minimizes wastage and maintenance costs. IoT-based systems for waste management let garbage be collected on time and maintain cleanliness with most minor intervention by human resources. Adaptive light systems increase security and save more energy as they adjust according to the occupation level and availability of natural light.

As a result of smart technologies automating routine tasks and monitoring conditions in real-time, management and planning members can concentrate on strategic decision-making and long-term sustainability. The community is also engaged through easy access to data regarding green space usage and environmental conditions, such as feelings of ownership and participation.

This thesis thus presents an integrating framework with which to approach issues about managing urban green spaces within the circle of urbanization and the development of smart cities. As it is integrated with appropriate intelligent technologies with thoughtful community-centered approaches, the case is different in terms of sustainability and livability towards the urban green spaces. This factor later contributes to positively influencing the wellbeing and resilience of the urban ecosystem to residents.

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