Master thesis

Strategic Product Design

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STRATEGIC ANALYSIS FOR WIRELESS CONNECTIVITY VIA A LIGHTING GRID

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Strategic Analysis for Wireless Connectivity via a Lighting Grid

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Preface

Two years ago, I started my educational journey as a Strategic Product Design master student. This thesis executed at BrightSites, a technology venture within Signify, marks the end of this journey. I would like to express my sincere gratitude to everyone who helped, inspired and supported me along the way.

First, I would like to thank Susan, Reliability expert at Signify, for introducing me to BrightSites.

Also, many thanks to Ronald, general manager of BrightSites, for giving me the support and opportunity to write my master thesis at the connected poles venture. It has been a great experience to learn about new product development inside the lighting industry.

A special thanks to Emre, product manager at BrightSites, for being a great mentor. I still remember the first time we met online. You asked the following: "So, what do you know about the industry?" I answered, hmm, I know Philips Hue. If someone would ask me the same question today, I am sure that I would be able to give a better answer. This is all due to your endless support and help.

I would also like to acknowledge the support of my supervisory team, who have been great mentors to learn from. To David, thank you so much for helping me to think outward, on the moments when I was thinking inward. You helped me to stay critical of my work. To Eui Young, thank you so much for always thinking along. Your PhD thesis inspired my research, and I can say that after all these months, I not only concur with your findings but that I can also relate so much.

I also owe my gratitude to all internal and external stakeholders who helped me in the research process. I could not write this thesis without your help.

To the experts from the various municipalities in the Netherlands, your input was fundamental for my research. Thank you for all your enthusiasm and interest in my graduation project.

Also, the input from the telecom and optical fibre experts have set the foundation for my thesis. Therefore, I would like to thank all experts from KPN, T-Mobile, Broadband Tilburg, Tu Delft and Primevest Capital Partners for sharing their extensive knowledge about the industry.

I am also thankful for all the help of SPIE's Smart City Business Development Manager, who shared valuable advice on succeeding in the intelligent street lighting industry.

I also owe many thanks to the internal Signify Experts. To Marcel and Tonnie, thank you for helping me understand Interact City and connected lighting systems. Also, thank you to Guido, Xiangyu, Sonia, and Asif for joining in my interviews or co-creation sessions.

Furthermore, to the whole BrightSites team, thank you for letting me perform research at your venture. I could not ask for a more dynamic, uncertain and challenging environment to write my master thesis in.

On a personal level, I would like to thank all my friends and family for their constant support and inspiration.

Thank you to my Industrial Design Engineering friends, Vivian, Ayyoub, Asel and Laura, for always being a listening ear during my graduation project and thinking along in co-creation sessions.

Thank you to Ioannis for being the "sensor" expert in my thesis and helping me with QGIS.

Last but not least, to the most loving and supportive people in my life: Mom, Dad, Harold and Ajus. Thank you for always encouraging my dreams and inspiring me to be better.

Even though my journey as a student will end now, I positively look back at my time as a student, and I hope I will never stop learning about new topics and industries. Thank you once again to everyone. I hope you enjoy reading my thesis and maybe learn something new too.

Sascha Brouwer
08-08-2021

Executive Summary

One of the critical questions in the current era is how to provide broadband internet for all and second how to realise the digitally connected city of the future. The Covid-19 pandemic painfully exposed a crisis of internet access in many low-income and rural areas in the world. While many people in the Western world could easily shift to teleworking and online education, still 3.7 billion people worldwide do not have access to reliable and high-speed internet (United Nations, 2021). Terragraph, an intellectual property technology that emerged from the Facebook Connectivity group, aims to bridge this digital divide and has a mission to bring more people online to a faster internet.

This thesis is executed at BrightSites, a technology venture within Signify. It is the result of almost six months of work covering multiple domains in the intelligent street lighting industry. The main research question of this thesis was to analyse the role of Gbit luminaires in the digitally connected city of the future. Gbit luminaires are innovative fixtures that can enable wireless connectivity on the outdoor lighting grid. These fixtures can provide fibre-like speeds due to the incorporation of mmWave radios that utilise Terragraphs' technology.

One of the research outcomes is a theoretical framework that shows stakeholders value capture and value creation motivations. In this project context, *value capture* is defined as how a particular stakeholder wants to be rewarded for becoming part of the Gbit luminaire ecosystem. On the other hand, *value creation* is defined as how a specific stakeholder can deliver value and strengthen the Gbit luminaire ecosystem.

The findings show that the Gbit luminaire is part of a conservative regulatory environment in an interdependent ecosystem. Furthermore, the framework sheds some new light on the gaps between BrightSites, market players and municipalities. In the Gbit luminaire ecosystem, the following gaps are perceived: 1. The value gap, 2. The knowledge gap, 3. The financial gap, and 4. The urgency gap.

The opportunities for technology-driven organisations to solve gaps and prepare for the future lay in user-centred roadmaps. The type of roadmap developed in this project is a design roadmap, which is still limited in use but getting more attention in the literature and across industries. Design roadmaps differ from traditional technology or product roadmaps as it centres on end-user's values, rather than the technology portfolio and organisational goals.

The design roadmap is developed from a European municipal decision-maker perspective while considering the shared desirability in the ecosystem. The main conclusion that can be drafted is that the product proposition should be perceived, developed and pitched from an ecosystem level. In addition, the author suggests that the (Gbit) luminaire should be positioned as a hosting solution rather than a wireless fibre extender. The main argument is that every stakeholder in the Gbit luminaire ecosystem should feel that a specific problem is solved since this is considered as the only way to succeed and achieve widespread deployment.

Glossary

5G	The next generation of mobile communications.
Backhaul	The underlying infrastructure to send data from one point to another on the internet, which is either wired, wireless or optical.
Bandwidth	The maximum data transfer over a network.
Client node	A mmWave radio that does not distribute the network further, also called a terminal unit.
Connected LED lighting	A system of LED fixtures that can be remotely controlled and monitored.
Data	Computerised information measured in bits.
Distribution node	A mmWave radio that distributes the network further to other nodes, also called a base unit.
Electromagnetic waves	Fluctuations in electromagnetic fields. To create these fluctuations electrons need to move around in a conductor (from + to -).
Fibre PoP	A smart pole or Citybeacon in a mmWave network infrastructure that incorporates a distribution node that is connected with optical fibre to the core network.
Fixed wireless access	A technique to provide broadband connectivity through radio links between two fixed points.
Gbit luminaire	An innovative fixture that consists of two components: energy efficient LED lighting and a mmWave radio.
Internet of things (IoT)	A network of physical objects embedded with sensors, software and other technologies that exchange data and connect wirelessly with other devices and systems over the internet.
Latency	The reaction time for two devices to respond to each other.
LED luminaire	The fixture that emits lighting on top of a light pole.
mmWaves	Radio waves within the frequency range in the electromagnetic spectrum between 30 GHz and 300 GHz. Also called, wireless fibre or fibre-in-the-air.
mmWave radio	A device that transmits data through millimetre waves.
Neutral host infrastructure	A network that is acquainted and operated by a third party that leases or rents the infrastructure to other players in the ecosystem.
Network architecture	The design of network devices with the core network.
Optical fibre	A wired backhaul technology that sends bits as light beams from one place to another.
Radio waves	Electromagnetic waves that have a frequency from 30 Hz up to 300 GHz.
Small cells	Small antennas that provide network coverage.
Smart cities	Places that are made more efficient by using digital and telecommunication technologies that benefit inhabitants and businesses.
Smart hub	Digital kiosks with a wide range of functions, such as edge computing, digital display screening, and telecom equipment hosting.
Smart pole	A light pole that utilizes energy-efficient LED lighting, sensors, wireless connectivity and other innovative functions into one single unit.
Telecommunication infrastructure providers	Companies that develop, acquire and operate networks on behalf of clients, for example, for mobile network operators.
Throughput	The actual amount of data a link transfers through a network, measured in bits per second.

TU Delft Signify

Content

Chapter 1

INTRODUCTION

1.0 // Introduction

In the past several years, and especially during the Covid-19 pandemic, it became clear that reliable internet access is not a luxury; it is a necessity for the day-to-day. BrightSites, a new business unit within Signify, is introducing an innovative fixture that provides wireless high-bandwidth connectivity using energy-efficient LED lighting. In this thesis, these innovative fixtures are also called gigabit or Gbit luminaires.

The project aims to develop a framework that maps out the stakeholders in the urban connectivity for smart street lighting ecosystem. The framework will be used to analyse value streams and to identify new strategic design directions. The project's outcome is a design roadmap that maps out the expected key user needs over time with the products, services, and technologies a company wishes to deliver.

In the first chapter, some background information regarding the project is provided. This concerns a short introduction about Signify, smart cities, data networking and BrightSites. In addition, the assignment is further clarified along with the methodologies being used throughout this project.

1.1 // Background

Signify

Signify, previously Philips Lighting, is a lighting company headquartered in Eindhoven, the Netherlands. Signify is the world leader in conventional and LED lighting for consumers and professionals. With 2020 sales of 6.5 billion euros, approximately 38.000 employees and a widespread presence in over 70 countries, Signify continues to unlock the extraordinary potential of light for brighter lives and a better world. To achieve its purpose, Signify focuses on its values: innovation and sustainability. Foremost, Signify is a company that has innovation written in its DNA. For more than 125 years, the company is pioneering breakthroughs in the lighting industry. With 4.8% of total sales invested in R&D, over 100 partnerships with universities, and 17.750 patents, Signify continues to lead the market with groundbreaking innovations. Signify is currently the industry leader in connected lighting systems for the IoT, and they continue to innovate in other industries such as LiFi and 3D printing.

In addition, sustainability is fundamentally present in the company's operations and offerings. Signify recognises that the world is changing: carbon emissions are at a record high causing global warming. Furthermore, the world population is growing, with more and more people living in cities causing new challenges. Signify is committed to contributing towards a more sustainable future and improving the lives of people, businesses and cities through lighting. The transition to LED lighting can, for example, reduce energy consumption by up to 80 per cent. While connected lighting can offer the right light at the right time, helping people see, feel, and function better in the everyday.

Signify consists of global brands, specialty brands and technology brands. The global brands are Philips, Philips Hue, Interact, Color Kinetics and Wiz. Moreover, the company has the following speciality brands: Strand, Vari-Lite, UHP and Modular. And a set of technology-focused brands: Trulifi, NatureConnect and BrightSites.

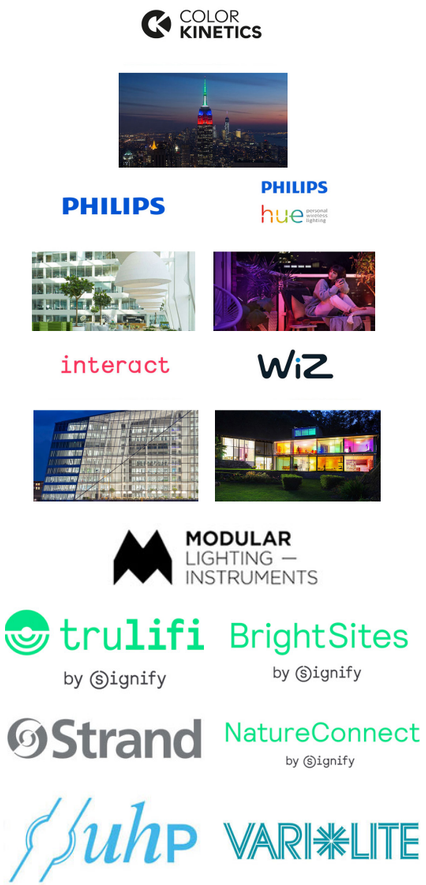


Figure 1.1 - Brands

Signify has a company strategy to reach its purpose of unlocking the extraordinary potential of light for brighter lives and a better world, see figure 1.2. This strategy is based on three global trends that, in the present day, are affecting the industry.

1. The transformation of the industry - Signify is operating in a different world than it was a few years ago. Undoubtedly, the Covid-19 pandemic led to challenges of unprecedented scale. The pandemic reinforced the need for connectivity and triggered the digital and e-commerce industry. In addition, more companies are entering the lighting industry with competitive pricing. There is also a higher need for connectivity, LED, and data services, which means that the company has to rethink operations and hire people with the right expertise for these new customer demands.

2. A changing world - Signify is a global company with a widespread presence; however, companies worldwide are looking inward, which means that Signify has to deal with international trade obstacles and an increase in import tariffs. Besides, nowadays, customers expect more. They have a wide range of products to choose from and expect better service, quality and corporate social responsibility. Therefore, it is a must that companies they buy products from share the same view on issues like climate change.

3. Increased digitalisation - The Covid-19 pandemic has shown that reliable internet access is not a luxury; it is necessary to perform day-to-day activities such as home working. In addition, online transactions rapidly increased, and the number of digital buyers keeps growing year on year. Among other things, smart technologies such as artificial intelligence and robotics are not just trends of the past. Signify recognises that these technologies are used today, and Signify as a company has to rethink how to grow with these new technologies and markets.

Figure 1.2 - Company strategy of Signify

Smart cities

Cities need to become smart as it is expected that by 2050, two-third of the world population will be living in cities (United Nations, 2018). The growing number of citizens will strain cities resources, environment, traffic conditions and overall quality of life. Smart cities can solve the problems caused by rapid urbanisation, for example, poor air quality and increased crime. In research from the European Commission (n.d.), smart cities are defined as places that are made more efficient by using digital and telecommunication technologies that benefit inhabitants and businesses. The attractive outlook of job opportunities, among other factors, attract people to move to cities. In addition, research has shown how the economic growth of cities determines national GDP growth (Hsieh & Moretti, 2015); (World Bank, 2020). However, expected urbanisation levels have consequences for the liveability of cities. Smart technologies have the potential to increase this liveability inside cities, and most of these run on 5G, requiring the deployment of small cells that provide network coverage.

In the present day, telco equipment and IoT devices are widely present in the city landscape and attached to light poles. However, this leads to clutter in the environment since they are not integrated into the light pole but often placed onto the light pole.

According to the research of (McKinsey & Company, 2018), smart cities consist of three layers. The first layer, the technology base, consists of smartphones and sensors connected by high bandwidth communication networks. In the second layer, the raw data from the first layer is turned into alerts and insights. Lastly, the third layer refers to the adoption and usage of these smart city applications. Meaning the extent cities and citizens use the insights and alerts of these applications to make better decisions and improve the overall quality of life by adapting to behavioural change.

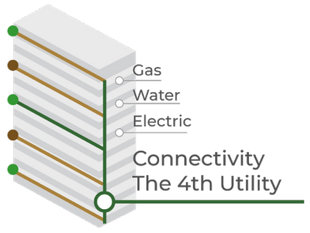


Figure 1.3- Connectivity as the 4th utility

Figure 1.4 - The three layers of a smart city (McKinsey & Company, 2018)

Data networking

IoT devices and 5G small cells require a backhaul medium to transport data from one point to the core network. Data has the option to transport itself through different backhaul types: wireless, wired and optical. A representative example is seeing data networking as a transportation system, where backhaul is the type of road the device takes to reach its destination. Two essential parameters concerning backhaul are bandwidth and latency. Foremost, bandwidth is the maximum data transfer over a network, and latency is the reaction time for two devices to respond to each other.

BrightSites

BrightSites, internally known as connected poles, is a new business unit within Signify that commercialises wireless connectivity on the outdoor lighting grid by introducing Gbit luminaires. These are innovative fixtures that provide wireless high-bandwidth connectivity using energy-efficient LED lighting. It is a plug-and-play solution for regular light poles or smart poles that provide wireless fibre-like capacities at a fraction of the cost of fibre.

Most of the theories on smart city applications are focused on explaining the increased need for high bandwidth and low latency. The wired backhaul type, optical fibre, has high bandwidth and low latency characteristics. However, it has significant disadvantages. First, the price of trenching fibre is soil dependent and costly—secondly, the disturbance for citizens. Trenching fibre takes months. It is even more disturbing that network operators predominantly do not share fibre optics, which means that multiple network operators, either internet service providers or mobile network operators, individually trench fibre.

Thirdly, network operators require permission from municipalities to place their equipment in the urban environment, including for trenching fibre. These permitting procedures take time, money and effort.

Figure 1.5 - Light poles with clutter

1.2 // Assignment

Problem

BrightSites becomes a first-mover in the lighting and smart city industry by commercialising wireless connectivity on the lighting grid. By being a first mover, a product or service gains a first-mover advantage. This advantage will enable BrightSites to set the industry standard, get strong brand recognition and customer loyalty (Investopedia, 2020). On the other hand, the downside of being a first mover is that there are often more questions than answers. While competitors can lean on the success of the first mover, the first mover needs to heavily invest in product and software development, understanding the product-market fit, pilot projects and persuading potential customers to try out a new product.

In addition, the meaning of innovation has shifted in the post-industrial Western world. See figure 1.6. In the present day, the meaning of innovation is not just about developing the best technology and creating the most outstanding product or service. Instead, it is about designing products and services that carry significant value.

The meaning of innovation previously referred to as	In present-day innovation is considered to be about
technology	value
products	anything that can carry value
management and calculating risks	creativity, entrepreneurship and vision
owned by R&D	part of the organization's culture
something taking place inside the company boundaries	taking place both inside and outside the company
hard, risky and a nuisance	hard, risky and fun

Figure 1.6 - The meaning of innovation in the past and present-day (Abbing, 2010)

Moreover, smart cities are by definition trans-sectoral issues, meaning that the success of a smart city requires a multi-disciplinary approach. By entering the smart city connectivity market, BrightSites will not have to deal with the buyer of the gigabit luminaire alone. In fact, the buyer of the gigabit luminaire and its software is not by definition the end-user. In the gigabit luminaire market, sellers, buyers and end-users are disconnected. This makes the customer journey complex and the decision-making process of a potential buyer lengthy. According to a Harvard business review, there are three main problems to solve in markets where users and buyers are disconnected (Yoon, 2020). The first problem to overcome for companies is to recognize all buyers and users in their proposition. The second, is to efficiently coordinate across buyers and users. And the third, is to align the interests of buyers and users.

Goal

The project aims to develop a framework that maps out the stakeholders in the urban connectivity for smart street lighting ecosystem. The framework will be used to analyse value streams and to identify new strategic design directions.

This project answers the following research question:

What is the role of gigabit wireless-enabled luminaires in the digitally connected city of the future?

- What are the relations between different stakeholders?
- What are the value streams in this ecosystem?
- How do these findings relate to BrightSites (digital) product strategy?

The project's outcome is a design roadmap that maps out the expected key user needs over time with the products, services, and technologies a company wishes to deliver.

1.3 // Approach

The project will be executed in the product development team for urban connectivity and will use a product management and design thinking approach.

Product management

Product management's main objective is to build a new product, where building the right product and building the product right is balanced. See figure 1.7. Foremost, building the right product, in this project context, is about understanding the context, users and buyers of gigabit wireless-enabled luminaires. In sum, it is about understanding the pain points and needs of all relevant stakeholders.

Second, the technology behind the gigabit luminaire and network architecture needs to be thoroughly analysed to understand the language being used in the ecosystem and to be able to interact with the relevant stakeholders. Thus, building the product right is about understanding the technology, product, and software architecture and linking this back to what users want out of a product.

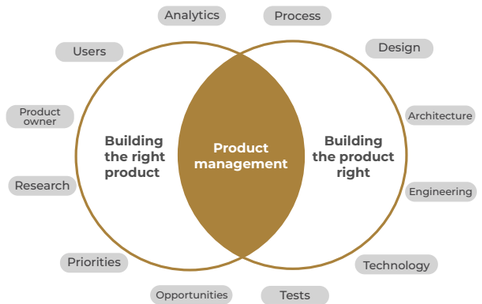


Figure 1.7 - The goal of product management

In essence, product management is about balancing business objectives, turning technology requirements into engineering guidelines and having a deep understanding of potential customers.

Design thinking

Design thinking is a human-centred, iterative process designers use to tackle complex problems (Dam & Siang, 2021). It is most often used in projects where problems need to be tackled that are unknown or unclear. The design thinking process is often demonstrated into a double diamond structure (see figure 1.8), which requires divergent and convergent thinking. The process starts by exploring what is desirable from a human point of view, by empathising with the world of people. It is about fully understanding people's needs and why they think, feel and demonstrate particular behaviour in a specific context. The goal of the first diamond is to define human-centric statements that give insights into peoples' problems, challenges and desires. While in the second diamond, potential solutions are developed, explicitly considering the viability and feasibility aspect of a solution. In this way, strategic design thinking is applied.

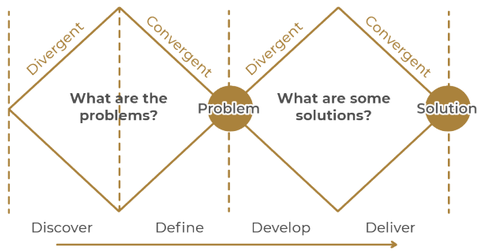


Figure 1.8 - Design thinking double diamond structure

Strategic design is about influencing innovation decisions while balancing the business outcome's desirability, feasibility and viability (Calabretta et al., 2010). See figure 1.9. This outcome does not necessarily have to be a new product. It can also be a new service, a business opportunity or a vision that influences companies' innovation strategy.

By using a product management and design thinking approach, the project will deliver two outcomes: a value flow framework and a design roadmap. First, the product management approach is needed to understand the development of a new product, the underlying technology and to be able to communicate with stakeholders actively to develop the value flow framework. Second, the design thinking method is used from the start of the project to empathise with the different stakeholders. The project's outcome is a design roadmap that gives strategic insights into the role of the Gbit luminaire in the digitally connected city of the future.

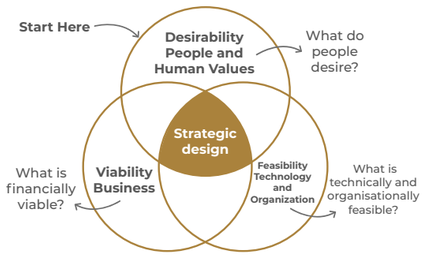


Figure 1.9 - The elements of strategic design

Value flow framework

In this project, the theoretical framework supports the findings of the stakeholder analysis. It aims to show each stakeholder's value capture and value creation motivations in the Gbit luminaire ecosystem. In this project context, *value capture* is defined as how a particular stakeholder wants to be rewarded for becoming part of the Gbit luminaire ecosystem. On the other hand, *value creation* is defined as how a specific stakeholder can deliver value and strengthen the Gbit luminaire ecosystem.

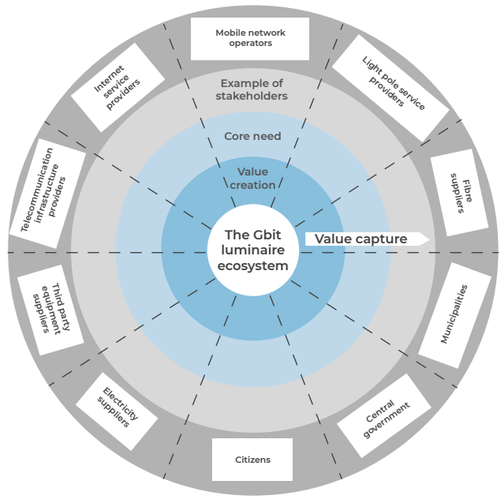


Figure 1.10 - Value flow framework

Design roadmapping

Product and technology roadmapping is a common method in organisations to integrate business objectives with technology. However, the challenges in the world are becoming increasingly complex and unpredictable. A number of authors and practitioners in the field have recognised that developing a successful innovation strategy in a world that continues to accelerate is becoming more complicated (Brynjolfsson & McAfee, 2011); (Schwab, 2017). As a consequence, traditional product and technology roadmaps are not agile, flexible, responsive or scalable enough in an ever-changing world with increasing competition and uncertain market environments (Phaal, Simonse & Den Ouden, 2008). Some authors have driven the further development of roadmapping by analysing the traditional roadmapping methods. The traditional roadmapping processes mainly focus on the features and technologies of a product, which result in several challenges. The work of (Kim, Yao & Agogino, 2015) addressed three challenges of traditional roadmaps and opportunities for future roadmaps. The first challenge is the ineffectiveness of traditional roadmaps to predict the future and develop accurate user and market forecasts. This results in companies spending an adequate amount of money, resources and time on products and services that do not meet market demands. Second is the lack of incorporated feedback of end-users in the product development process. Moreover, the buyer of a (digital) product does not have to be, by definition, the end-user, likewise in the Gbit luminaire ecosystem. In such an ecosystem where the number of stakeholders is abundant, and there is a big gap between the buyer, decision-maker and the end-user, insights may become distorted. Thirdly, over-dependence on features may lead to deviation from the core needs of the end-user. If companies add features based on technological advancement or feasibility, it may lead to a mismatch between the (digital) product and the actual customer need.

The opportunities for technology-driven organisations lay in user-centred roadmaps. The type of roadmap developed in this project is a design roadmap, which is still limited in use but getting more attention in the literature and across industries. Design roadmaps differ from traditional technology or product roadmaps as it centres the end-users values, rather than the technology portfolio and organisational goals. Prior research addressed three primary principles that form the core of a design roadmap (Kim, Chung, Beckman & Agogino, 2016): 1. Focus on evolving customer needs and experiences over time, rather than just the features; 2. Involve designers early in the roadmapping process; and 3. Provide a means for challenging and unpredictable market conditions by shifting away from future prediction towards future preparation.

Step
1. Gather comprehensive data on users, users' experience, and trends
2. Extract core design principles from the user needs, experiences and trends
3. Gather an exhaustive list of technologies containing core feature sets of the design concept and prioritize them
4. Map projects to design principles
5. Create Design Roadmap

Figure 1.11 - The five step design roadmapping process (Kim et al., 2016)

1.4 // Methodology

The project consists of four phases, employing different design research methods that contribute to answering the sub and main research question(s). In the first phase, the focus was on creating a comprehensive understanding of the product, the industry and engaging with stakeholders that are part of the Gbit luminaire ecosystem. The Gbit luminaire ecosystem encompasses four primary research domains: data networking, telecommunications, smart cities and intelligent street lighting. To understand the product proposition and ecosystem, literature research and stakeholder engagement have been an ongoing process, which was not limited to only one phase of the project. Instead, it has been a continuous process of collecting and synthesising information, followed by drawing insights about the ecosystem of the Gbit luminaire.

The first phase includes five different design research methods: secondary research, internal analysis, competitive analysis, semi-structured interviews and trend mapping. In the second phase, the findings of phase one have been materialised into empathy maps, customer profiles, a stakeholder power-interest matrix, a customer experience map and a SWOT analysis. The outcome of phase two is a value flow framework that maps out all the stakeholders in the Gbit luminaire ecosystem and their value creation and capture mechanisms.

Phase three consists of the following design methods: "how might we?" questioning, idea mapping, co-creation and technology scouting. After the problem and opportunity spaces have been identified, a "how might we question?" for the product and the (digital) product have been set up. This method is often used at the beginning of the design process, turning a potential problem or opportunity space into a question statement. Based on the developed questions, idea mapping has been applied. This is a brainstorming technique to find a solution to the "How might we?" questions. The ideas have been mapped out on the design roadmap and include individual idea mapping and collaborative involvement of experts and students. The experts are both internal and external, and the students come from either an Industrial Design Engineering or Electrical Engineering background with a specialisation in Wireless Communication and Sensing. Additionally, ten experts of various municipalities in the Netherlands have participated in knowledge sharing sessions throughout the entire project. The municipalities' experts come from multiple backgrounds, ranging from experts with a more political background to experts with a more technical and strategic background. After the question statements were set up, SPIE's Smart City Business Development Manager contributed to this research to give his stance on the identified problem statements. SPIE is the largest lighting operator in the Netherlands, and the Business Development Manager of SPIE has both expertise in telecommunications as well as intelligent street lighting solutions. One of the key insights of this conversation was to use coalition agreements of cities as the basis of ideation and, after that, see how a product of Signify could potentially play a role in meeting those city goals. In addition, bi-weekly student sharing sessions have been used as input for this project, as well. These students have either a Strategic Product Design or Design for Interaction study background. Based on the input of these sessions, it became evident to look at the fundamental psychological needs of cities and see how the Gbit luminaire could align with those needs.

Overall, the project took a stance from a European municipal decision-maker perspective, as cities in most European countries own the light poles, making them the key decision-maker. The regulations regarding network roll-out and smart city IoT are likewise similar in terms of privacy and security by design. The final phase is the roadmapping phase, which results in the final outcome of this project: the design roadmap

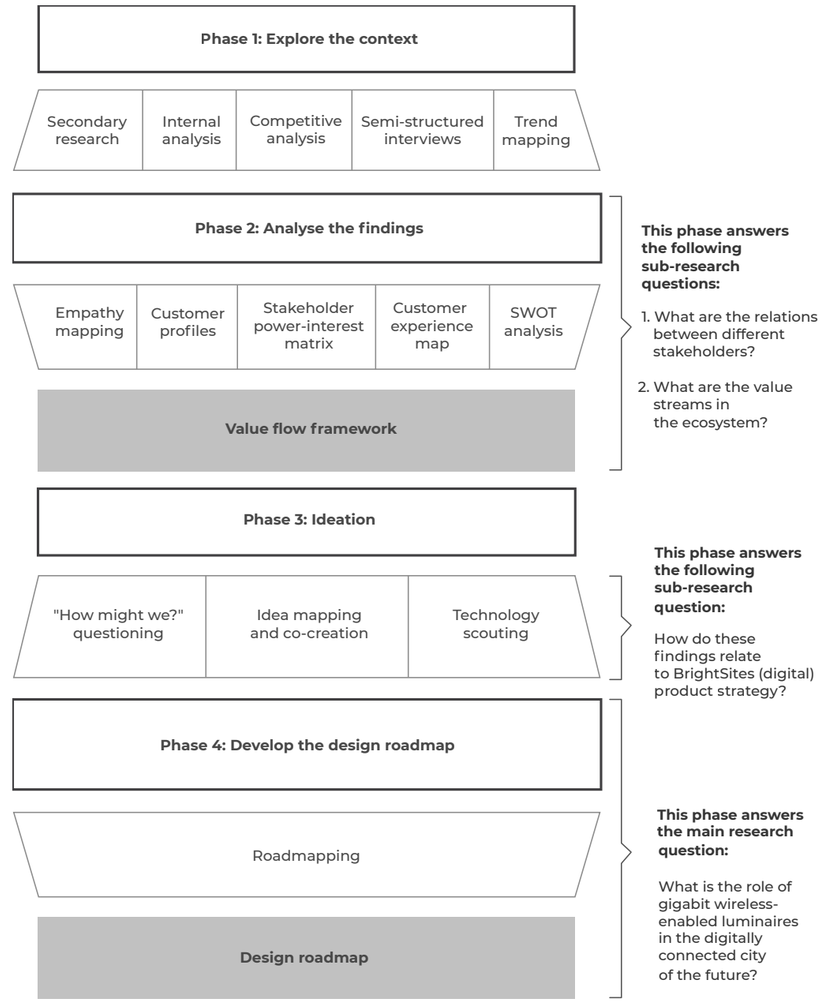
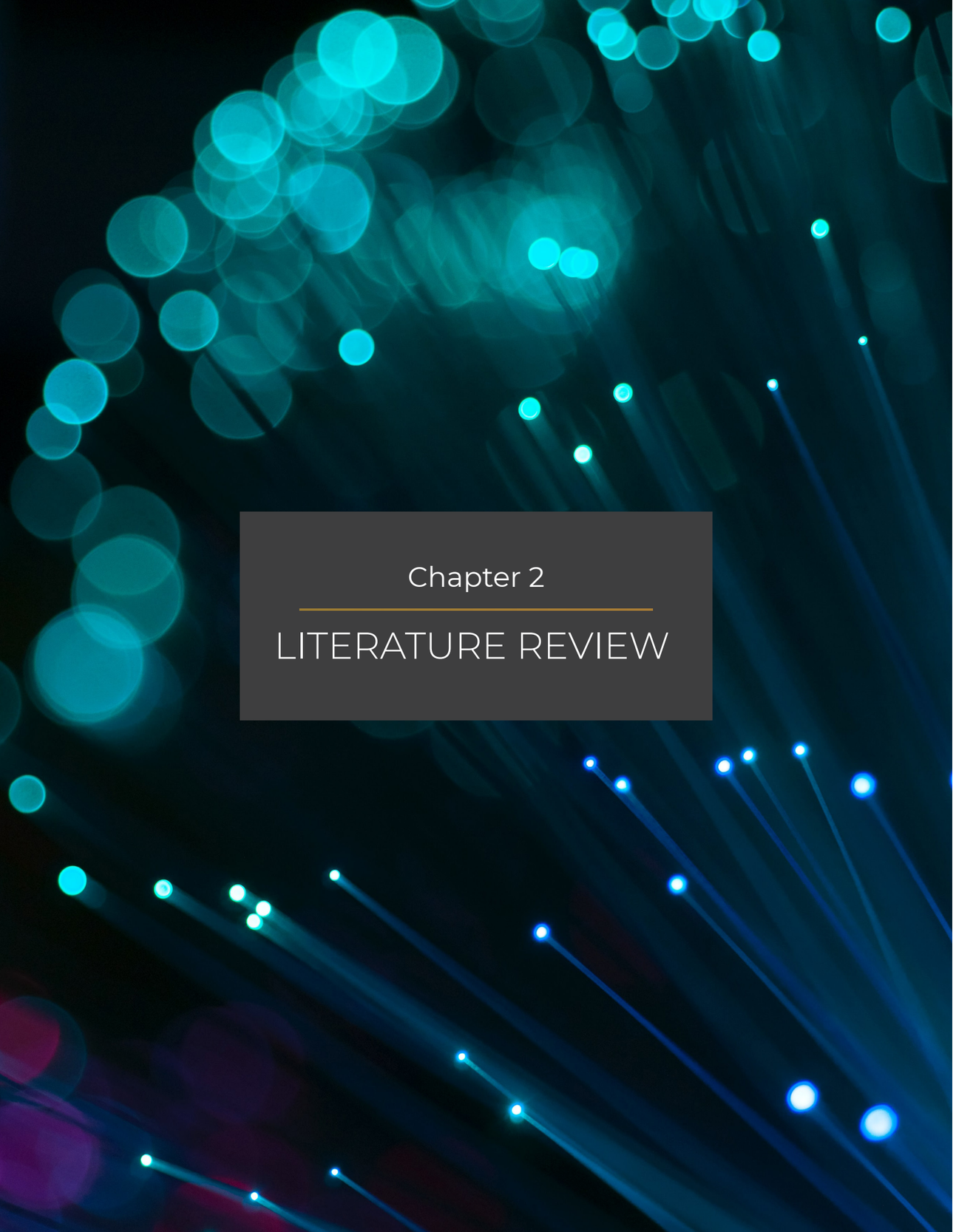


Figure 1.12 - Methodology



Chapter 2

LITERATURE REVIEW

2.0 // Literature review

One of the critical questions in the current era is how to provide broadband internet for all and second how to realise the digitally connected city of the future. The Covid-19 pandemic painfully exposed a crisis of internet access in many low-income and rural areas in the world. While many people in the Western world could easily shift to teleworking and online education, still 3.7 billion people worldwide do not have access to reliable and high-speed internet (United Nations, 2021). Terragraph, an intellectual property technology that emerged from the Facebook Connectivity group, aims to bridge this digital divide and has a mission to bring more people online to a faster internet. BrightSites utilises Terragraph's technology in its Gbit luminaire.

This chapter will interact with previous research to develop a stronger sense of the key technologies, concepts, and theories in the Gbit luminaire domain. This chapter aims to shed some light on the four primary subjects: data networking, telecommunication, smart cities and intelligent street lighting.

2.1 // Literature review

Data networking

The internet can be seen as a postal service, where it has one simple task, to move computerised information or data from one point to another. The underlying infrastructure to send data from one point to another on the internet is called backhaul. There are three types of backhaul technologies: 1. wireless, 2. wired, and 3. optical. See figure 2.1 for a list of common backhaul technologies.

Wireless	Wired	Optical
Microwave	Optical fiber	Laser
V-band (60 GHz mmWave)	(A)DSL	
E-band (70/80 GHz)		
Satellite		
Wi-Fi mesh		
LTE backhaul		
TD-LTE backhaul		
Self backhauling		

Figure 2.1 - Backhaul technologies

For sending data from one point to another, the sender and the receiver need to understand each other by speaking the same language. In a network, speaking the same language means that devices agree on how data is sent, received, organised and handled. They agree on a process that they all follow, which is called a protocol. Network software and hardware are designed with these protocols in mind. The Terragraph technology makes use of the 802.11.ay protocol and allows a fleet of millimetre waves operating in the 60GHz spectrum to deliver multi-gigabit speeds over a wireless mesh network. The advantage of a mesh network is that nodes form multiple paths to other nodes in the network, increasing redundancy in case of link failure. See figure 2.2.

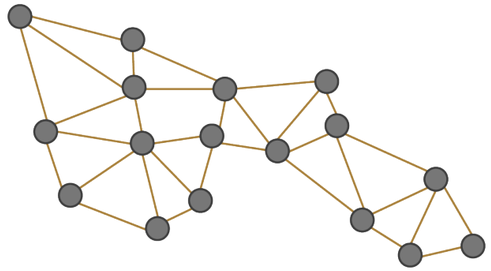


Figure 2.2 - Mesh network

Millimetre waves are defined as radio waves within the frequency range in the electromagnetic spectrum between 30 GHz and 300 GHz (Bogale et al., 2017). See figure 2.3. Data networking in the 60 GHz frequency band, in which Terragraph operates, has several advantages. First off, the spectrum band is unlicensed, meaning that no license has to be bought from the Federal Communications Commission or any other organization that regulates interstate and international data communication. Moreover, the high amount of bandwidth available in this spectrum and low latency characteristics. The downside, however, is the line of sight aspect since millimetre waves can not travel through buildings, trees or other obstacles. In addition, rainy weather possibly influences the quality of the network.

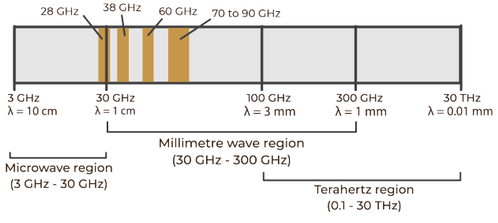


Figure 2.3 - Millimetre wave region as part of the electromagnetic spectrum

The actual amount of data a link transfers through a network is defined as the throughput, measured in bits per second. It is widely acknowledged in literature and the field that a high throughput and low latency are critical for the next generation of telecommunication and smart cities functioning (Yang, 2018); (Hayes, 2020).

Telecommunication

Around every ten years, there is a new mobile access technology that is significantly better than the previous generation. 1G was the first generation of telecommunication and introduced the first analogue cell phone. 2G introduced the first digital cell phone that let people communicate through SMS for the first time. 3G brought people access to the internet and has let people experience data rates up to 2 Mbit/s (European Commission, 2021). It was the start of a generation where connectivity became more relevant for the day to day since it allowed people for the first time to use video call, play mobile gaming and stream video. In 2010, 4G was introduced, which had significant performance enhancements compared to the previous generation. With the current 4G speeds a one hour, HD video is streamed in 6 minutes (European Commission, 2021). Nonetheless, with the next generation of telecommunication, 5G, a one hour HD movie can be streamed in just 6 seconds. In the present day, 5G is seen as the revolutionary technology to create a truly connected society. It is seen as the foundation for smart applications and the internet of things (IoT).

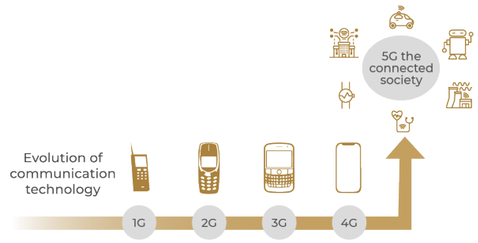


Figure 2.4 - Evolution of communication technology

The IoT is defined as a network of physical objects embedded with sensors, software and other technologies that exchange data and connect wirelessly with other devices and systems over the internet (Oracle, 2021). The transition to 5G is needed since it is projected that the number of IoT devices worldwide will reach 30.9 billion by 2025.

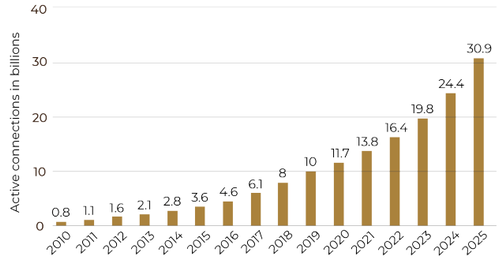


Figure 2.5 - Active IoT devices connections worldwide from 2010 - 2025 (Statista, 2021)

For all these devices to connect wirelessly over the internet, network infrastructure needs an upgrade, which comes at a high cost. Traditionally, mobile telecommunications consists of an end-user device and three network infrastructures, see figure 2.6.

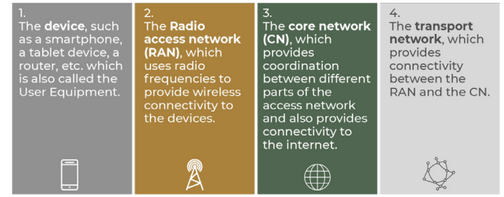


Figure 2.6 - The four domains of telecommunication (Ericsson, 2020)

In research from Grijpink et al. (2019), mobile network operators would have to increase their total cost of ownership (TCO) by 60 per cent from 2020 till 2025 to meet demands. This TCO includes the costs of upgrading the operating expenditures (OpEx) and capital expenditures (CapEx) of the radio access network and backhaul transmission.

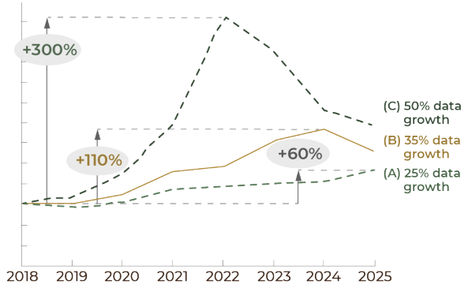


Figure 2.7 - Increase in total cost of ownership for mobile network operators (Grijpink et al., 2019)

The network infrastructure costs, coverage and speed, are dependent on the 5G spectrum bands. See figure 2.8 for the different spectrum bands of 5G. The thing to remember is that the lower the spectrum band, the wider the coverage, the slower the speed, and the other way around. Thus, the disadvantage of increased speed is that the radio waves can not travel far, which can be solved by deploying new macro cell towers, small cells and distributed antenna systems to improve network coverage.

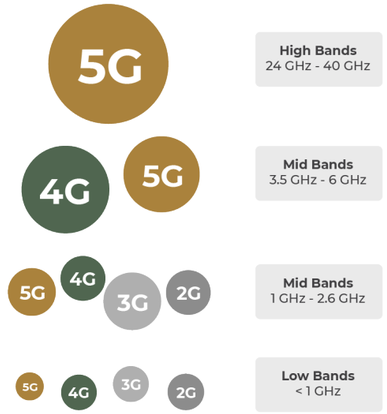


Figure 2.8 - 5G spectrum bands - low, mid and high band (Nokia, 2021)

Smart cities and intelligent street lighting

A number of authors have recognised that making cities smart is a key strategy to solve the problems caused by urbanisation and population growth (Chourabi et al., 2010); (Batty et al., 2012). By 2050, it is projected that two-thirds of the world population will be living in cities (United Nations, 2018).

Smart city IoT applications are seen as the solution to solve environmental and social problems caused by urbanisation in an effective and efficient way. For example, switching towards LED luminaires with smart controls can lead up to energy savings for cities up to 80%. The key argument for municipalities to switch to LED lighting is that approximately 30 per cent of a city's energy consumption is generated by street lighting. Therefore, to reduce carbon footprint and meet climate goals, switching to LED lighting is considered highly necessary.

Small cities with over 200 thousand inhabitants till big cities with over 10 million inhabitants are currently switching to energy-efficient LED lighting. The main advantages of connected LED street lighting in the present day are 1. Reduced costs and the investment can be earned back in a few years, 2. Energy reduction, thus decreasing environmental impact, 3. Enhancing public and road safety and 4. Energy optimization. Next to these benefits, street lights can also be turned into a valuable asset for a city's infrastructure. According to a performance benchmark of US cities, streetlights are seen as the foundation of smart city initiatives (Northeast Group, llc, 2019). It is evident that many cities are turning their street lights to smart connected LED lighting, and it is considered as one of the most actionable and ready-to-implement technologies.

In addition, previous studies have highlighted the potential of street lighting for providing new digital services and the potential barriers (Henke & Perry, 2020). There is consensus in the industry that street furniture, particularly light poles, are very suitable for the development of 5G small cell locations and smart city IoT infrastructure since the lighting grid offers near-ideal characteristics:

- Proximity: the lighting grid is located in areas where people live and travel
- Density: the grid density is higher (lower) in regions with more (less) people and traffic
- Scale: the lighting grid is present globally and is considered a necessary part of urban and transportation infrastructure
- Elevation: almost all telco, WiFi, and IoT equipment requires elevation (height), and in most cases, the lighting grid offers sufficient or even near-optimal height

Nevertheless, going beyond illumination is not an easy business to enter and dependent on ownership and operation. Light pole ownership and operation vary per country. Some countries own and operate light poles themselves, while in certain countries, light poles and ownership is outsourced to utilities and electricity supply companies. However, in the European market, light poles are most often owned by municipalities.

The following barriers are identified in the literature regarding challenges that have to be overcome to go beyond illumination, see figure 2.9. Municipalities are often risk-averse, and investments are only made when the demand is there, future costs are calculated, the technology is widely accepted, and above all, the law allows for doing so.

- Well-defined applications	- Organization
- Predictable use prospects	- Business models
- Resilient solutions for operation	- Definition of responsibilities

Figure 2.9 - Barriers of going beyond illumination (Henke & Perry, 2020)

For instance, municipalities recognise the new possibilities and opportunities that can be exploited on the lighting grid, but without any revenue generation, investment is costly. Therefore, municipalities do not go beyond illumination because there is a strong focus on costs and the lack of imagination regarding use cases that positively impact the city and lead to new monetisation opportunities (Henke & Perry, 2020).

Light poles in the present day not only have functional capabilities, but they also strongly contribute to the sense of safety of citizens, mood and overall city ambience (Henke & Perry, 2020). A comprehensive explorative study executed by (Brock et al., 2019) analysed four case studies of Philips Lighting over a period of five years from 2012 till 2017. Technology-driven companies, such as Philips Lighting, now Signify, are indeed needed to realise the smart city of the future. However, some challenges have to be overcome since product-centric business models do not meet demand anymore (Brock et al., 2019). One method employed by the researchers was to analyse the levels of value creation and value capture of each Philips Lighting smart city project and the implications this had on the overall ecosystem.

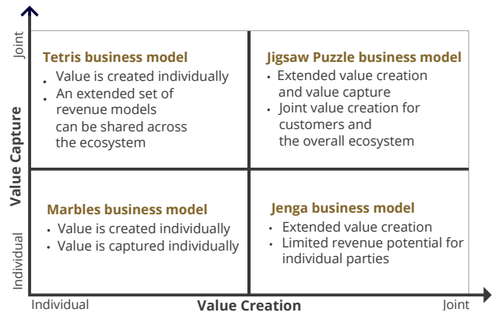


Figure 2.10 - Barriers of going beyond illumination (Henke & Perry, 2020)

The literature review shows that smart cities became a buzzword over the past decade and have billion-dollar potential. However, incumbents who want to enter the smart city ecosystem need to shift from a centralised mindset to go beyond pilot projects. It appears that smart cities are not built inside a company but around it. From analysing the previous Philips lighting projects, the following lessons can be learned to succeed in the industry: 1. Move horizontally from individual to joint value creation, 2. Move vertically from individual to joint value capture.

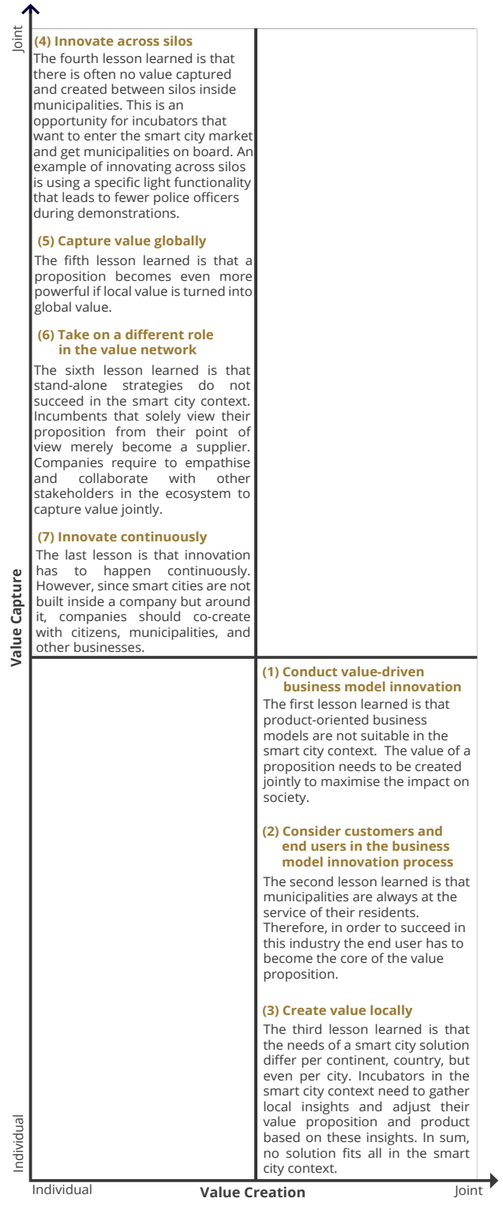


Figure 2.11 - Lessons from previous Philips Lighting projects (Brock et al., 2019)

Lessons from smart city initiatives outside Philips Lighting also have been widely explored in existing literature. It appears that scaling beyond a pilot project goes extremely slow and in order to successfully implement a smart city initiative, several challenges have to be overcome. The integrated framework developed by (Pierce & Andersson, 2017) examined the key challenges that affect the implementation of smart city initiatives. These challenges are divided into technical and non-technical challenges, see figure 2.12

Key insights from the literature review:

- Smart city applications require high bandwidth and low latency characteristics.
- 5G is seen as the revolutionary technology to create a truly connected society.
- The number of IoT devices is growing to 30.9 billion devices worldwide by 2025.
- IoT and telecom devices require a backhaul technology to travel back to the core network.
- mmWave is a form of backhaul technology, that is incorporated into BrightSites Gbit luminaire.
- Connected LED lighting is considered as one of the most actionable and ready-to-implement technologies.
- Light poles are very suitable for the development of 5G small cell locations and IoT devices.
- Smart cities have a billion-dollar potential; that is why many companies want to enter the market.
- Many projects in the smart city contexts failed due to product-oriented business models, and a lack of focus on the process- or service business model.
- Going beyond illumination and operating in the smart city context is not easy.
- Technology is essential, but co-creation and collaboration are paramount for project success.

Non-technical challenges	Technical challenges
Collaboration	**Security**
Weak collaboration with internal stakeholders, many initiatives are performed independently with municipal silos between departments and no clear definition of roles (Bakıcı, Almirall & Wareham, 2013); (Van den Bergh & Viaene, 2015)	System failures (Heo et al., 2014)
Weak collaboration with external stakeholders (Baccarne, Mechant & Schuurman, 2014); (Kitchin, 2014)	Outsourcing the smart city initiative to private sector providers (Pierce & Andersson, 2017)
The absence of a shared vision of the smart city initiative with internal and external stakeholders (Van den Bergh & Viaene, 2015)	
Institutional resistance (Lee et al., 2014)	
Financial	**Interoperability**
Limited public funding and private investments (Carvalho, 2015)	Difficulties in planning ahead, technological change is accelerating (Pierce & Andersson, 2017)
Lack of clear business models (Zanella et al., 2014)	The fusion of ICT and IoT with urban systems (Theodoridis, Mylonas & Chatzigiannakis, 2013); (Heo et al., 2014); (Zanella et al., 2014)
Large up-front investment costs (Manville et al., 2014)	
High-investment risks due to long return on expected values or profitability (Manville et al., 2014); (Ferrer et al., 2013)	
Governance	**Privacy**
Lack of policies that support smart city initiatives (Lee et al., 2014)	Information that is monitored by sensors affect citizens rights (Bianchini & Avila, 2014)
Political	Making use of big data while maintaining citizens privacy and data security (Boulos & Al-Shorbaji, 2014)
Political hyper-activism, technology driven enthusiasm and restraining high investment risks leads to political uncertainties (Nam & Pardo, 2011)	
Awareness	
Lack of knowledge, expertise or understanding of the technology (Pierce & Andersson, 2017)	

Figure 2.12 - Smart city initiatives challenges

Chapter 3

INTERNAL ANALYSIS

3.0 // Internal analysis

BrightSites is a new business unit within Signify that has the ambition to enable wireless connectivity on the outdoor lighting grid by incorporating mmWave radios into luminaires that provide fibre-like speeds. These luminaires are called Gbit luminaires and can be placed onto regular light poles or embodied into a smart pole. The Gbit luminaire uses energy-efficient LED lighting and Interact City, a connected LED lighting system and management platform.

This chapter discusses the venture's internal situation, including its product portfolio, Gbit luminaire network architecture and customer value proposition. In addition, two observational interviews were conducted with system experts of the public segment to understand the Interact City platform further and learn how city operators currently monitor and manage a lighting network.

3.1 // BrightSites

BrightSites is a venture with a clear mission in mind, and that is to deliver the next generation of connectivity on the outdoor lighting grid for brighter lives and a better world. The venture's mission embraces Signify's strategy to leverage the lighting infrastructure for developing new capabilities and services.

The venture recently added Gbit luminaires to its extensive product portfolio of smart poles. Gbit luminaires are innovative fixtures that provide wireless high-bandwidth connectivity using energy-efficient LED lighting. With its new proposition BrightSites is turning the lighting grid into a platform of connectivity. It is a plug-and-play solution for regular light poles or smart poles that provide wireless fibre-like capacities. A Gbit luminaire can thus be seen as a fixture that consists of two components: a data networking component and a lighting component. Foremost, the Gbit luminaire transfers bytes from one point to another due to a built-in mmWave radio into the luminaire. The intellectual property technology of this mmWave radio derives from Terragraph, a venture that emerged from the Facebook Connectivity Group. Terragraph offers this technology free of charge to partners that develop mmWave radios with this technology and sell these to other companies, including BrightSites.

Terragraph describes its technology as a high-bandwidth, low-cost wireless solution to connect cities (Facebook Connectivity, 2019). The mmWave radios are devices that altogether create a wireless self-organising mesh network, delivering gigabit speeds even under bad weather conditions or dense urban environments. The main advantage for network vendors to acquire Terragraphs mmWave radios is that the devices are small, approximately 240 by 190 millimetre, making installation quick and a one-person job. In addition, the purchasing price of a mmWave radio is only a fraction of the cost of fibre, leading to a low total cost of ownership. The advantages of Terragraphs' mesh technology is that even though the mmWave radios require line of sight, the network automatically re-routes in case of link failure, ensuring high availability and reliability. This link failure can, for example, happen by a truck blocking the line of sight between two nodes. Furthermore, in present-day, Terragraphs radios can quickly be deployed on existing street furniture, such as rooftops and light poles, and can therefore be easily scaled when needed by simply adding more mmWave radios into the mesh network.

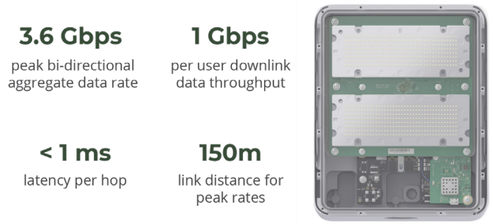


Figure 3.1 - Network capabilities of Terragraphs' technology (Facebook Connectivity, 2019)

A network built with mmWave radios consists of three components: 1. A fibre point of presence (PoP), 2. A client node, and 3. A distribution node. The fibre PoP is where a mmWave radio is connected with fibre and is always a distribution node. It is the location where all connections come together and where the network distributes further. The difference between a client node and a distribution node is that a client node cannot distribute the network further, and due to these limitations, it is sold at a much lower cost than a distribution node.

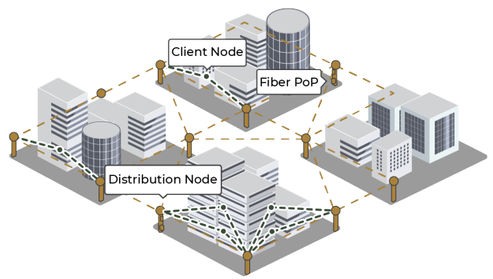


Figure 3.2 - The three components of Terragraph's mesh network

BrightSites Gbit luminaire offers the best of both worlds: energy-efficient LED lighting and gigabit connectivity integrated into one fixture. With this product proposition, BrightSites unlocks new use cases for the digitally connected city of the future. Below a list of current use case stories is listed.

Fixed wireless access

Fixed wireless access is a technique to provide broadband connectivity through radio links between two fixed points. It is considered as a cost-efficient option for last-mile connectivity, referring to the core network of a provider and the user. In BrightSites' proposition, fixed wireless access is delivered from a distribution node attached to a light pole to a client node. This client node is attached to residential buildings, businesses or offices to provide high-speed internet without rolling out optical fibre. Especially in rural and remote areas, fixed wireless access is considered as an attractive technique since the costs of optical fibre roll-out are relatively high in these areas. In the present day, service providers have to require permission from cities or utilities to attach mmWave radios onto light poles; with BrightSites Gbit luminaire, the distribution node is concealed into the luminaire. The assumption is that cities or utilities are more likely to give access to the lighting infrastructure with the Gbit luminaire. Since there are three values met of cities: 1. Sustainability because of the energy-efficient LED lighting, 2. No urban clutter because of the integration of the mmWave radio into the luminaire 3. The high-speed connectivity for residents and businesses is considered vital for economic growth and increased digitization in society.

Public Wi-Fi

Wi-Fi connectivity nowadays is present in cities hotspots, such as airports and shopping malls. One functionality of the Gbit luminaire is that Wi-Fi access points can be attached for providing public Wi-Fi: providing seamless connectivity on any location near a light pole, enhancing the tourist experience and bridging the digital divide.

Small cell backhaul

With the Gbit luminaire network infrastructure, 5G small cells can be wirelessly connected, leading to the slightest disturbance above and under the ground. In the Netherlands, there are approximately 3.500.000 light poles. For the entire 5G roll-out in the Netherlands, approximately 90.000 small cells have to be rolled out by all three network operators, which means that there has to be a small cell installed on every 39 light poles for the entire 5G experience. In the current product proposition, small cells can be connected wirelessly and aesthetically be covered into a smart pole. In the future, BrightSites can explore how small cells can be aesthetically integrated into the Gbit luminaire fixture.

Smart city IoT applications

From all sensor types, cameras require real-time transmission frequency and transfer the highest amount of bandwidth. In the present day, the mmWave technology requires line-of-sight and can only beam downwards with a 20-degree angle. Therefore, smart city IoT applications need to be placed at the same height as the distribution node with the current technology. Examples of camera use cases are surveillance and crowd control management.

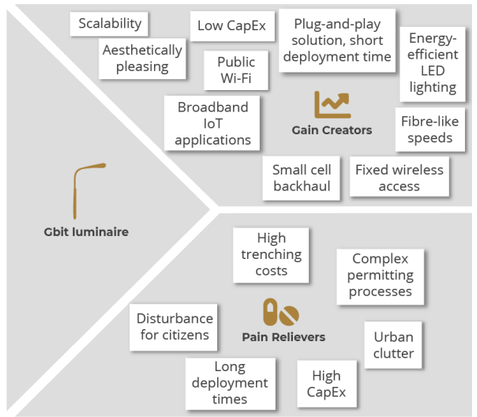
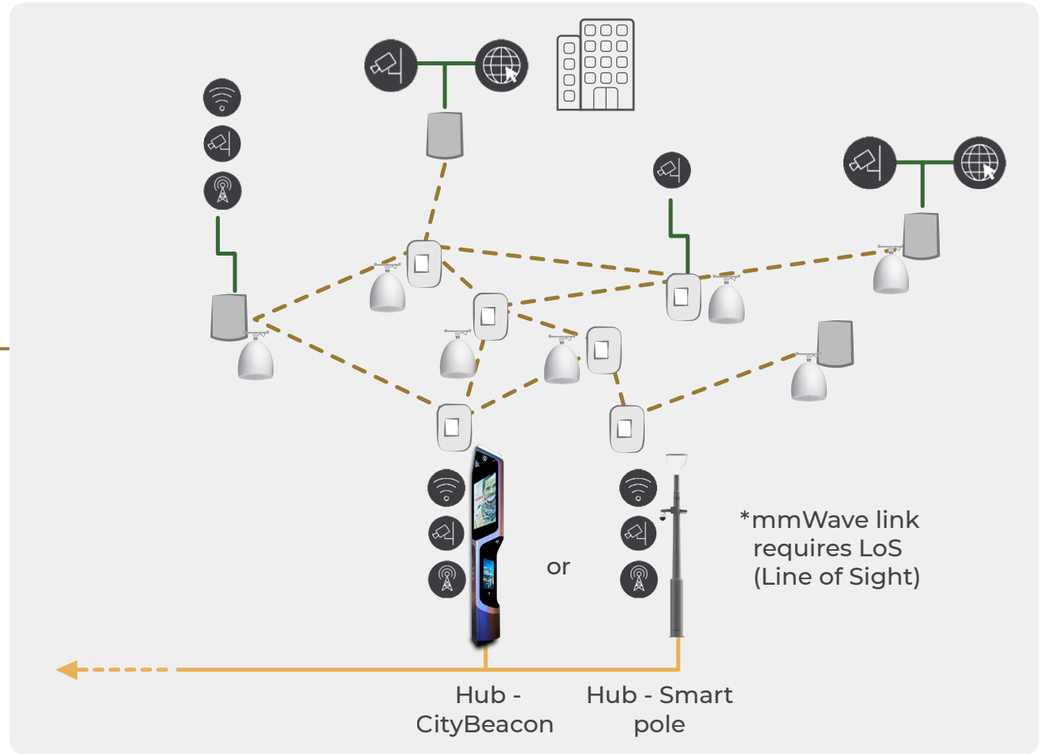


Figure 3.3 - BrightSites value proposition

BrightSites
by signify

Network architecture



60GHz mmWave link
Optical fibre
Ethernet cable

= Distribution node

= Client node

BrightSites
by signify

Product portfolio

Smart poles

Smart poles are light poles that can hide telecom and IoT equipment inside the pole while utilizing energy-efficient LED lighting.

Smart hubs

Smart hubs are digital kiosks with a wide range of functions, such as edge computing, digital display screening, and telecom equipment hosting.

Luminaires with Gbit technology

A Gbit luminaire is an innovative fixture consisting of energy-efficient LED lighting and a mmWave radio.

FIRST INSTALLATION

On the 17th of June 2021, the first Gbit luminaire network infrastructure was installed in Tilburg, the Netherlands. The goal of the pilot project is to investigate the influence of a wireless connectivity system via the lighting grid on the smart city of Tilburg. The findings of this day show that installing a Gbit luminaire is indeed a plug-and-play solution, taking up to approximately 15 minutes. The municipality considers the lighting infrastructure as an ideal starting point to create a platform for IoT applications; the upcoming months will clarify the technical capabilities and the fit of such a system with the city.

3.2 // Interact City

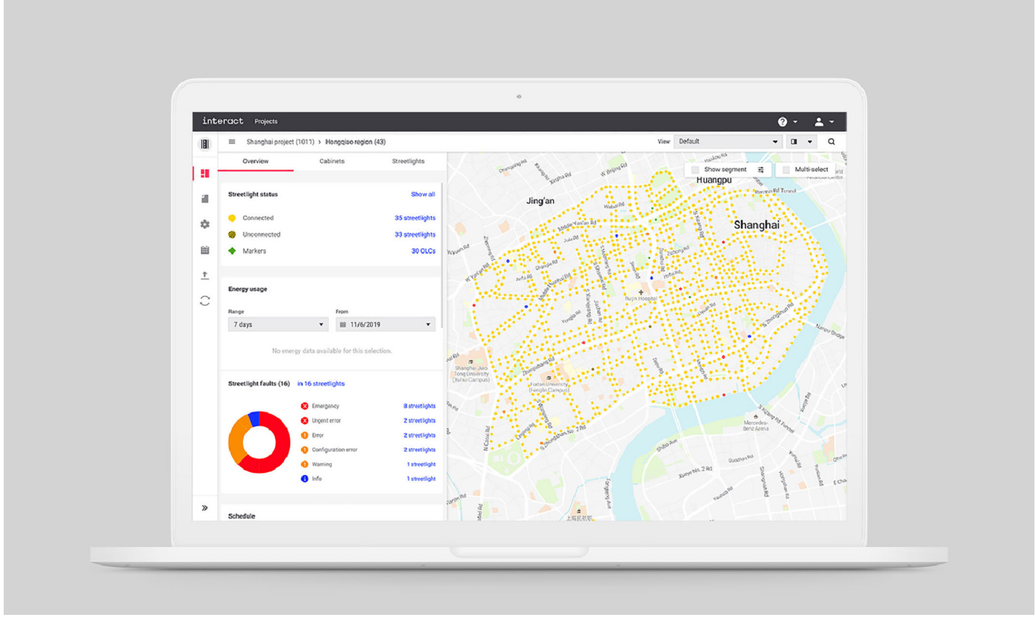
BrightSites Gbit luminaire will make use of energy-efficient LED lighting and the Interact City asset management service. Interact City is the solution for making cities more intelligent and liveable. Interact City is globally present in over 50 countries with more than 2.000 project sites and 2 million connected light points. The Interact City asset management service consists of two components: 1. OLC, a device that is placed on the luminaire for remote control and monitoring, 2. Interact City software, a connected lighting and management platform that allows cities to manage their city lighting, including roads, streets, pedestrian sidewalk and crossings, bridges, parks and plazas. The business model is a Software-as-a-Service model, meaning cities do not own the software but use contracts.

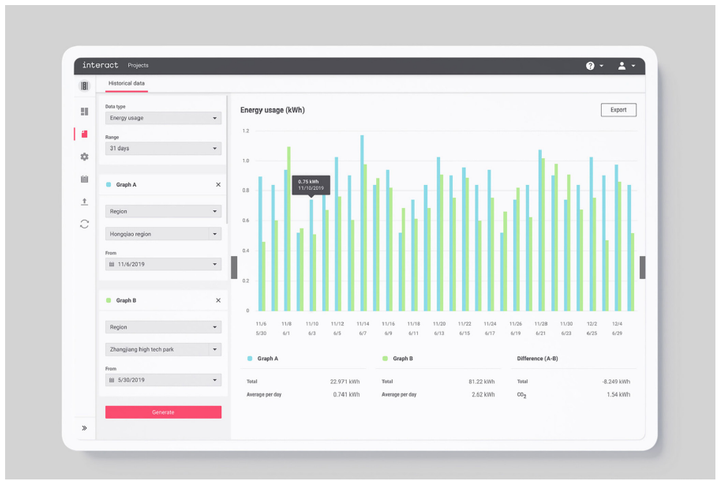
Interact City has the following three main functionalities: 1. Lighting management, 2. Scene management, and 3. Energy optimization. Foremost, lighting management lets lighting operators manage and monitor existing luminaires, detect faults, and check energy performance. Second, scene management allows cities to give citizens the right light at the right time. For example, with Interact City, cities can now deliver the right light at the right time, which means that individual and grouped light points can be dimmed at specific times and specific months or events. Third, LED lighting with OLC devices helps cities save up to 80% of their energy consumption. The investment to change to LED lighting can thus be earned back in no time. Two observational interviews were conducted with two system experts of the public segment to understand Interact City further. This observational interview aimed to understand how lighting operators currently monitor and control a lighting network.

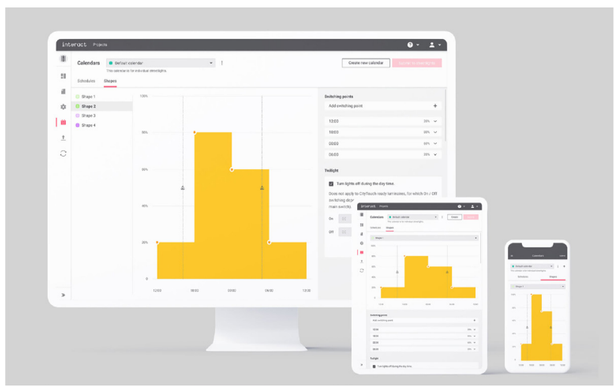
The system experts of the public segment acknowledge that managing a lighting network with Interact City is not a job that requires complicated thinking. It can be said that the type of thinking being used by lighting operators is instead on auto-pilot, where its main task is to detect faults. Both Interact City experts do not consider the current workforce at the lighting department of cities suitable for managing a data network. Another challenge for network operation is that most faults in the Interact City dashboard only get visible after 24 hours, which can take up to 48 hours and only after six days a fault is registered as a critical fault. It is thus not as critical for lighting operators to have a single luminaire not working compared to having network downtime due to a Gbit luminaire. Fault management using alarms is thus a point of attention for BrightSites in the operation phase because alarms are highly dependent on the setup of the network infrastructure. To clarify, imagine there is a setup with two or more fibre access points, then a degraded link is less critical than a network infrastructure with only one fibre access point. Therefore, there should already be defined how crucial a link is in a network in the planning phase, which then should be referred to the criticality of the alarms in the dashboard.

For the complete list of insights, see appendix I.

Figure 3.4 - OLC device







Chapter 4

EXTERNAL ANALYSIS

4.0 // External analysis

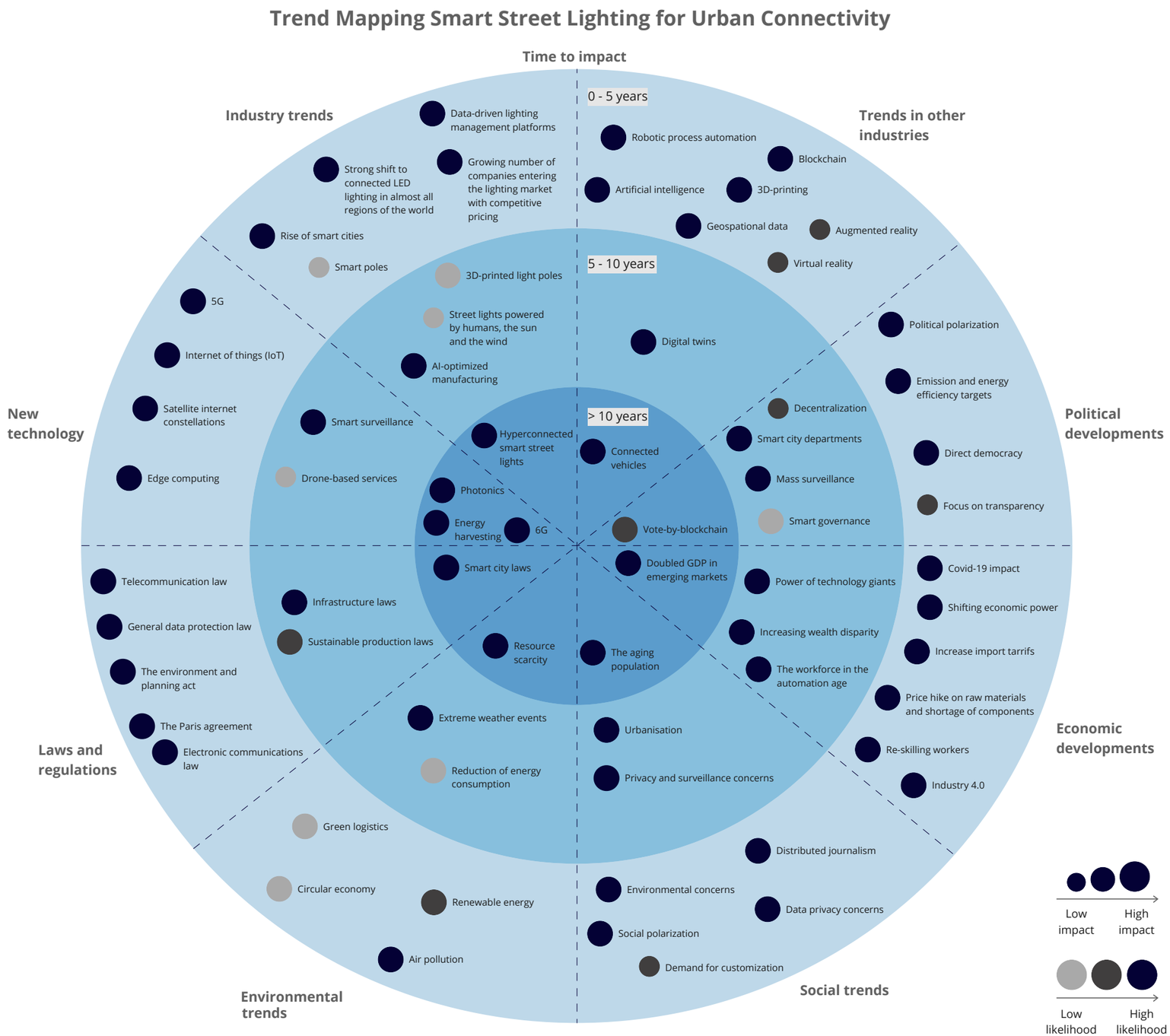
Cities all around the globe are shifting to energy-efficient LED lighting; however, the demand for smart city services is not as developed yet. Therefore, the challenge for companies that want to go beyond illumination, including BrightSites, is to understand all stakeholders their priorities and link how a proposition addresses those needs.

In the Netherlands, light poles are owned by municipalities, making them the primary decision-makers for project success. However, the digital knowledge inside municipalities is low. Not to mention that municipalities are facing budget shortages and are nine out of ten times not the buyer of a smart city solution. For BrightSites to grow as a venture, all stakeholders and their underlying values are mapped out into a value flow framework. This framework is developed by conducting semi-structured interviews with relevant stakeholders, which are then turned into empathy maps and customer profiles.

This chapter discusses the findings of the trend analysis, competitor analysis, stakeholder analysis and finalises with a value flow framework that sums up the findings.

4.1 // Trend mapping

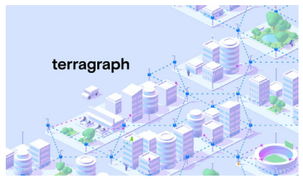
This chapter presents the trends that are influencing the smart street lighting for urban connectivity ecosystem. The trends are divided into the following parameters: industry trends, new technology, laws and regulations, environmental trends, social trends, economic developments, political developments and trends in other industries. The trend mapping method enables companies to understand the external shifts that are taking place that might internally affect a business or product proposition. The trend map will be used later in the design process as a source of inspiration and to recognise potential barriers in BrightSites proposition. The outer layer of the trend map represents the trends that are most likely to impact the business in the upcoming five years, in this case, the time period of 2021-2026. The second and the third layer represent the time period 5-10 years and >10 years, respectively.



4.2 // Competitor analysis

BrightSites will be the first to market a Gbit luminaire in the intelligent street lighting industry. However, the Terragraph technology that a Gbit luminaire inherits is offered by multiple vendors. A Gbit luminaire differs from these vendors by the aesthetic integration of the mmWave radio into the luminaire. In the short term, the widespread deployment of separate mmWave radios is needed to make the product more well-known. Nevertheless, these vendors can form a significant threat to BrightSites venture in the future by competing with the price, aesthetically redesigning mmWave radios or by making the product smaller and thus less visible on the light pole.

facebook connectivity



Terragraph is a technology from the Facebook connectivity group which allows a fleet of radio nodes that operate in the 60 GHz spectrum to form a mesh distribution network which can deliver fiber-like speeds, but at a fraction of the costs of fiber, and also at a much faster deployment speed.

Facebook licenses this technology free of charge to vendors that develop mmWave radios with the Terragraph technology:

IgniteNet
RADWIN
MikroTik
Siklu
Cambium Networks
common_

mmWave radio mounted on a pole

BrightSites
by signify

BrightSites aesthetically integrates a mmWave radio from a vendor into a luminaire fixture, transforming existing luminaires into Gbit luminaires

mmWave radio aesthetically integrated into a luminaire fixture

Apart from the hardware product, BrightSites needs to develop a software tool for customers to operate their network and assets divided into a lighting and network management dashboard. From an operational perspective, the existing skillsets of a lighting operator and a network operator do not align. Ideally, one person would be responsible for managing a Gbit luminaire network infrastructure. However, based on the knowledge gap, it would be likely that multiple stakeholders are involved in network and lighting management. Next to the operation stage, the Gbit luminaire requires software for the other phases of the product offering:

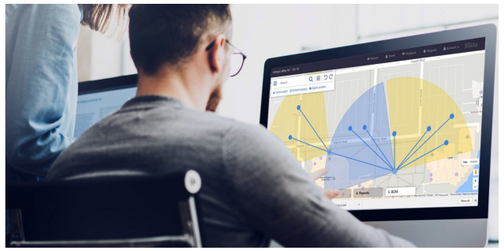


Figure 4.1 - Network planning tool (Siklu, 2018)

1. Planning phase

In the planning phase, the software needs to position the smart pole or smart hub, which acts as the fibre points of presence in the network architecture, and the Gbit luminaires in the correct position. The fibre PoP needs to connect with at least one Gbit luminaire to create a line of sight. From this Gbit luminaire, the network can be distributed to create a complete self-organising mesh network.

Two planning software tools have been analysed in-depth: the Siklus WiNDE planning tool and the Facebook Advanced Network Planner tool. See appendix III for the pros, cons, and opportunities for BrightSites if the venture develops its own software.

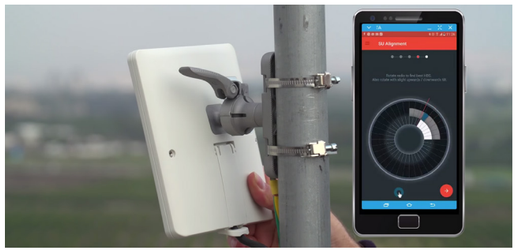


Figure 4.2 - Commissioning software tool (Radwin, 2017)

2. Commissioning phase

In the commissioning phase, the Gbit luminaire needs to be commissioned by an engineer using commissioning software.

Figure 4.3 - Network management tool (Radwin, n.d.)

3. Operating phase

In the operational stage, the Gbit luminaire network infrastructure needs to be controlled remotely to observe the status, performance, and alarm messages.

Regarding network operation, several tools have been analysed as well. Unfortunately, since it is a relatively new product, access to this software is not openly available or not even fully developed by competitors.

Even though BrightSites is the first to market a Gbit luminaire fixture, the venture is certainly not the first venture in the Netherlands that is trying to go beyond illumination. As mentioned in the literature review, smart cities have enormous market potential, and the lighting grid is considered as the ideal location for smart city IoT and small cell deployment. However, based on external expert interviews, it is not self-evident for companies that want to go beyond illumination to have widespread market deployment. A company with a compelling vision regarding smart cities is the Dutch lighting company, Sustainder. The company is relatively new and set up by people with a KPN telecommunication background who aim to create a more sustainable society through intelligent lighting solutions. The company's first product was only introduced at the beginning of 2017, the Anne luminaire. Subsequently, the second product, the Alexia luminaire, shortly followed in June 2017. The company has a mission to create a space inside the luminaire where all smart city IoT comes together, a sensor hotel, see figure 4.7. Based on the city's needs, cities can aesthetically integrate extra functionalities with the help of a modular cassette system, for example, adding public Wi-Fi or environmental monitoring sensors. Sustainder approach is to see lighting as an IoT object. However, in reality, convincing cities to change to LED or switch to LED lights with new functionalities goes extremely slow as this depends on previous investments made in cities. In addition, Sustainder only has two types of luminaire styles, and the style of these luminaire fixtures do not aesthetically fit everywhere. Therefore, the challenge for companies is to understand the legacy base of cities and understand how their product could play a role in this specific luminaire style.

Furthermore, it is observed that companies who add extra functionalities to their product can charge their product for a higher price. However, the moment a company starts adding new functionalities to its product with sensors, it will have to enter the world of law and regulations. For example, a camera integrated into the luminaire of Sustainder can not be hacked. So regarding cybersecurity, there are likewise many conditions that need to be met. In the Netherlands, the main law regarding privacy and security is called the General Data Protection Regulation (AVG) law.

Figure 4.4 - The Anne luminaire of Sustainder and its functionalities (Sustainder, n.d.-b)

Figure 4.5 - The Alexia luminaire of Sustainder (Sustainder, n.d.-a)

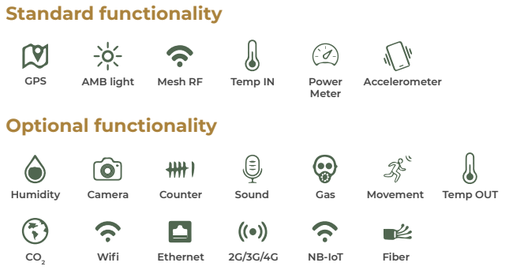


Figure 4.6 - The functionalities of the luminaires of Sustainder (Sustainder, n.d.-a)

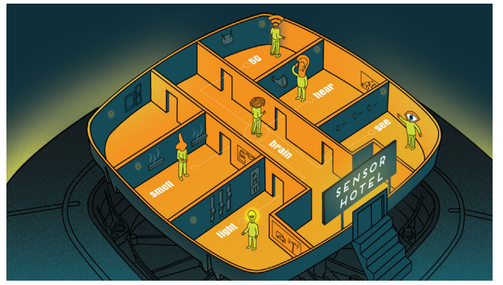


Figure 4.7 - Sensor hotel vision (Sustainder, 2019b)

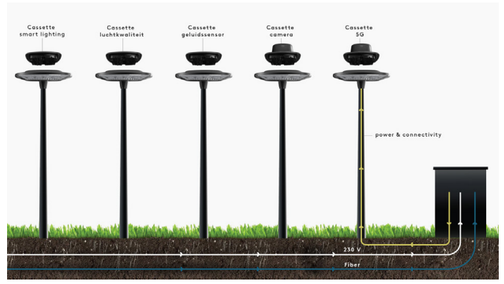


Figure 4.8 - Partnership of Sustainder, Nokia and Eurofiber for 5G installations on the lighting infrastructure (Sustainder, 2019a)

Key lessons for BrightSites:

- Products of other companies can be aesthetically integrated into the luminaire, e.g. sound cameras from Sorama. With the help of artificial intelligence traffic lights can react to the speed and location of vehicles and in this way improve traffic flows. This is a great example of how a solution aligns with key priorities of cities, smart mobility.
- 212 municipalities in the Netherlands and Germany currently make use of Sustainder its products.
- Sustainder has a similar mission as BrightSites regarding smart city IoT and small cell deployment, apart from that the devices are connected with optical fibre instead of mmWave technology.
- The modular cassette system offers cities the flexibility to add extra sensor functionalities in the future.
- Sustainder worked together in the past with Nokia and Eurofiber to aesthetically integrate telco equipment into the luminaire. Based on expert interviews and the Tu Delft Telecom Business Architectures and Models course there are only a few telecom equipment vendors worldwide. It can be said that mobile network operators have a ‘marriage like’ relationship with these telecommunication equipment providers. In the Netherlands, KPN mainly works together with Nokia, T-Mobile with Huawei and Vodafone with Ericsson.
- In the prototype, a Nokia 5G radio antenna is placed, which is an open system that enables every mobile network operator to share the same antenna, preventing double set-up points. As of today, no 5G deployments are aesthetically integrated on the lighting infrastructure of Sustainder. However, BrightSites can derive many insights from this partnership and prototype project since the project has a similar vision regarding small cell installations on the lighting grid.

4.3 // Stakeholder analysis

In the smart street lighting for urban connectivity ecosystem the following key stakeholders are identified:

- Central government
- Municipalities
- Citizens
- Third party equipment suppliers
- Fibre suppliers
- Light pole service providers
- Electricity suppliers
- Mobile network operators
- Internet service providers
- Telecommunication infrastructure providers

For creating a comprehensive understanding of each stakeholder involved in this ecosystem, the following internal and external stakeholders participated in semi-structured interview(s) to share their experiences and knowledge, for the full list of insights see appendix IV.

Municipalities:

- Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht
- Process Director for the Living Environment, Municipality of Tilburg
- Infrastructure Engineer, Municipality of Delft
- Advisor Lighting, Innovation and IoT, Municipality of Eindhoven
- Advisor of Innovation and Digital Technology, Municipality of Breda
- Program Manager for Digital Connectivity, Municipality of Amsterdam

Mobile network operators/ telecommunication experts:

- Assistant Professor Tu Delft, Telecom Business Architecture and Models
- Technical Lead Industrial 5G Field Labs, KPN
- Fund manager, Primevest Capital Partners

Fibre supplier:

- Director, Broadband Tilburg

Telecommunication infrastructure provider:

- Previous Global Head of Country Coordination, Cellnex Telecom

Light pole service provider:

- Business Development Manager Smart City, SPIE Infratechniek B.V.

Interact City, Signify:

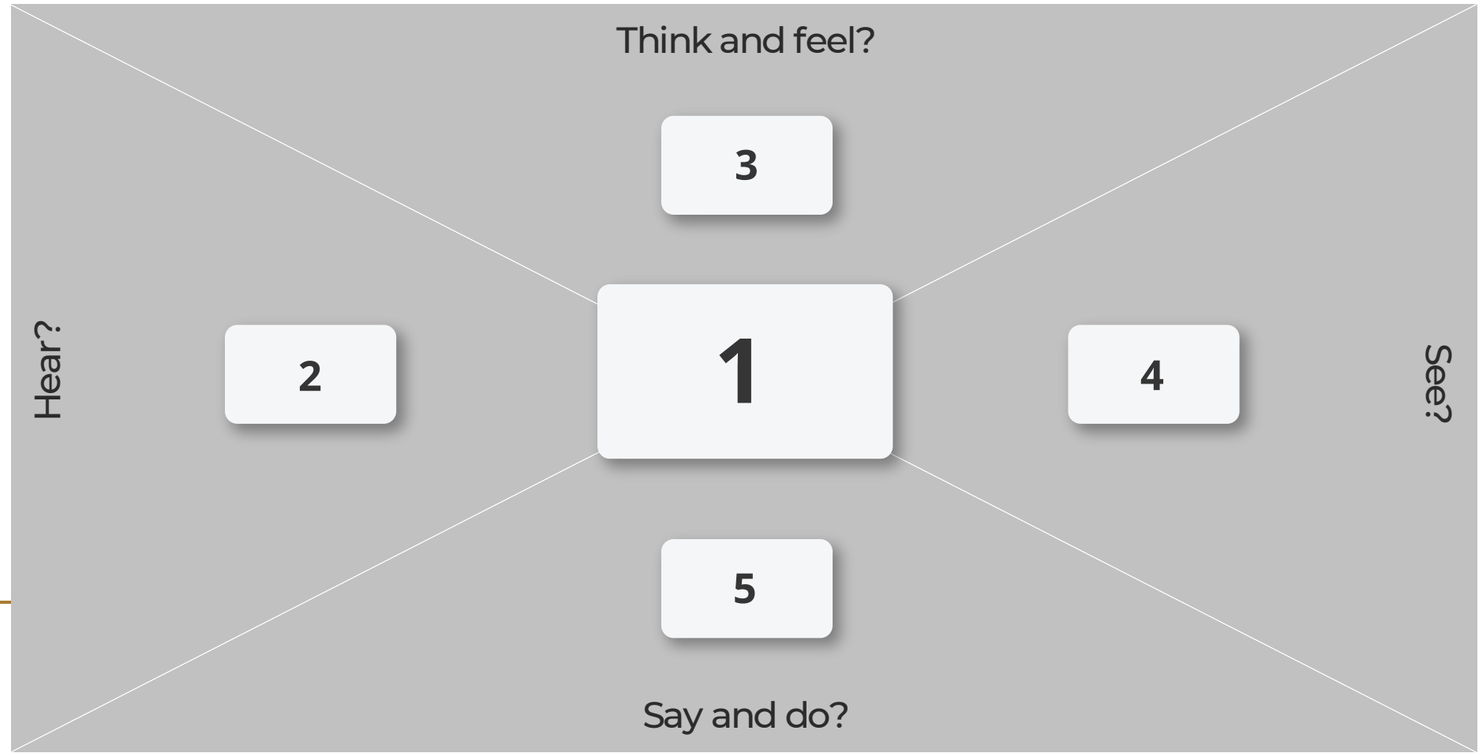
- System Expert Public Segment Interact City cellular lighting
- System Expert Public Segment Interact City RF lighting

BrightSites, Signify:

- Product Architect
- Lead Development Engineer

4.3.1 // Empathy mapping

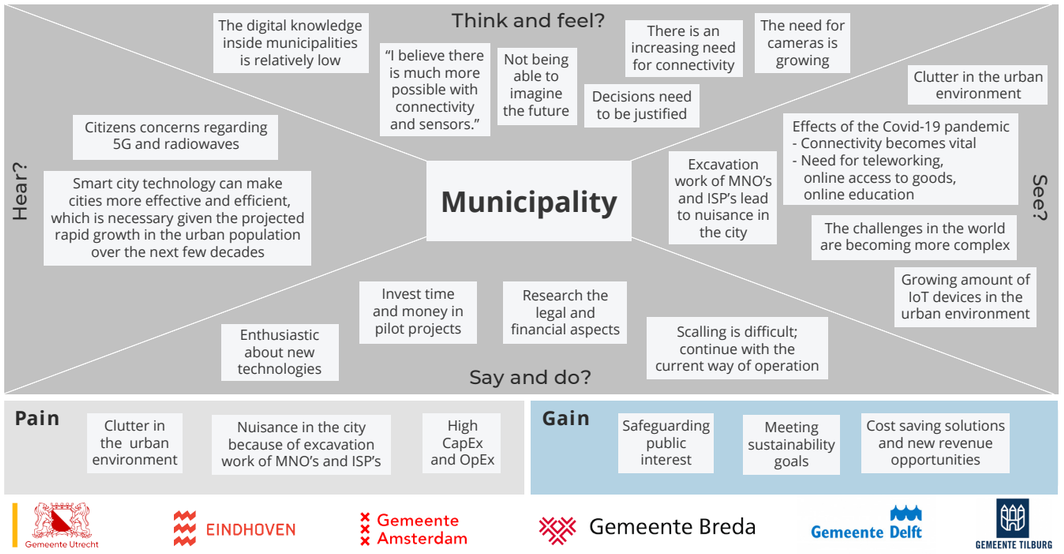
Empathy mapping is a design method to articulate what a product team knows about a particular user (Adobe, 2020). For this research, four key stakeholders have been mapped out onto an empathy map: municipalities, mobile network operators, telecommunication infrastructure providers and fibre suppliers. In this project context, an empathy map helps to create a holistic understanding of the world of each stakeholder, their pain points and identify new opportunity spaces.



Pain 6

Gain 7

1: Stakeholder	2: Hear?	3: Think and feel?	4: See?	5: Say and do?	6: Pain	7: Gain
With who are you trying to empathize	What and who influences the stakeholder	What does the stakeholder think and feel on a regular basis regarding the problem that exists	In what environment is the stakeholder commonly involved in	The attitudes and behavior of the stakeholder towards the proposition	The fears, frustrations and obstacles of the stakeholder	What makes the stakeholder happy



Municipalities

There is a consensus among municipalities that connectivity increases cities' value and that the demand for connectivity is growing. Technologies such as 5G and mmWave technology are needed to meet the demands of municipalities in the future. However, municipalities in the Netherlands can not foresee how much data backhaul a specific location needs or how much bandwidth a city needs for a specific use case. Not to mention that municipalities in the Netherlands are fairly conservative organisations and that the urge to innovate mainly occurs in big municipalities.

Nevertheless, even in the bigger municipalities, it is prevalent to continue with the current way of operation because scaling is complex due to the different interests of stakeholders. Furthermore, market players can often not prove the substantial added value of new technologies that benefit cities in the short term. Despite cities recognising the increased need for connectivity, they do not see themselves responsible for rolling out a municipal network because this can be seen as a market disruptive action. Likewise, the digital knowledge inside municipalities is low, meaning that a market player should be responsible for network operation in case of network rollout.

Key insights

- Municipalities are not business oriented, but value oriented. Investments in the public space are made with government money, therefore choices need to be justified.
- Municipalities highly care about the applications on the light pole, and preferably want to make data collected in the public environment available for all. This implies that the application technologies of the Gbit luminaire are more important than the underlying backhaul technology.
- Municipalities foresee problems if they put themselves in the position of a network operator. They do not see themselves as being the direct owner of a mmWave network. Therefore, the responsibility of managing a network will be by a market player.
- There is a shift in the landscape where lighting administrators/operators will also become responsible for reading out sensor data and communicating this back to the municipality.
- In most cities in the Netherlands the lighting grid does not receive 24/7 power supply, which is a requirement for the Gbit luminaire.
- Municipalities own the light poles in the Netherlands, making them the key decision-maker.

Quote

"I think is important to look at the needs of municipalities, what needs arise from the municipality's task, and how the products of Signify can play a role in this."

- Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

"I worked myself in a corporate organisation as well, simply said if one euro delivers more value than it costs, then there is already a business. But this is definitely, not how it works from a municipality perspective. From a municipality perspective, there are many interests that do not express themselves financially."

- Process Director for the Living Environment, Municipality of Tilburg

Quote

"For this pilot project, I can imagine there needs to be a dashboard to show that the technology works, however I do not see it happening that we will be a direct owner or administrator of this solution in a next phase."

- Process Director for the Living Environment, Municipality of Tilburg

"Network management is a profession on its own and should just be the responsibility of a market player."

- Program Manager for Digital Connectivity, Municipality of Amsterdam

Quote

"A municipality will not say in this period that we will deploy a widespread Wi-Fi network. Why? Because Wi-Fi is already widely available, and there are already other technologies such as 4G and 5G. This is a vision municipalities had 10 years ago to stimulate digital communication inside cities; nowadays many people already have access to the internet."

- Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

"Cameras will be placed on locations where it is needed, from a safety perspective, not where it is technically feasible for Brightsites."

- Process Director for the Living Environment, Municipality of Tilburg

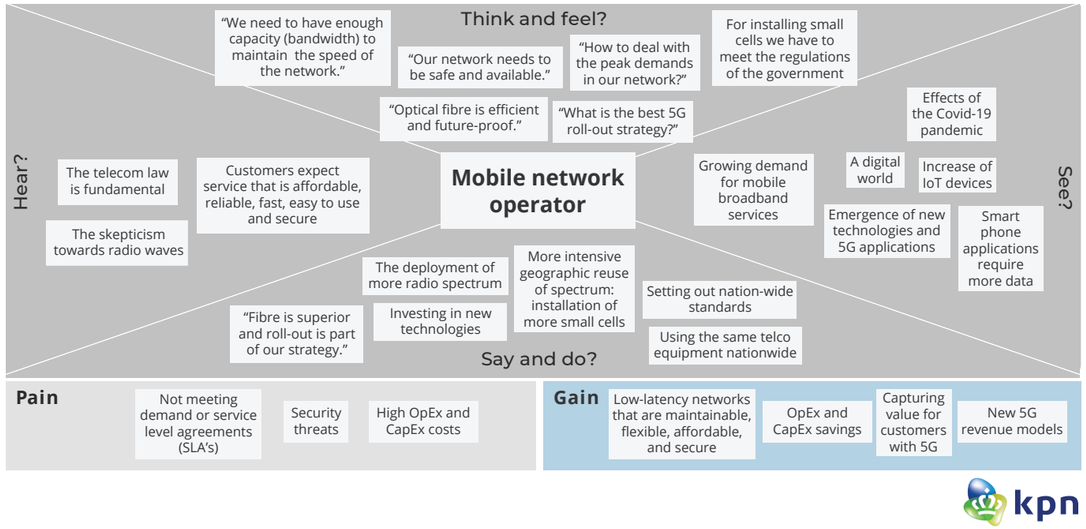
Quote

"BrightSites is a progressive company, and Signify is the world leader in lighting. But they will need other parties for their proposition and admit that they need to position this jointly."

- Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

"The market must come up with hybrid solutions that fit into existing systems."

- Advisor of Innovation and Digital Technology, Municipality of Breda



Mobile network operators

Mobile network operators, such as KPN, recognise that the world ten years from now will be different. Nobody knows how different that world will be, but what is known for sure is that it will become a digital world with 5G as the foundation. According to KPN, the shift towards 5G technology is needed to keep up with the growing demands of bandwidth and low latency requirements in the digitally connected city of the future. Nevertheless, capacity planning is costly for mobile network operators; to illustrate, KPN spends 1.2 billion euros yearly to increase its capacity and meet customer demands. This is approximately one-fifth of KPN's yearly revenue that has to be invested back into the company.

It is recognised by KPN that there will always be places where fibre roll-out is not possible, but the preferred option is to connect these sites to fibre eventually. For the reason that KPN has to communicate service level agreements or SLA's back to its customers, fibre is considered the most reliable and secure backhaul option. Furthermore, KPN sets out nationwide standards, and this means that KPN does not prefer to have mmWave backhaul technology in one city and fibre backhaul in another.

Key insights

- The preferred backhaul technology for small cells is optical fibre.
- The telecom law is fundamental for the 5G small cell roll-out strategy.
- Capacity planning and 5G frequency bands licensing are costly; therefore, mobile network operators are looking for new business models with 5G.
- It is recognised that network operation is not the core business of municipalities.
- The challenge for KPN is to find new locations where capacity can be increased; 70 people currently work at the site management department.
- Photonics is seen as a promising future technology to increase network capacity.
- KPN wants to have full control over the network, and potential software of new backhaul technology should be fully integrated with KPN's larger management system.
- Data networking will become more important, but security is paramount.

Quote

"To realise the smart city of the future, actors can not only see their proposition as a business case, so what's in it for me, it is a value case what's in it for us."

- Assistant Professor Tu Delft, Telecom Business Architecture and Models

"We want to have complete control over our network, and we do not want to use a shared network with cameras or Wi-Fi access points. Next to safety, we also have to guarantee enough bandwidth for each customer."

- Technical Lead Industrial 5G Field Labs, KPN expert

Quote

"KPN currently has sites where fibre roll-out is too expensive or where it is impossible to roll out fibre in the short term. For these sites, we use microwave links. However, it is our goal to link these sites to fibre eventually."

- Technical Lead Industrial 5G Field Labs, KPN expert

"Connecting new sites is preferred with optical fibre because this is the most reliable, and the capacity is optimal. However, there are sites where this is not possible. For these sites, we currently use an 80 GHz backhaul technology."

- Technical Lead Industrial 5G Field Labs, KPN expert

Quote

"The core activity of a mobile network operator is to offer a secure connection over which data can be sent, this is not the primary task of a manufacturer."

- Assistant Professor Tu Delft, Telecom Business Architecture and Models

"From a maintenance and management perspective, a mobile network operator does not want other parties inside their network."

- Fund Manager, Primevest Capital Partners

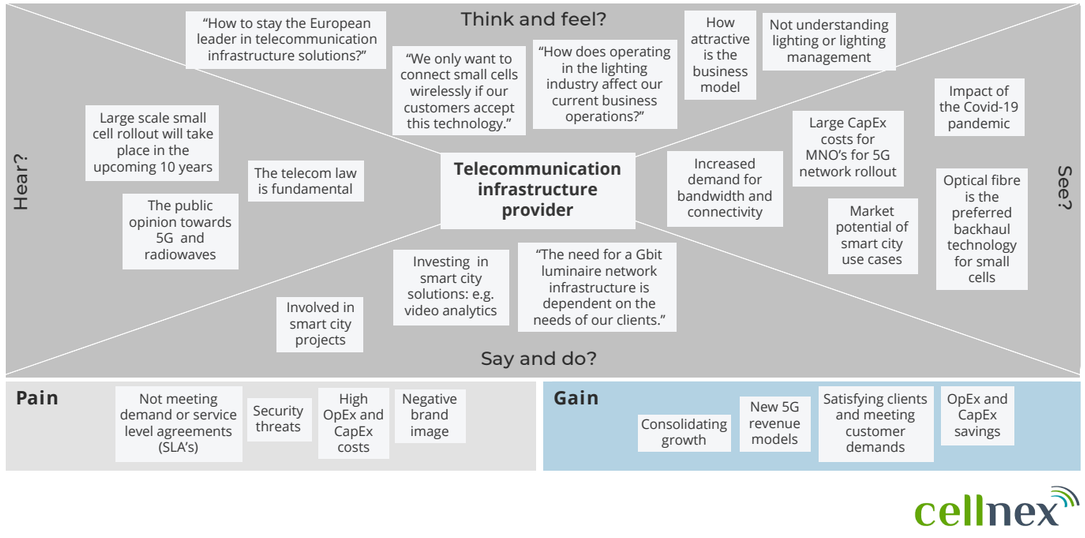
Quote

"By looking at the current technology, all three operators will say, if I can place an antenna in your luminaire, then I want to have an optical fibre connection and not a mmWave backhaul. Why? Firstly, because it is not a proven technology. Secondly, no service levels can be agreed on this technology, which Mobile Network Operators have to communicate towards their customers."

- Fund Manager, Primevest Capital Partners

"Every mobile network operator sets requirements before rolling out a network. KPN will set out a national standard, and make national agreements for this and use the same equipment nationwide."

- Fund Manager, Primevest Capital Partners



cellnex

Telecommunication infrastructure providers

More than fifty percent of all mobile network operators have outsourced their network infrastructure to a telecommunication infrastructure provider. Cellnex is an example of a telecommunication infrastructure provider and is currently the number one leading infrastructure provider for wireless communication in Europe.

In present-day small cell deployment inside Cellnex is just about hosting the small cells, providing power and maintenance. There is no software for Cellnex to monitor these small cells, since small cells have to connect to the core network of the operators. This also becomes the borderline of Cellnex primary function, a tower company and the role of an operator.

Key insights

- Mobile network operators that see the network infrastructure as part of their portfolio are less likely to hand over operation to an external party, such as Cellnex.
- Small cell deployment is a relatively small part of Cellnex business, and if they are deployed they are connected with optical fibre.
- Cellnex has been a tower company, but previously has been a telecom operator, meaning that Cellnex has knowledge in network design and operation.
- For distributed antenna systems Cellnex provides the infrastructure and then operates the network on behalf of the mobile network operator.
- Small cells are not operated by Cellnex, since they just focus on hosting, power supply and maintenance.

Quote

"I think small cells will be wirelessly connected as soon as their deployment takes on a massive rollout. So once the rollout starts, surely there's going to be a need for networks transporting that traffic from the small cells at a street level without putting fibre there. But since the rollout of the small cells in a massive manner is not happening yet. Then the need for having that network is not coming for the meantime."

- Previous Global Head of Country Coordination, Cellnex Telecom

Quote

"We're having to serve at different levels of criticality. It's not the same for an operator to have its network not working at a certain point than it is for a traffic camera."

- Previous Global Head of Country Coordination, Cellnex Telecom

Quote

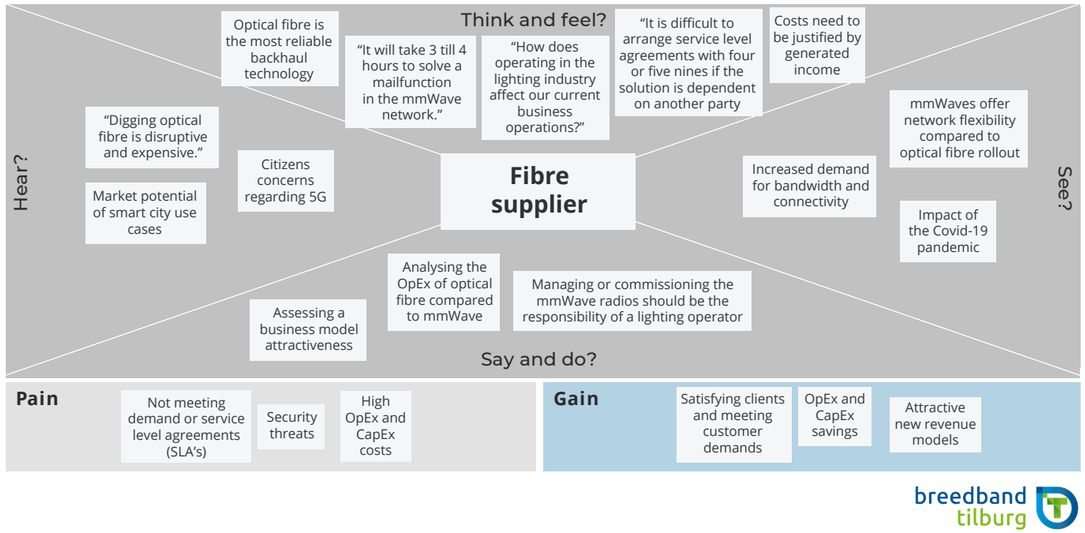
"As of today, I think the main challenge is consolidating all the growth that took place in a very short period of time. So in, I would say, five years. They went from one or two countries to twelve."

- Previous Global Head of Country Coordination, Cellnex Telecom

Quote

"I think we have a very powerful solution. But it's going to take time to educate the market and have people collaborating on different department levels. I would say, it's not going to be an easy task, and you know, public things depend on the country, but at least the ones I know in the south of Europe, they take their time."

- Previous Global Head of Country Coordination, Cellnex Telecom



Fibre suppliers

At present-day, Broadband Tilburg is merely delivering the optical fibre cables and sees themselves as a facilitator that provides the infrastructure for the digitally connected city of the future. For Broadband Tilburg, the product is an entirely new technology; therefore, they still have to figure out to what extent this technology fits their current business and operations. At present, Broadband Tilburg can technically manage a Gbit luminaire network, but this depends on the fit with the company.

According to the director of Broadband Tilburg, SPIE, a lighting operator in the Netherlands, could be a suitable party to manage such a Gbit luminaire network. SPIE is responsible for various industries, such as intelligent lighting, connectivity, and telecommunications, which aligns with BrightSites proposition.

Key insights

- Managing or commissioning the Gbit luminaire should be the responsibility of a lighting operator.
- The challenge of this proposition is that it becomes more than just a cost calculation compared to fibre roll-out.
- For Broadband Tilburg, it would be better if the dashboard would fit their overall management system. However, since they are still small scale, it would also be alright if there would be a separate dashboard interface.

Quote

"The greater the pain or problem, the more people look for a solution and are willing to pay for it."

- Director, Broadband Tilburg

Quote

"A business case is not only about the costs and expenses but also about the generated income."

- Director, Broadband Tilburg

Quote

"I see the most value in the camera applications, compared to widespread Wi-Fi deployment but the profitable business case I do not see yet."

- Director, Broadband Tilburg

Quote

"Broadband Tilburg would like to take responsibility for the signal, but not for the data transmission."

- Director, Broadband Tilburg

Stakeholders in an ecosystem can possess different roles. See Figure 4.9. The decision-maker is the stakeholder who makes the final decision and does not necessarily have to be the buyer of a proposition. In the Gbit luminaire ecosystem in Europe, municipalities are the decision-makers since the city most often owns the light poles.

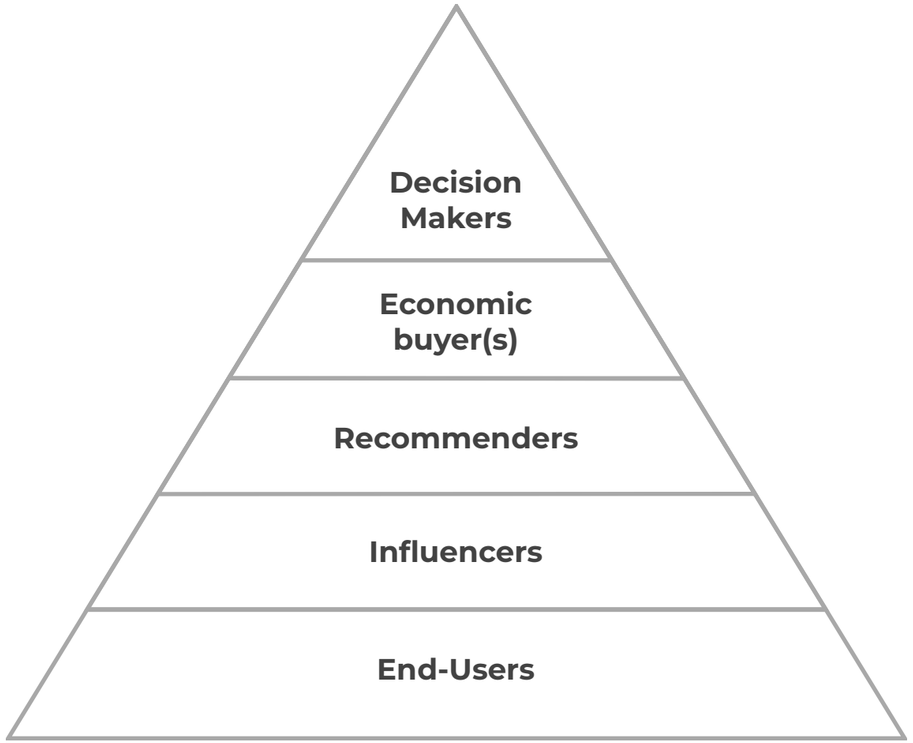


Figure 4.9 - The different roles in an ecosystem

4.3.2 Customer profiles

A *customer profile* is a tool used to represent and summarize the various facets of a customer's experience with a particular product or service. It works by gathering various parameters such as personality, interests, and tech savviness. Compared to empathy mapping, which aims to represent how a stakeholder feels and behaves, a customer profile aims to explain who a stakeholder is. See appendix V for the customer profiles.

4.3.3 Stakeholder power-interest matrix

The stakeholder power-interest matrix is a tool to map the key stakeholders of an ecosystem into a model to identify the relationship between stakeholders depending on their level of interest and power. See figure 4.10. The X-axis defines the level of interest of a stakeholder, and the Y-axis the level of power a particular stakeholder has to influence the success of a proposition. Dependent on where a stakeholder is projected on the map, the following engagement strategy is applied:

- Manage closely: Stakeholders that fall into this part of the matrix yield high power and high interest in wireless connectivity on the lighting grid and are likely to be the key decision-makers or economic buyers of a proposition.
- Keep satisfied: Stakeholders that fall into this part of the matrix yield high power but a low interest in the proposition. Because of their high power, they can negatively influence project success.
- Keep informed: Stakeholders that fall into this part of the matrix yield high interest but low power. In the Gbit luminaire ecosystem, roll-out success depends on the devices of these 3rd party equipment suppliers.
- Monitor: Stakeholders that fall into this part of the matrix yield low power and low interest in wireless connectivity on the lighting grid. These stakeholders have to be monitored with minimum effort.

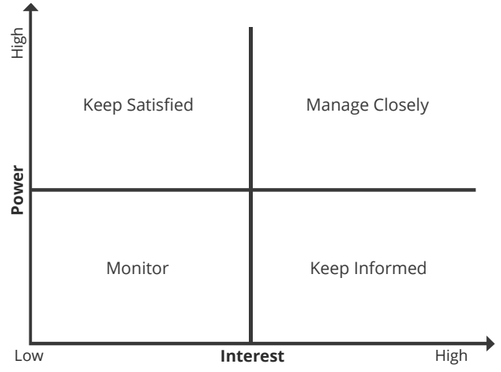


Figure 4.10 - Stakeholder power-interest matrix

A various number of stakeholders are part of the Gbit luminaire ecosystem. These stakeholders are either interested or affected by the proposition. See figure 4.11 for the map that shows the relations between stakeholders in the ecosystem and their role. The central government, and thus directly municipalities, are the key decision-makers of the Gbit luminaire proposition since they own the light poles and set up guidelines, regulations and requirements for wireless connectivity on the lighting grid. Earning their trust, approval, and support is paramount for project success even when they are not the buying customer. It is about fully understanding and recognising the challenges and pain points municipalities face and positioning the Gbit luminaire from their world since avoiding or not involving the government is highly unlikely.

For the short term, there are two potential economic buyers in the Gbit luminaire ecosystem: municipalities and telecommunication infrastructure providers. Foremost, there has to be kept in mind that municipalities will only be a buying customer of the Gbit luminaire if the proposition is positioned as value-driven and only after that financial driven. From a municipality point of view, the Gbit luminaire only becomes of interest when the application technology attached to the Gbit luminaire helps the city to meet social, environmental or financial goals. In other words, the Gbit luminaire is seen as a means to an end. The challenge, however, is that municipalities face budget constraints and that the application technologies on the Gbit luminaire require a significant return on investment for them to make the potential investment on the Gbit lighting network infrastructure. Therefore, a second potential economic buyer could come into play: telecommunication infrastructure providers, such as Cellnex, BAI communications, Deutsche Funkturm, INWIT, Tilson and Ontix. These companies see potential in turning the lighting infrastructure into a strategic asset to run smart city applications. However, even these companies have to obey the government and its wishes.

Mobile network operators are perceived as a recommender in the Gbit luminaire ecosystem, and their opinion carries weight on the decision of economic buyers. However, the question remains open whether mobile network operators in the future will allow telco equipment, such as small cells, to connect wirelessly and if they are obligated to take the access that is offered to them on the lighting grid. They also can become a threat to the Gbit luminaire if they start developing their own IoT devices and sensors with affordable 5G sim cards. At the moment, these sim cards are still quite pricey; however, mobile network operators, such as KPN, also want to play a role in IoT and smart cities. Since the main strategic challenges for tier 1 mobile network operators changed after 2000, the competitive advantage before was mainly seen in network infrastructure. Nowadays, in the IoT and AI age, it is seen in reach, technology, data, skills, knowledge and ideas.

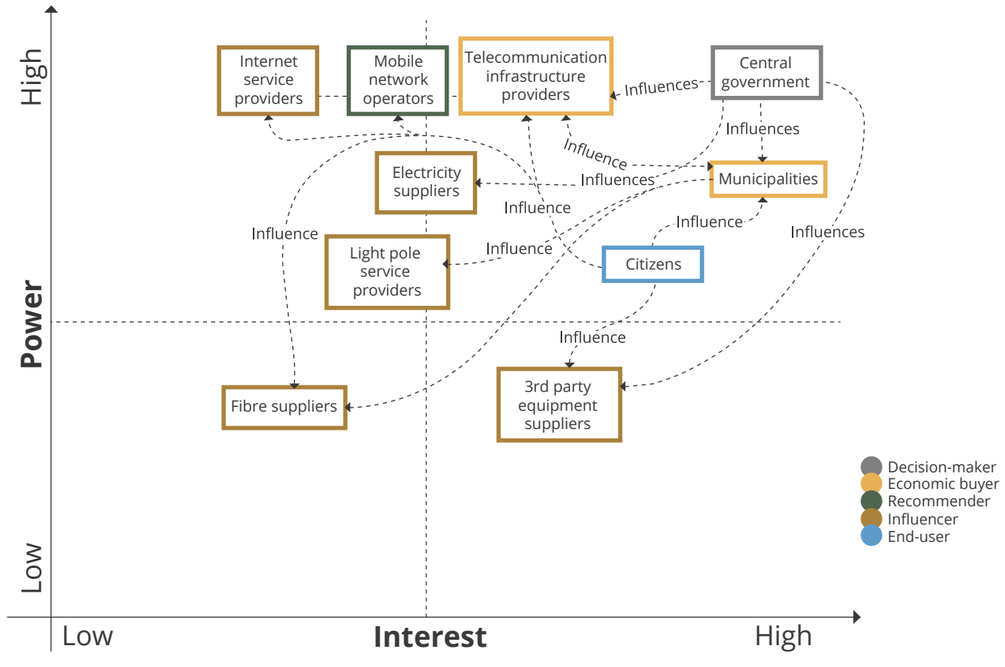


Figure 4.11 - Power-interest matrix of the Gbit luminaire ecosystem

4.4 // Customer journey experience map

The goal of the customer journey experience map is to represent the journey of the key decision-maker before committing to an investment of a Gbit luminaire network infrastructure or agreeing with a neutral host solution. In the second case, a neutral host solution, a third party will invest and operate the network on behalf of the city. The customer journey experience map is developed from a European municipal decision-maker perspective since the beliefs regarding transparency and security align. Furthermore, in Europe, most lighting infrastructure is owned by the municipality.

Customer journey experience mapping is crucial since it is proven that companies who put customers at the heart of the proposition and understand the steps a customer is going through are more likely to succeed. Therefore, globally, the most prominent firms, such as Google and Amazon, currently have customer experience managers to understand customers' steps from the first interaction with the brand to purchase (Lemon & Verhoef, 2016).

Based on the stakeholder analysis, the proposition becomes of interest if cities already have a vision or belief regarding the contribution of technology in delivering a better quality of life. Thus, the ideal target customers are cities that already have a Chief Technology Officer and are actively experimenting with smart city solutions. What does not change is that municipalities have to fulfil a societal role, whether that is in Spain, Germany or the Netherlands. The only difference is that cities with a strong smart city vision are the changemakers that are needed to bring BrightSites' vision to life.

The customer journey experience map shows that cities go through two awareness cycles before considering a Gbit luminaire network infrastructure. In the first awareness cycle, cities recognise that there are problems in the city, and technology could be a means to tackle these problems. This is a lengthy and illustrative process. To illustrate, municipalities in the Netherlands have been active since 2015 to run smart city applications, but scaling goes extremely slow. The characteristics of these cities are that they are open to new technologies, as long as it aligns with the IoT principles, standards and goals of their city. For example, the municipality of Amsterdam has a coalition agreement that states that Wi-Fi tracking is forbidden and privacy by design is the standard.

Figure 4.12 - Coalition agreement document municipality of Amsterdam

Cities that fall into awareness cycle 1.0 can be characterised as cities that do not look at limitations but opportunities. These cities understand that strong collaboration is needed with private companies, knowledge institutions, and citizens to solve present day's complicated challenges.

BrightSites' product, the Gbit luminaire, becomes of interest if critical decision-makers in the municipality have reached awareness cycle 2.0. In this phase, cities realise that technologies bring benefits to reach city goals and have negative consequences that eventually have to be tackled. These cities consist of strategic thinkers who are curious and explorative, who feel obligated to create better cities, neighbourhoods, and streets while aligning with the regulatory and financial objectives. The strategic thinkers of these cities feel that there is much more possible in creating the digitally connected city of the future; they are curious but also concerned about dealing with clutter in the urban environment.

The challenge is that the Gbit luminaire is currently seen as a niche product rather than a must-have product. However, cities that have an open-minded and explorative vision want to explore what else is possible. In the consideration phase, cities have to perform various actions, but what has to be kept in mind is that the Gbit luminaire is seen as a means to an end. What is essential for cities is that the backhaul technology works flawlessly, it is not harmful to citizens' health and that the public widely accepts it. Costs are important, but as long as choices can be justified, costs only become part of the conversation relatively late in the journey.

In awareness cycle 2.0, BrightSites should step in. There are a few factors that can be used to analyse whether a city belongs to awareness cycle 1.0 or awareness cycle 2.0:

- Previous investment in LED lighting, cities that recently <10 years changed their lighting infrastructure are less likely to make another significant investment in the lighting infrastructure.
- Previous experiences with intelligent lighting projects or smart city initiatives. Did these projects fail, succeed and scaled out eventually?
- Understand the prior experience of the city with Signify, previously Philips lighting. Was this a positive or negative encounter? What can be learned from the previous projects?
- Figure out if the city has a Chief Technology Officer and why?
- Read the coalition agreements of cities, in particular the section regarding digitalisation or smart cities.

There are eight fundamental factors to make the proposition successfully roll out based on the customer experience journey:

1. First and foremost, the public opinion regarding the Gbit luminaire.
2. The aesthetic fit, especially in historical city centres.
3. The alignment with city goals and its pain points.
4. Application technologies that deliver concrete social, financial and or environmental value.
5. The trust in the neutral host party and its' intentions to monetize services on the lighting grid.
6. Cities ability to manage the Gbit luminaire network or trust in a market player for operation.
7. Attractiveness and clarity of the business model.
8. Fit with the existing power supply infrastructure.

Customer Journey Experience Map: A Wireless Connectivity System via the Lighting Grid

From a European municipal decision-maker perspective

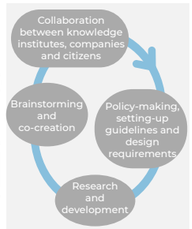
Guiding principles

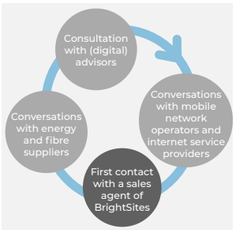
The key decision-maker is value-driven	Testing new technological solutions is a long and iterative proce	Municipalities go through two awareness cycles: (1) the first awareness cycle is the city its standpoint towards smart cities, (2) the second awareness cycle consists of the curiosity level, strategic thinking ability and concerning thoughts regarding smart cities	The Gbit luminaire starts to become of interest if cities have reached awareness cycle 2.0	The Gbit luminaire is a means to an end

Phase of the journey

Awareness 1.0	Creating solutions for urban challenges	Testing solutions	Awareness 2.0	Consider	Purchasing or agreeing with a neutral host solution	Operating
To what extent is a city aware of how technology can deliver a better quality of life?	To what extent is a city active in creating solutions for urban challenges that require connectivity?	To what extent is a city involved and open for testing solutions jointly with knowledge institutions, private partners and citizens?	To what extent does a city realize how much data backhaul the digitally connected city of the future needs to run all these smart city applications? To what extent does a city realize how the next generation of connectivity (5G) will positively but also negatively impact the city?	To what extent does a city understand the concept of "backhaul" and the different backhaul technology options? To what extent does a city see light poles as a strategic asset? To what extent does a city want to make us of Interact City's energy-efficient LED lighting?	**Purchasing or agreeing with a neutral host solution** **Purchasing:** To what extent can the investment of the Gbit luminaire be justified into financial and/or significant social value? To what extent is the mmWave technology accepted by the public? **Agreeing with a neutral host:** To what extent does a city have trust in the neutral host party? To what extent does a city agree, support and have trust in the applications attached to the Gbit luminaire? How attractive is the business model for a neutral host solution?	**Operating** To what extent does a city want to be responsible for managing a mmWave data network? **Depends on:** To what extent does a city feel capable of managing a mmWave data network? To what extent does a city see value in managing a mmWave data network? To what extent does the law allow a city to manage a mmWave data network?

Actions
What does the customer do?



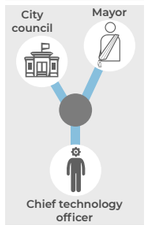


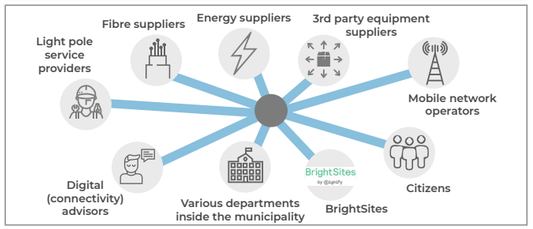
- Consultation with (digital) advisors
- Research the different backhaul technologies, and research the pro's and con's
- Look at previous investment made in the city regarding lighting infrastructure: did the city already made an investment (<10 years) in LED lighting?
- Look at the power supply: does it have 24/7 power supply on the lighting grid?
- Look at the aesthetic fit of the solution with existing city landscape
- Analyse the privacy and security aspects
- Analyse the (technical) limitations of the proposition
- Analyse how a proposition positively impacts the city and aligns with city goals
- Analyse the urgency of a solution
- Analyse the policy aspects
- Analyse the public standpoints regarding radio waves and in particular mmWave technology
- Analyse other cities who (successfully) rolled out a mmWave network and derive learnings from these projects

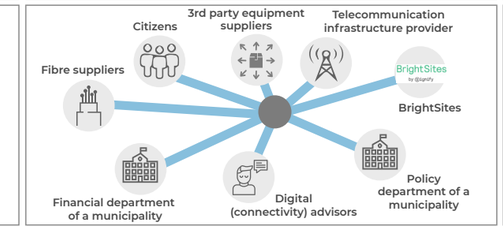
- Consultation with (digital) advisors
- Consultation with policy and financial department
- Conversations with light pole service providers
- Conversations with energy and fibre suppliers
- Perform a business case analysis
- Perform a cost/impact analysis
- Calculate a return on investment
- Negotiation with neutral host players
- Analyse intentions and objectives of neutral host players
- Analyse how the intentions and objectives fit with the objectives of the city

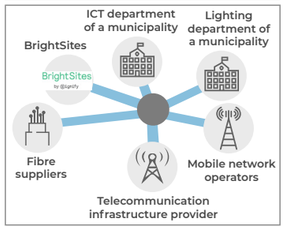
- Analyse the legal aspects of managing a network
- Analyse the impacts on the business processes if doing so
- Analyse the fit of existing or future workforce with the tasks of network operation
- Analyse the capability and complexity of managing a mmWave network
- If interested, ask for permission to the European Union council in Brussel

Process ownership
Who is in the lead on this?









Customer Thought
What is the customer thinking?

1. *"How to solve the big urban challenges in the fields of energy, circularity, digitization, climate resilience, mobility and food?"*
2. *"Let's create better streets, neighborhoods and cities."*

1. *"How to utilize technology in the a responsible and effective way to solve urban challenges?"*
2. *"What is the effect of this solution on the city?"*
3. *"What are the constraints of this solution?"*

1. *"How to deal with clutter in the urban environment?"*
2. *"How to satisfy the needs of each stakeholder involved?"*
3. *"What is the public opinion of this smart solution?"*

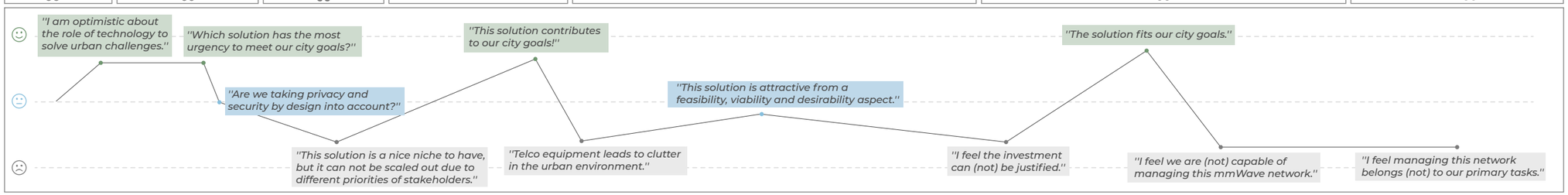
1. *"How to scale these solutions?"*
2. *"How to aesthetically cover small cells and other telco equipment?"*
3. *"How to create the least resistance above and under the ground?"*

1. *"How does a Gbit luminaire network infrastructure help us to meet social, financial and/or environmental goals?"*

1. *"What is the public opinion about the Gbit luminaire?"*
2. *"How well does the Gbit luminaire fit with the existing city landscape?"*

1. *"Is it legal to operate a mmWave network?"*
2. *"Are we disrupting the market, by doing so?"*

Customer Feeling
What is the customer feeling?



BrightSites by signify

Environmental factors

Own specific factors

Opportunities

- Cities see technology as a means to solve urban challenges
- Mobile network operators are looking for new ways to create value with 5G
- Fixed wireless access is a promising technology
- Light poles are seen as a valuable asset
- 5G small cell densification and capacity planning is extremely expensive for mobile network operators

Threats

- 5G chips for cameras that are becoming cheaper in the future
- Clashing values between stakeholders
- Service providers and telecom operators that have fibre roll-out as part of their core strategy
- Security and privacy concerns regarding software, IoT devices and sensors
- mmWave radio vendors that start to aesthetically re-design mmWave radios based on cities and campuses aesthetic needs
- Governmental laws that state that public assets need to be made available for telecom equipment
- Negative public opinion towards radiowaves and public Wi-Fi
- Regulatory laws that forbid municipal networks
- Financial barriers of municipalities
- A negative opinion of telecom operators towards mmWave technology and connecting sites wirelessly
- Market players that do not want to make use of a shared network
- Market players that do not want to be bothered with lighting

Strengths

- Part of signify, the world leader in lighting
- Cities are heavily investing in LED lighting, and the Gbit luminaire makes use of energy-efficient LED lighting
- Aesthetic integration of the mmWave radio into the luminaire
- Access to the lighting infrastructure
- The technology sparks interest and there is a reason to belief in the technical capabilities
- Great connectivity is now more important than ever
- Diverse team with various industry backgrounds: lighting, software development, business and telecom
- The lighting infrastructure is considered as a suitable location for small cells and smart city IoT densification by cities and MNO's
- Partnership with CityBeacon
- Innovation capability

Weaknesses

- Brand recognition in lighting and not in data networking or operation
- The solution is perceived as a niche product and not a must-have product
- The venture is operating in an highly sensitive environment full with regulations
- Higher costs of the mmWave radio integrated into the luminaire needs to be justified
- Solution is dependent on 24/7 power supply of the lighting grid, this requires a large sum of infrastructure investment
- No urgency by stakeholders to buy the product
- Most customers of BrightSites are financially driven, while lighting is a primary task of municipalities who are value driven
- Energy bill of the different application technologies
- Costs of fibre rollout is dependent on the conditions of the soil per country, cost estimations thus need to be made per location and can not be generalised
- The technology is offered free of charge by Facebook, meaning that other vendors can offer the same capabilities
- Market players do not care about aesthetics: they care about the services they can provide, the customers they can serve and the money they can generate
- Public Wi-Fi is an outdated vision in developed countries

Strategies to make use of Opportunities through our Strengths

- Use the lighting infrastructure for new 5G use cases to get mobile network operators on board and shape new business models
- Collaborate closely with Interact City to approach existing clients that soon have to change their LED infrastructure
- Tapping into specific city goals and city strategy
- Focus on customers that care about urban clutter and want to maximize concealment

Strategies to prevent Threats through our Strengths

- Analyze critically what the laws and regulations are per city regarding telecom equipment, IoT, sensors, security and privacy, network operation
- Co-creation with stakeholders about aesthetics and application technologies
- Transparent communication
- Clear division of responsibilities and roles of each stakeholder
- Build strong strategic partnerships with application technologies vendors
- Wide-scale field tests

Strategies to make use of Opportunities to minimize Weaknesses

- Spark imaginations on how Gbit luminaires are a valuable asset to meet social, climate and economic goals
- Create urgency on building a network infrastructure
- Reinforcing lighting, connectivity and the application technology
- Innovating across silos in the application technologies

Strategies to minimize the potential dangers lying in sectors where Weaknesses meet Threats

- Create a shared vision between all stakeholders involved
- Privacy and security by design
- Collaborate closely with power supply companies
- Facilitating a collaborative environment

4.5 // SWOT analysis

The SWOT analysis above shows a business analysis of all the insights from stakeholder meetings, internal experts and external experts. The boxes coloured in yellow are the main strengths, weaknesses, opportunities and threats in the Gbit luminaire ecosystem. First and foremost, the need for LED lighting and connectivity is only growing, which means that the current product proposition is tapping into current and evolving societal needs. However, the question remains whether market players care about aesthetics as much as cities do and if they have the same values regarding network rollout. The strategy lies in creating a sense of urgency in creating a network on the lighting grid and facilitating a collaborative environment between stakeholders.

Own specific factors

Strengths

BrightSites is part of Signify, the world leader in lighting solutions, which gives BrightSites a significant advantage due to brand recognition compared to market players that are less well-known and want to enter the market. In addition, the Gbit luminaire consists of energy-efficient LED lighting, which is considered as one of the most actionable and ready-to-implement technologies for smart cities.

In the Netherlands, 15 percent of all the light poles consist of LED luminaires, and cities worldwide are transitioning towards LED lighting. The aesthetic integration of the mmWave radio into the luminaire in conjunction opens up opportunities to exploit new functionalities on the lighting infrastructure. This is attractive for innovative cities as they consider the existing lighting infrastructure as a suitable location for smart city IoT densification. In addition, based on the expert interviews, light poles are considered as the best location for 5G small cell rollout. T-Mobile, for example, tried experiments with rolling out 5G small cells on bus shelters, but this is not considered as suitable as light poles. The technology, in addition, sparks interest and the reason to believe in the technical capabilities of mmWaves is present among the various cities that participated in this study. Furthermore, the venture has a partnership with CityBeacon, which can act as the fibre PoP in a Gbit luminaire network infrastructure. CityBeacons are considered as a multifunctional solution for cities, based on the insights of this project.

Nevertheless, above all these reasons is the timing of product introduction and the innovation capability inside the venture. First, the Gbit luminaire is developed in a period where connectivity became part of people's daily functioning. Undoubtedly, wireless connectivity will become even more important with the prospect of emerging IoT technologies and massive small cell rollout on the lighting grid. Second, the innovation capability inside the venture. As BrightSites is part of Signify, they have the financial means and knowledge inside the team to make outstanding products.

Weaknesses

Several weaknesses are identified, although they are not perceived as weaknesses in this project but as challenges to overcome instead. The main challenge is that smart poles or Gbit luminaires are considered niche products. Therefore, a sense of urgency must be created for the key decision-maker to either invest or give access to the lighting infrastructure. After this, the challenge of aligning stakeholders' values and vision of the Gbit luminaire has to be overcome. Market players are financially driven, which might clash with the vision cities have.

Moreover, the venture is operating in a highly sensitive environment full of regulations and dependencies. The application technologies, for example, are the main reason for cities to invest or give access to the lighting infrastructure, which at the same time opens up new entry opportunities for market players to exploit smart city services. However, above all means, these applications need to align with the regulations and vision of cities. Next to this, the solutions require a 24/7 power supply on the lighting grid. Based on the stakeholder interviews, it can be stated that there is no infrastructure readiness in the Netherlands to deploy a wireless connectivity system on the lighting infrastructure as of today. For instance, changing the current energy infrastructure in Eindhoven, a city in the Netherlands, requires a large sum of investment. For this reason, BrightSites should also consider infrastructure readiness costs since this is critical for the Gbit luminaire network infrastructure functioning. In conjunction, many needs of the key decision-maker in the European market are not expressed financially; thus, aligning with their values and the public opinion is crucial. In addition, the technology is offered free of charge by Facebook, meaning that other wireless communication providers can provide the same capabilities at a lower cost than the Gbit luminaire. Therefore, the higher price of the Gbit luminaire or smart pole needs to be justified in significant brand or financial value.

Environmental factors

Opportunities

The challenges in the world are becoming more complex, and cities are looking for ways to tackle the complicated challenges that are part of the present day. The main advantage is that innovative cities consider technology as a means to solve urban challenges. For this reason, municipalities nowadays hire digital advisors to scout new technologies and facilitate smart city IoT pilot projects. The opportunity for BrightSites lies in understanding the challenges that are part of the city and aligning the product proposition to the city's needs. This can be achieved by actively reading the coalition agreements of cities, which sometimes even shows the available budget for a particular smart city theme.

Furthermore, there is an agreement in the literature and among stakeholders that light poles are an excellent location for introducing new IoT services and small cell deployment. Likewise, mobile network operators are struggling to find new antenna locations, and capacity increment takes up a large share of yearly revenues. On the downside, both cities and mobile network operators do not feel a sense of urgency to invest or give access to the lighting infrastructure. For this reason, the product proposition could use visualisations on the effect the product can solve. Another opportunity is to innovate across silos. This means that BrightSites can scout application technologies that reduce costs or create revenue in another domain. For example, fewer accidents happen because of innovative camera technology on the lighting grid, leading to lower medical care costs.

Threats

Several threats are identified for successful implementation of the Gbit luminaire, based on the insights from stakeholder meetings, internal meetings and external experts. At present-day, wireless infrastructure providers that develop mmWave radios are needed to make the product more well-known among cities and industries. However, in the future wireless infrastructure providers can form a significant threat to the current product proposition by aesthetically re-designing mmWave radios based on campuses and aesthetics needs. These wireless infrastructure providers can, for example, change the colour or apply branding techniques to make the mmWave fit more to the needs of potential customers. Nowadays, these mmWave radios are rather unattractive. However, there is a potential for them to aesthetically improve their product proposition, especially for customers that solely see potential in mmWave radios as a "wireless optical fibre" extender or means for fixed wireless access to residential areas and businesses. In addition, the sizing of these mmWave radios could also be made smaller due to technological advancements. At present, these devices are approximately 240 by 190 mm, yet there has to be taken into account that these devices can eventually become more negligible. Second, is that the clashing values of municipalities and private companies have to be overcome. Municipalities have as their primary task to represent the citizens' voice and ensure safe and reliable public lighting. If citizens negatively think about the technology, the municipality must at least listen to these concerns and communicate a clear communication strategy to remove worries. Another threat are market players that do not want to be bothered with lighting because they do not want to operate in a business outside of their core expertise.

4.6 // Value flow framework

The value flow framework is the result of the stakeholder analysis. The outer layer consists of the stakeholders that are part of the Gbit luminaire ecosystem. The second layer consists of example stakeholders, followed by their core needs and value creation. In this project context, *value creation* is defined as how a specific stakeholder can deliver value and strengthen the Gbit luminaire ecosystem.

Finally, the circle in the middle represents the Gbit luminaire, which has an arrow moving away from it. The arrow moving away from the inner circle, represents value capture. In this project context, *value capture* is defined as the way a particular stakeholder wants to be rewarded for becoming part of the Gbit luminaire ecosystem.

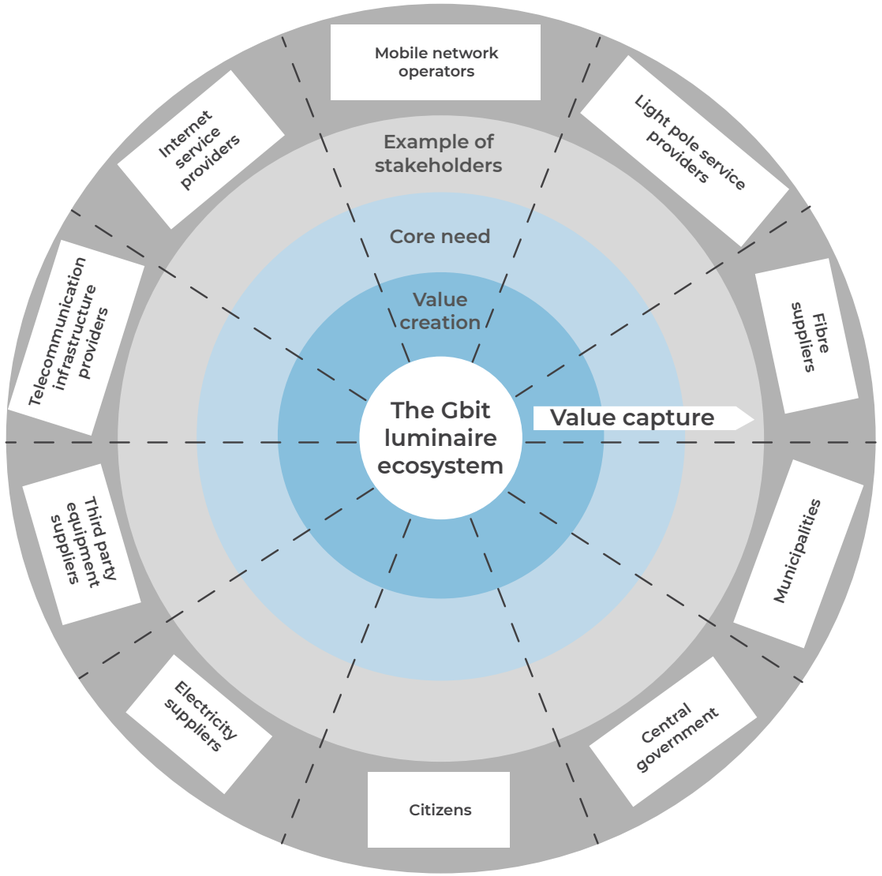


Figure 4.13 - Value flow framework

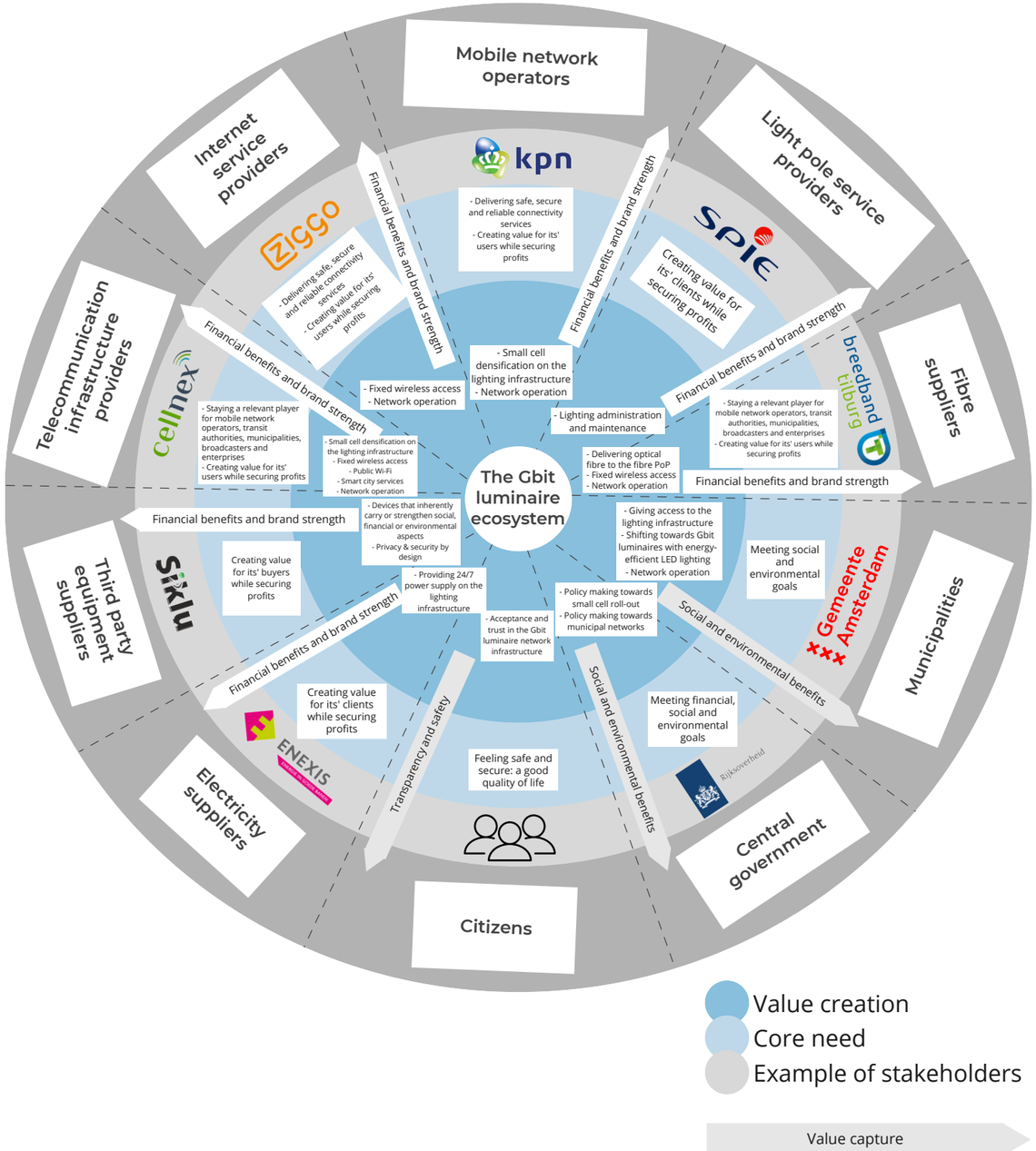


Figure 4.14 - Value flow framework of the Gbit luminaire ecosystem

4.7 // Conclusion stakeholder analysis

In conclusion, based on the stakeholder analysis, it would appear that there are chances, but also points of attention for successful implementation of the Gbit luminaire in the smart city ecosystem. This research demonstrates that municipalities are the key decision-makers for successful implementation in the European market, since they are the owners of the light poles and influenced by the regulations of the central government. The challenge, however, is that the current proposition is positioning itself as a less disturbing and cost-saving backhaul technology. The first point is partly proven since key stakeholders that are part of the Gbit luminaire ecosystem recognise the hurdles, inflexibility and disturbance that fibre roll-out brings along. On the other hand, municipalities in the Netherlands at least, do not see network roll-out and operation as their primary tasks. In fact, they are obligated to fulfil a societal role and they are more interested in the concrete applications that positively impact the city than the underlying backhaul technology.

The current applications that can be attached to the Gbit luminaire are Wi-Fi access points and surveillance cameras. However, these applications require a few points of attention. Foremost, in the Netherlands, widespread Wi-Fi deployment is seen as an outdated vision since many people nowadays have a mobile phone subscription with 4G. Second, municipalities place surveillance cameras on where it is needed from a safety perspective, not where it is technically feasible for BrightSites. For instance, if a surveillance camera needs to be placed on a specific location where no line of sight can be achieved, a municipality will still keep on drilling fibre, regardless of the costs. In addition, municipalities in the Netherlands make plans with the police and other parties to discuss where cameras should be placed, making Signify a follower rather than an initiator of surveillance camera deployment.

The opportunity, however, for BrightSites lies in innovating across silos. An interesting question is how the captured value in one silo could be captured in a different silo. For instance, an example of innovating across silos is that a specific application technology of the Gbit luminaire, such as a camera reduces costs or generates revenue in another domain. This is important to address because a business case should always be viewed from two angles: how much a solution costs or saves is one side; however, the other side, which is how much a solution generates, is regarded as essential. Stakeholders, namely, wonder whether it can be proven how revenue can be generated with the Gbit network infrastructure. Therefore, it becomes even more critical to make value capture tangible and transparent for all stakeholders involved; otherwise, the proposition will just be seen as a shift of internal costs.

For municipalities, it is an immense value that 5G small cells can be aesthetically covered into the light pole and wirelessly connected, leading to the slightest disturbance above and under the ground. However, from the conversations with relevant stakeholders, widespread 5G small cell roll-out will not occur in the Netherlands until 2027. In addition, the question is whether mobile network operators can make their own choices in small cell network deployment or if laws restrict them from doing so. Moreover, a value clash between the motives of cities and the motives of private companies is observed. Cities will never operate a network for private companies, and the question is whether mobile network operators want to have a shared network with other IoT equipment. Likewise, cities and market players do not have the budget to turn every light pole into a smart pole that can aesthetically cover small cells. Thus, the success of wireless small cell backhaul is dependent on the laws per city and the total cost of ownership.

However, the prediction is that if the telecom law forces mobile network operators to connect small cells wirelessly, from a financial perspective, it would be more attractive to buy the separate mmWave radio for a lower price. Furthermore, it can be concluded that market players do not care at all about aesthetics: they care about the services they can provide, the customers, and the money they can generate. This makes the role of telecommunication infrastructure providers and mobile network operators for small cell roll-out in the short-term limited and uncertain in the Netherlands.

The contradiction, however, is that municipalities do not see themselves investing in network roll-out or responsible for network operation as they see this as the responsibility of a market player. Stakeholders, such as telecommunication infrastructure providers, mobile network operators and fibre suppliers, would technically be able to manage a Gbit luminaire network. However, in the same manner, these parties require clarity in how operating a Gbit luminaire network generates revenue for them by doing so.

By looking at the developed value flow framework, this becomes a critical point of attention for BrightSites. Since the parties that can technically manage a Gbit luminaire data network have a contradicting vision on value capture, which answers the following question: how does a stakeholder wants to be rewarded for becoming part of the Gbit luminaire ecosystem?

The contradiction lies in the difference between value-driven and financial-driven motives. Market players are first, financial-driven and only after that value-driven, while for municipalities, the other way round. Municipalities are looking for solutions that improve the liveability of cities and create significant social, environmental or financial value. The technology and capabilities of the Gbit luminaire spark the interest of municipalities. However, in present-day municipalities perceive themselves as a facilitator of a Gbit luminaire network infrastructure. The problem that occurs when there are no clearly defined roles and a lack of clear business models, smart city initiatives are prone to failure, which is also widely discussed in the literature. Based on the interactions with key stakeholders, it also becomes troublesome to go beyond a pilot project if more than one stakeholder views themselves as a facilitator because in the end there still needs to be a paying customer.

The opportunity, however, lies in the fact that telecommunication infrastructure providers are looking for new ways to execute power in the digitally connected city of the future and are internally seen as the key players to open up the market. This aligns with the view of various experts in the industry that contributed to this research. According to SPIE's smart city business manager, the largest lighting administrator in the Netherlands, companies have to do mass roll-out to be successful in this business. However, mass roll-out is considered as extremely difficult since the decision-making of the Gbit luminaire also highly depends on previous investments that are made by cities. To illustrate, cities that have shifted to LED lighting the past 10 to 20 years are highly unlikely to be interested in replacing existing LED luminaires with Gbit luminaires since light pole replacement is seen as a long term investment.

In the Netherlands, there are currently around 3.500.000 luminaires, and approximately 15% of these luminaires are LED. By incorporating a network device into a luminaire, BrightSites brings two worlds together; lighting and data networking. It is an enormous asset for the product positioning that the Gbit luminaire consists of energy-efficient LED lighting. By shifting to LED lighting, cities immediately see the effect of energy reduction. In the same way, it helps cities meet climate goals, which is nowadays standing high on the priority list of cities. Furthermore, it is proven that the investment in LED lighting can be earned back in a few years time due to a significant reduction of energy consumption.

Nevertheless, there has to be kept in mind that the central government and, thus, directly municipalities stay the key decision-makers even though they do not have to be the buying customer. For the following reason: municipalities in European cities most often own the lighting infrastructure and make the regulations regarding telco equipment roll-out, sustainability, and data privacy. So even when market players see potential in the Gbit luminaire proposition, they will still need the support, trust, and approval of municipalities to run smart city applications on the lighting grid. Based on their financial-driven motives, this may lead to a mismatch between municipalities and market players. A city in the Netherlands, for example, recently got a fine of as much as 600.000 euro because of Wi-Fi tracking practices. Another point to mention, is that by solely positioning the proposition as a digital pathway, BrightSites might run themselves into a problem. Since, it would be extremely harmful for a new venture if they would be negatively put into the market based on the application technologies attached to the Gbit luminaire. The finding is that the application technologies are the first purchase to trigger, but are also the devices that can break the whole brand image. By looking again at the value flow framework it shows that market players in the short-term are needed to operate and invest into the system, but that this can only be achieved by obeying the needs of the key decision-maker.

Cities that, for example, have a strong vision on how the aesthetics of a luminaire should look like will not agree if a Gbit luminaire does not have the same aesthetic fit, regardless if the luminaire is offered for free. By entering this industry, the law and policies of cities are always the most influential factor for project success. If market players want to run smart city applications, but the policy or vision of a municipality does not align with this vision, the project will be terminated regardless of how much money is put onto the table. This applies especially in Europe, where transparency and security are two fundamental beliefs in the digitally connected city of the future.

It can be concluded that there has to be kept in mind that stakeholders will invest or buy a proposition as long as it solves a concrete pain. The bigger the pain is, the higher the willingness to invest in a proposition. The biggest challenge for municipalities is that they are looking for new technologies to make cities more liveable. However, the question is whether municipalities can truly foresee the dynamics and chaos created if every IoT device and telecom equipment is connected with optical fibre. It appears that with the current proposition, Wi-Fi deployment and surveillance cameras are indeed applications that can connect wirelessly. However, these applications are not targeting enough upon a specific pain point in order to invest public money into network infrastructure and operation. On the other hand, municipalities are curious and feel that there is something more to this proposition. The opportunity for BrightSites lies in tapping into the specific use cases that are high on the agenda of cities and aligning their products to these evolving user needs.

KEY FINDINGS:

- Connectivity (Gbit luminaire) is a means to an end.
- The level of interest in the Gbit luminaire is dependent on the level of awareness/knowledge regarding smart city solutions.
- The level of interest in the Gbit luminaire increases when an application technology attached to the Gbit luminaire creates value in another domain. In other words, innovation across silos.
- Municipalities in the Netherlands have been active since 2015 to run smart city applications, but scaling, however, goes extremely slow.
- If lighting companies want to be successful in this business, they have to do mass roll-out; however, mass roll-out is difficult in this industry.
- Cities can not foresee how much data backhaul the digitally connected city of the future needs.
- The opportunity lies in sparking the imaginations of (non) smart cities on how existing assets can be turned into strategic assets.
- The second opportunity lies in understanding how much data backhaul all smart city applications require and the negative effect on the city if these are connected with optical fibre.
- BrightSites might run into problems if they solely view their product as a digital pathway.
- If they run themselves into a problem due to an application technology attached to the Gbit luminaire, this will be highly harmful to BrightSites brand image.
- For each municipality, the core values and goals have to be identified and see how the (digital) product can play a role in these values.
- The Gbit luminaire and smart poles are seen as niche products; the challenge, however, is to turn the product into a mainstream product. How can the product's image be shifted from a niche product that is a cool luxury to a must-have product?
- For municipalities it is an immense value to connect small cells wirelessly and aesthetically integrate them into smart poles, however municipalities will never operate a network for private companies and also do not have the budget to turn every light pole into a smart pole.

Chapter 5

IDEATION

5.0 // Ideation

In this chapter, the process of forming ideas for the (digital) product will be presented. Based on the research of the previous chapter, there are a few key lessons to keep in mind. First, operating in the smart city domain is always about collaboration. Second, pilot projects regarding smart city initiatives are indeed emerging, yet large scale deployments are not in place. One of the key arguments is that it is not always clear what will change for each party involved and how the current way of operation is affected. Third, private companies or cities invest primarily in projects that will create economic, environmental or societal value the fastest. Fourth, buyers, influencers, decision-makers should be fully recognised while at the same time not be intertwined.

Based on the value framework, two influential stakeholders are identified: municipalities and telecommunication infrastructure providers. From the insights derived from the previous chapter, ideation questions are drafted. Additionally, technology scouting, idea mapping and co-creation are applied as input for the final design roadmap.

5.1 // ''How might we?'' questioning

Based on the opportunities and points of attention for successfully implementing the Gbit luminaire in the smart city ecosystem, as discussed in the previous chapter, several how might we questions are set up as the starting point for ideation. The product positioning consists of three parts: 1. Product, which is the Gbit luminaire, 2. Digital product, which is the software to manage and operate the network infrastructure, 3. The application technology, which is the physical object that exchanges data with other devices and systems over a network. Below a problem statement is set up based on the stakeholder analysis:

Problem statement for the product:

"The Gbit luminaire in present-day is seen as a niche product, rather than a mainstream product. Likewise, rolling out a network infrastructure is not seen as urgent or a key priority inside cities since the predominant view is that this should be the responsibility of a market player. On the other hand, the smart city vision is attractive for cities as it can change cities for the better by utilising emerging technologies. Nevertheless, the realisation of this vision requires an upgrade of the existing communication networks by the deployment of small cells. According to the analysis, the expected 5G small cells roll-out, is leading to urban clutter and disruption is worrying cities; however, municipalities can not stop the market from doing so without regulatory restrictions that are limiting the right of telecom operators."

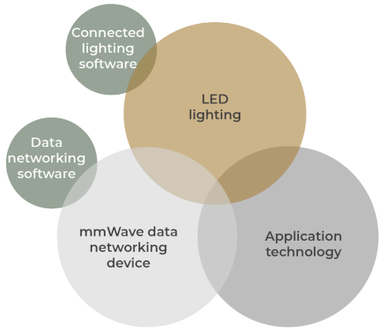


Figure 5.1 - The three components of the Gbit luminaire

"How might we?" questioning for the product:

- How can the Gbit luminaire play a role in the challenges that are part of the present-day and the future?
- How can the application technologies of the Gbit luminaire meet new economic, climate and social goals while aligning with the regulatory and financial aspects?
- How can the product's image be shifted from a niche product that is a cool luxury to a must-have product?
- How can BrightSites force cities to rethink priorities?
- How can the product maximise the value of light poles and unlock cutting-edge potential on the outdoor lighting infrastructure?

Problem statement for the digital product (software):

"Municipalities do not see network operation as their primary task. Likewise, they do not perceive the current workforce able to operate the network. Municipalities in the future might operate a network themselves as long as it serves a societal function. Market players can technically manage and operate a network; however, they need to get paid for doing so. In addition, if market players would operate a Gbit luminaire network infrastructure, preferably, it needs to be integrated with the larger management system."

"How might we?" questioning for the digital product (software):

- How can the dashboard be designed in a way that municipalities see themselves capable of doing so?
- How can the dashboard be developed so it fits with a private company's more extensive management system?

5.2 // Idea mapping and co-creation

The "How might we?" questions from the previous chapter are used as input to support the ideation process. The sessions with the internal experts were merely to understand how the venture perceives its' product positioning. In contrast, the sessions with external experts were set up to understand how the product is being perceived outside the borders of the company. The following participants contributed to individual or group co-creation sharing sessions:

Internal:

- Venture manager, BrightSites
- Product manager, BrightSites
- Sales manager, BrightSites

External:

- Business Development Manager Smart City, SPIE Infratechniek B.V.
- Wireless Communication and Sensing master student, Delft University of Technology
- Strategic Product Design master students, Delft University of Technology
- Design for Interaction master students, Delft University of Technology
- Industrial Design Engineering master students, Eindhoven University of Technology

Internally, the biggest question is how to approach the market in terms of value proposition or most addressable use case. Based on the developed value flow framework, there is quite a big clash between the people who can pay for it and those who own the existing lighting infrastructure. However, strategic design starts with thinking about what is desirable from a human-point of view and to what extent it can solve people's needs. Because if there is one thing evident about product development or design, the purpose, meaning, success or failure of a proposition depends on the extent to which it can satisfy people's needs (Desmet, 2020). According to (Desmet & Fokkinga, 2020), there are 13 fundamental psychological needs for human-centred design: autonomy, beauty, comfort, community, competence, fitness, impact, morality, purpose, recognition, relatedness, security and stimulation. See appendix VI. Companies can use the following three strategies in new product development based on customers' needs: 1. Strengthen a current need, 2. Introduce a new need, or 3. Reduce a harmed need (Desmet & Fokkinga, 2020).

To identify the main needs of municipalities, the coalition agreements of three different municipalities were analysed to dive deeper into cities' needs: 1. The Coalition agreement of the Municipality of Amsterdam, 2. The Coalition agreement of the municipality of Utrecht, and 3. The Coalition agreement of the municipality of Tilburg. After analysing the coalition agreements, three repeating themes highly on cities agenda were identified: 1. Sustainability, 2. Mobility and 3. Safety. See appendix VIII for the breakdown of the coalition agreements. Based on the breakdown of the coalition agreements and co-creation sessions, the following main needs for municipalities are selected: beauty, security, community, impact and morality. See appendix VII for the list of needs and sub-needs for the other stakeholders in the Gbit luminaire ecosystem.

An interesting finding from the coalition agreements was a point from the municipality of Utrecht regarding camera deployment. The excerpt of the municipality shows that cities have a camera surveillance policy that states the maximum number of cameras inside the city. This means that camera placement is part of a highly regulatory process inside municipalities. On the other hand, the excerpt shows that the city is striving for more flexible camera deployments instead of fixed ones. This is positive for BrightSites as a wireless connectivity system via the lighting grid can support flexible camera deployment.

1.7 Veiligheid

Utrecht wil een veilige en leefbare stad zijn, waar iedereen prettig kan wonen en verblijven. Hoewel criminaliteitscijfers op een aantal terreinen een dalende trend laten zien, voelt een aantal mensen in Utrecht zich thuis of op straat niet altijd veilig. Dat heeft bijvoorbeeld te maken met de toename van georganiseerde ondermijnende criminaliteit en straatcriminaliteit.

We blijven daarom stevig inzetten op veiligheidsbeleid. Dit start met preventie. We willen de burgerbetrokkenheid versterken en investeren in elkaar kennen en ontmoeten. Tegelijk willen we stevig ingrijpen en handhaven als het gaat om het aanpakken van criminaliteit. Utrecht blijft koploper in het aanpakken van mensenhandel.

Maatregelen:

- Iedereen moet zichzelf kunnen zijn in onze stad. Je afkomst, geloofsovertuiging, seksuele geaardheid of genderidentiteit maken geen verschil.
- Als basis van het veiligheidsbeleid zetten we extra in op preventie in het Integraal VeiligheidsPlan (IVP). We gaan bijvoorbeeld door met de succesvolle inzet van buurtvaders op straat. We investeren in het terugdringen van huiselijk geweld, intimidatie op straat en high impact crimes.
- De aanpak om radicalisering en polarisatie tegen te gaan wordt voortgezet, met een mix aan activiteiten gericht op weerbaarheid, dialoog en het betrekken van maatschappelijke organisaties die verankerd zijn in de stad (Utrecht zijn we samen).
- Het huidige beleid van cameratoezicht wordt voortgezet. Het huidige maximum aantal camera's blijft ongewijzigd en we hebben aandacht voor het beschermen van privacy. We streven (binnen het maximum aantal) naar meer flexibele en minder vaste camera's.

Figure 5.2 - Coalition agreement municipality of Utrecht 2018-2022 (Municipality of Utrecht, 2018)

Translation text in yellow:
The current camera surveillance policy will be continued. The current maximum number of cameras remain unchanged and we pay attention to privacy protection. We strive (within the maximum number) for more flexible and less fixed cameras.

The technology scouting analysis shows that cameras are the only sensors that would significantly benefit from a wireless connectivity system via the lighting grid. Other sensors could also be plugged into BrightSites' Gbit luminaire network; however, they would not need BrightSites solution in order to work effectively. On the other hand, the technology scouting analysis shows that emerging camera technologies can significantly benefit the city in the medium term, especially in the domain of mobility and security.

Therefore, the following vision was co-created:
"BrightSites should shift cities image from a state of future prediction, towards a state of future preparation by sparking the essential network considerations."

It was based on the idea that if cities truly want to prepare for the smart city of tomorrow, the best thing they can do is flexibly networking it today. Even though cameras are currently placed from a safety and security perspective. It is highly likely that there will also be other domains for camera technologies in the future, such as healthcare, economic development, waste and mobility cameras. Heat maps could, for example, spark imaginations how much bandwidth the digitally connected city of the future needs.

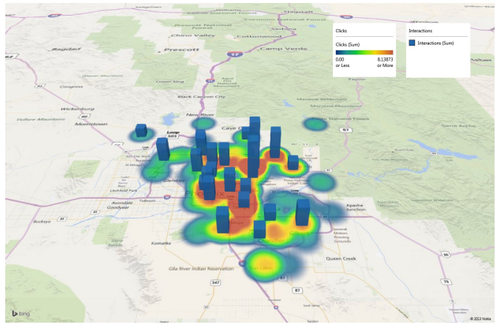


Figure 5.3 - Excel power maps to visualise required data in the digitally connected city of the future (Halpert, 2014)

However, the vision statement was also criticized by experts and the supervisory team since stakeholders will not invest or give access to the lighting infrastructure if they can not calculate a return on investment or perceive immediate benefits, especially in conservative environments. It is probably true that in the future, a growing amount of IoT devices require a backhaul medium to transfer back to the core network, and BrightSites' proposition could offer a flexible network infrastructure on the lighting grid. However, the product offering needs to touch upon a specific pain point. Even though the application technologies could lead to social, environmental and economic benefits, these technologies could also be executed without a wireless network infrastructure on the lighting grid, simply by using a different backhaul technology or acquiring a non-integrated mmWave radio. Thus, a new question came up in the ideation process: what can BrightSites offer that other players cannot?

At the same time, the ideation process was deviating from the developed value flow framework that states that the product should be perceived from an ecosystem level and not from an individual level. By ideating about use cases or technologies, the ideas mainly covered individual needs. However, the values of all stakeholders need to be aligned to become a widespread success. Therefore, the challenge was to find a common interest or pain point in the whole ecosystem that is relevant right now.

An online survey was therefore distributed among 60 participants to map out society's perception of 5G and see how society's view aligns with the view of municipalities. Participants were asked to write down the three keywords associated with 5G technology in the online survey. See figure 5.4 for the results of the online survey.

Figure 5.4 - Perception of 5G, n=60

What became evident from this online survey is that 5G technology is most positively associated with faster internet and most negatively with conspiracy theories. Another interesting observation was that none of the participants mentioned clutter in the urban environment or disturbance in the urban city centre. An explanation for this can be that experts in the municipalities engage with topics like this daily, and citizens do not see potential problems if it is not visible in the urban environment yet. However, keywords with a negative association, such as corona vaccination, brain manipulation, high costs and threat to the environment and birds, were repeatedly mentioned in the survey. The results of this survey demonstrate that the telecommunication industry has to work on the negative sentiment that is surrounded with 5G technology.

By linking all the information and ideas from the stakeholder analysis, the co-creation sessions and individual idea mapping, BrightSites should focus on shared desirability in the ecosystem and align the product-service proposition to those needs. The most promising opportunity for BrightSites in the short term concerns the rollout of 5G and the hosting of sensor technology in the medium term. See chapter 6.0 roadmapping.

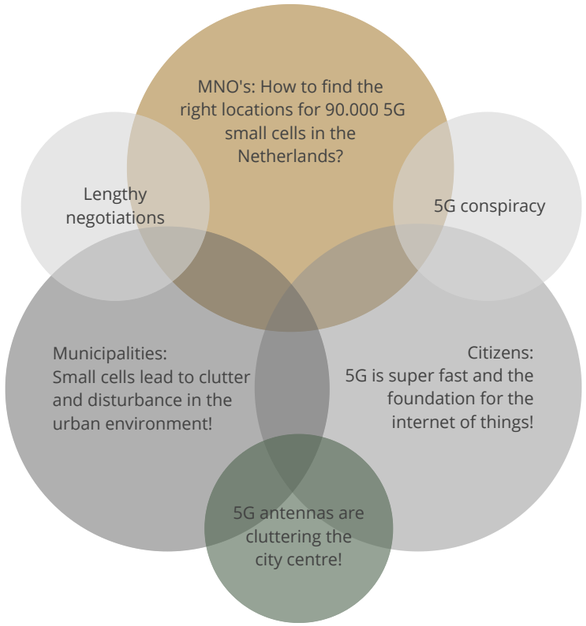


Figure 5.5 - Common interest and pain points in the Gbit luminaire ecosystem

5.3 // Technology scouting

One of the key findings of the stakeholder analysis is that cities perceive Gbit luminaires as a means to an end. Meaning that what cities can do with a Gbit luminaire is the main motivation to buy or give access to the lighting infrastructure. Furthermore, the application technologies that can be supported need to have significant social, environmental or financial value in order to be considered in the first place.

To understand which use cases and technologies a wireless connectivity system on the lighting infrastructure could support, the work of (Manolopoulos, 2019) have been thoroughly analysed. In his research, he investigated the mountable and non-mountable sensors currently being used in Utrecht, the Netherlands.

Sensor types that are mountable on light poles	Sensor types that are not mountable on light poles
Air quality 95	Disabled parking 50
Surveillance 138	Charging & Parking 36
Road users 4	Waste 3598
Traffic 25	Precipitation 11
	Groundwater 181
	Water 1046
262 sensors in total	4922 sensors in total

Figure 5.6 - The different sensor types in Utrecht, the Netherlands (Manolopoulos, 2019)

The literature review shows that cameras are the only sensors in the present-day city landscape that require high bandwidth and real-time transmission frequency. These cameras are either connected with optical fibre or a 3.5 GHz wireless connection. The other sensors are either powered by LoRa or narrowband internet of things (NB-IoT). For BrightSites, this means that cameras are technically the only sensors that could significantly benefit from a wireless connectivity system via the lighting grid. The contradiction, however, is that cameras are placed in the Netherlands from a safety and security perspective. Meaning that camera deployment is a collaborative process between the police and the government, BrightSites can thus not influence placement. The approach for the co-creation session, therefore, was on identifying camera applications that fall under a different domain than safety & security.

In a co-creation session, the following five domains were identified based on the coalition agreements of cities and analysing existing smart city initiative papers.

- Safety & security applications
- Healthcare applications
- Economic development applications
- Waste applications
- Mobility applications

Key insights from technology scouting:

- In the future, camera technologies with underlying technologies such as deep learning, facial recognition, and motion tracking will become part of the city landscape giving cities relevant information about city life.
- European cities, however, are concerned about how to include social values into the design of such sensors. An example in the Netherlands of a governmental organisation for smart sensing is the responsible sensing lab of the Municipality of Amsterdam.

	Safety & security applications	Healthcare applications	Economic development applications	Waste applications	Mobility applications
Use case	· Public order & safety · Theft prediction · Crowd & pedestrian management	· Tackling noise pollution · Medical assistance · Emergency services · Pandemic management	· Public Wi-FI · Fixed wireless access	· Object detection for urban waste · Waste monitoring · Recycling	· Identification and classification of road users · Traffic management · Traffic studies · Carpool parking management · Management of Low Emission Zones · Incident detection · Access control · Parking control · Monitoring of restricted traffic lanes · Detection of stolen or wanted vehicles
Technologies	· CCTV video camera, facial recognition · AI-enabled cameras · Deep learning · Motion tracking · Drone cameras	· Acoustic AI-enabled cameras · Drone cameras · AI-enabled cameras · Thermal (infrared) cameras	· Wireless access point · Antenna	· AI-enabled cameras, machine learning · Thermal imaging cameras · Hyperspectral imaging cameras	· Thermal (infrared) cameras · License plate detection cameras · AI-enabled cameras · Radar and CCTV cameras
Fundamental psychological need of cities	· Impact · Morality · Security	· Impact	· Impact · Community	· Impact · Morality	· Impact · Morality · Security
Estimated time period for market implementation	0-10 years	0-15 years	can be immediately implemented	0-5 years	0-15 years

Chapter 6

ROADMAPPING

6.0 // Roadmapping

This chapter presents the design roadmap to the future of wireless connectivity via the lighting grid. Design roadmaps differ from traditional technology or product roadmaps as it focuses on end-users values, rather than the technology portfolio and organisational goals. Based on the findings of this research, two factors are highly influencing the future of the Gbit luminaire infrastructure. First, the extent to which municipalities can influence the choices of market players and second, the alignment of values with market players. Based on the findings, the rights of telecom operators and the associated 5G roll-out strategy are highly influencing the success of widespread Gbit luminaires deployments. The challenge is that municipalities can not force mobile network operators to use a Gbit luminaire wireless network infrastructure. In addition, it is observed that the 5G small cell roll-out is a big concern for cities; therefore, cities see the value in BrightSites offering the backhaul technology for these small cells. However, the contradiction is that cities merely want to be a facilitator. They will never operate a network infrastructure for the devices of market players and do not have the financial means for widespread deployments. Municipalities only invest in the highly necessary and are always at the service of their residents. The goal is to convince cities of why they need to own or give access to a wireless connectivity system via the lighting grid for their own smart city services while admitting that cities require funding and can not influence the choices of market players if no regulatory law is holding them back.

6.1 // Design roadmap

The design roadmap is developed from a European municipal decision-maker perspective considering the external analysis, which emphasised that municipalities are the key decision-maker in the Gbit luminaire ecosystem. A municipality will inevitably become part of the conversation since public lighting belongs to its primary tasks, and objects placed in the urban environment require permission and acceptance of the city.

Another key argument is that the aesthetic fit is only a key priority for cities based on the developed customer profiles. If cities do not agree with the aesthetic fit of the Gbit luminaire or do not want to use Signify's lighting products, they will still be able to sabotage the deal. Other market players that could potentially be interested in the Gbit luminaire are telecommunication infrastructure providers, mobile network operators, internet service providers and fibre suppliers. However, because of their financial-driven nature, the aesthetic fit is less of interest for them. Suppose other market players would be interested in the functionalities of mmWave technology, then it is likely that they will contact mmWave radio vendors and try to negotiate with municipalities for placement on public assets for a lower price than the Gbit luminaire. The key arguments for this are that market players are financially driven and have little lighting knowledge; they would preferably step into a business with only their core expertise, data networking.

The final design roadmap consists of three horizons, all having a specific name representing the focus of that horizon. The periods chosen for the design roadmap are the following: the year 2021-2025, 2026 and 2030.

Current value proposition

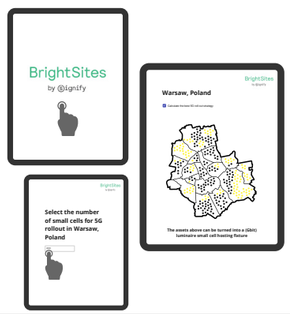
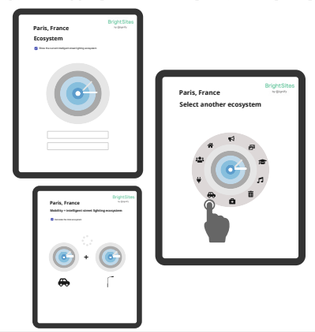
The current Gbit luminaires are positioned as wireless fibre extenders with lighting capabilities. However, the current product only solves long deployment time, lessening the disturbance in the city centre and potential CapEx savings. However, based on the research in this study, fibre roll-out costs highly vary per country; therefore, fibre roll-out costs can not be generalised. In addition, based on the stakeholder analysis OpEx of optical fibre is considered to be lower. Another misconception based on this research is that fibre roll-out is a source of income for cities; therefore, it is not only perceived as negative by cities.

Optical fibre	Wireless fibre by Gbit luminaires
Disruption in the city	No disruption in the city
Long deployment time	Extremely quick deployment time, less than 15 minutes. → is proven by the first installation in Tilburg, the Netherlands.
High CapEx → is doubted by multiple experts in the stakeholders analysis, since this is highly dependent on country, soil conditions and existing fibre rate inside a city.	**Cheaper than optical fibre** → is doubted by multiple experts in the stakeholder analysis since the OpEx and the risk of a malfunction in the network is considered to be higher. One stakeholder sketched a scenario that if optical fibre is rolled out, the chance that the optical fibre gets damaged is relatively low. However, suppose a mmWave Gbit luminaire network infrastructure is rolled out. In that case, the chance something will happen with the network is higher, e.g. someone driving against a light pole and leading to malfunction of the wireless network. → it is not cheaper than a single mmWave radio from any other vendor utilising Terragraphs technology: Siklu, IgniteNet, Radwin, Cambium networks etc.
Digging optical fibre in the street by market players is a source of income for municipalities → not only negative for cities.	**Not solving aesthetic integration, still leads to clutter in the urban environment** → Market players can offer the same functionalities with a cheaper mmWave radio from a different vendor. In the end, there still will be clutter in the urban environment if BrightSites does not offer aesthetic integration options for IoT devices, Wi-Fi access points and telecommunication equipment.
Location density influences prioritisation of optical fibre roll-out → meaning that if by 2050, two-third of the world population will be living in cities, fibre rollout will be prioritised inside cities by market players.	**Permission from cities** → Mobile network operators and telecommunication infrastructure providers will still need permission to place their equipment in the urban environment. → IoT equipment installation needs to align with the vision of cities.

Figure 6.1 - Optical fibre versus wireless fibre by Gbit luminaires

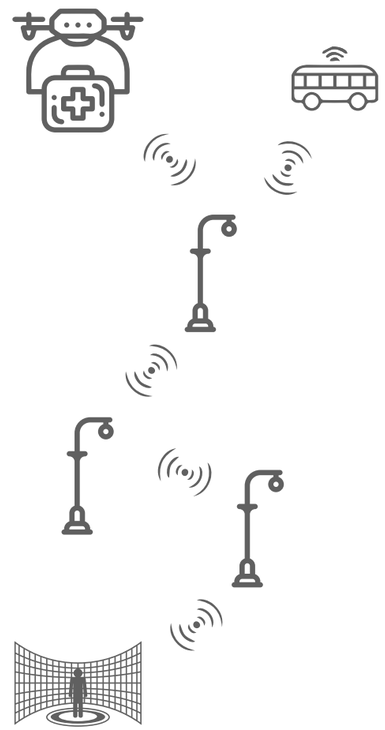
Design Roadmapping: A Wireless Connectivity System via the Lighting Grid

From a European municipal decision-maker perspective

	Horizon 1: 2021 - 2025 Out of sight, out of mind	**Horizon 2: 2026** Beyond illumination	**Horizon 3: 2030** Enlightening
	BrightSites as the bridge	BrightSites as the IoT menu	BrightSites as the neural network
Fundamental psychological needs of municipalities	Beauty Security Community Impact Morality **Constant**		
Municipality values	Improving citizens' overall quality of life by making cities inclusive, safe, resilient and sustainable Safety, Security & Happiness for all citizens Sustainability Inclusivity, access to connectivity for all **Constant** **Horizon specific** Help us with the best 5G small cells concealment strategy above the ground and the least disturbance under the ground **Aesthetics, avoiding urban clutter**	**Horizon specific** Help us to reduce polarization inside society by aesthetically concealing telecom equipment and IoT devices **Aesthetics, avoiding urban clutter, getting rid of the spying society "image"**	**Horizon specific** Help us to realise the full potential of intelligent street lighting in the digitally connected city **Creating shared impact**
Value proposition	"BrightSites forms the bridge between cities, telecommunication infrastructure providers and mobile network operators by introducing a tool to foster collaboration and offering a new version of the Gbit luminaire fixture that can host small cells aesthetically."	"BrightSites enables cities to transform the meaning of safety and security by identifying strategic IoT locations and incorporating high-bandwidth technologies of interest aesthetically into the Gbit luminaire."	"BrightSites fosters ecosystem mapping in the intelligent street lighting industry and co-creates luminaire fixtures beyond the limits of the corporate organisation."
Product-service offering	**Communication tool for (Gbit) luminaire small cell hosting fixtures** 	**Communication tool for (Gbit) luminaire IoT hosting fixtures** 	**Ecosystem mapping tool for intelligent street lighting** 
Technology in the digitally connected city	4G 5G 6G Artificial intelligence, Machine Learning, Robotic Process Automation Geospational Sensor Connected vehicles Edge computing Satellite internet constellations	Photonics Energy harvesting	

Vision

"We help cities to unlock cutting-edge potential on the lighting grid by jointly turning existing infrastructure into strategic assets."



A bright future ahead!

BrightSites

by Signify

Horizon 1: Out of sight, out of mind (2021-2025)

By looking at the proposition from a desirability perspective, aesthetic integration of small cells and connecting small cells wirelessly is the domain BrightSites will have the most significant market impact. The challenge, however, is that a tool is missing to bring municipalities and mobile network operators to the same page for small cell rollout since municipalities are value-driven and mobile network operators financially driven. On the other hand, mobile network operators struggle to find new antenna locations, and aesthetic integration can potentially lead to a better brand perception of mobile network operators. The goal is to focus on the shared interest or common pain point, and align the current Gbit luminaire product-service proposition with stakeholders' needs.

New value proposition

"BrightSites forms the bridge between cities and mobile network operators by introducing a tool to foster collaboration and offering a new version of the Gbit luminaire fixture that can host small cells aesthetically."

Product-service offering

- Online tool that can be used in the negotiation or sales process, called the small cell marketplace. See appendix IX for additional wireframes.
- Gbit luminaire fixture that can aesthetically host small cells wirelessly but also with an optical fibre connection.

Based on the stakeholder analysis, the urgency first needs to be created, and the impact needs to be understood before a stakeholder will operate, give access or buy a solution. Likewise, the product-service offering needs to touch upon a specific pain point, as the more immense the pain, the higher the willingness to become part of the Gbit luminaire ecosystem. A shared pain point for mobile network operators and municipalities is that they have to spend significant time negotiating and in finding suitable antenna locations. This problem will only become more prominent with the prospective mass 5G small cell rollout and polarization in society regarding 5G and IoT technology.

The new product will be called the (Gbit) luminaire small cell hosting fixture. The focus will not merely be on creating fibre-in-the air but on the aesthetic integration of 5G smalls cells and speeding up the negotiation process for new antenna locations.

To validate the idea, a T-Mobile expert got contacted. The feedback was that mobile network operators base the rollout of small cells on the existing data traffic, and new small cells will be rolled out based on congested data traffic locations. This means that small cell rollout is not an all-in-one process but a step-for-step process. In addition, T-Mobile does not want to make use of the same small cell as other network operators. For BrightSites, this means that the (Gbit) luminaire small cells hosting fixture needs to support the equipment of multiple operators.

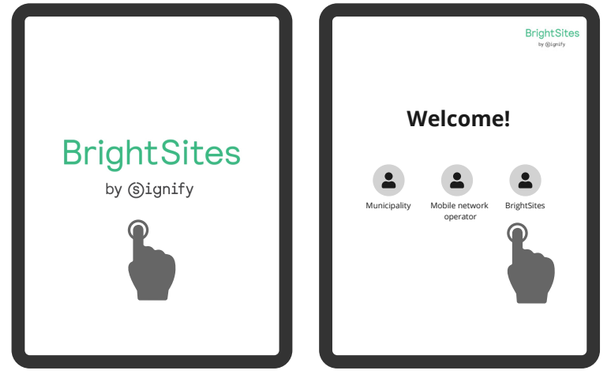
Compared to the previous KPN feedback, connecting small cells wirelessly would be more interesting for T-Mobile than KPN since T-Mobile does not own much optical fibre infrastructure in the Netherlands, which T-Mobile currently has to lease. According to the T-Mobile expert, KPN owns a lot more optical fibre than T-mobile, which could be why KPN prefers to connect small cells with optical fibre. However, similarly, T-Mobile does not want to have a shared network with other mobile network operators or IoT equipment. For T-Mobile, this makes wireless small cell connections of interest as long as no other parties are using the same network.

Another point of attention is that T-Mobile would prefer to rent the location in the (Gbit) luminaire small cell hosting fixture from another party, such as a telecommunication infrastructure provider, rather than buy a (Gbit) luminaire fixture individually.

Quote

"A tool like this would make the negotiation process with municipalities smoother."

· T-Mobile expert



Main need of municipalities

Help us with the best 5G small cells concealment strategies above the ground and the least disturbance under the ground.

Main need of mobile network operators

- Help us to find suitable 5G small cell locations that give the option to be connected with our preferred backhaul technology.
- Help us to smoothen the process and strengthen the relationships with municipalities for 5G small cell rollout

Future need of mobile network operators

- Help us to get rid of our negative brand perception.

Barriers

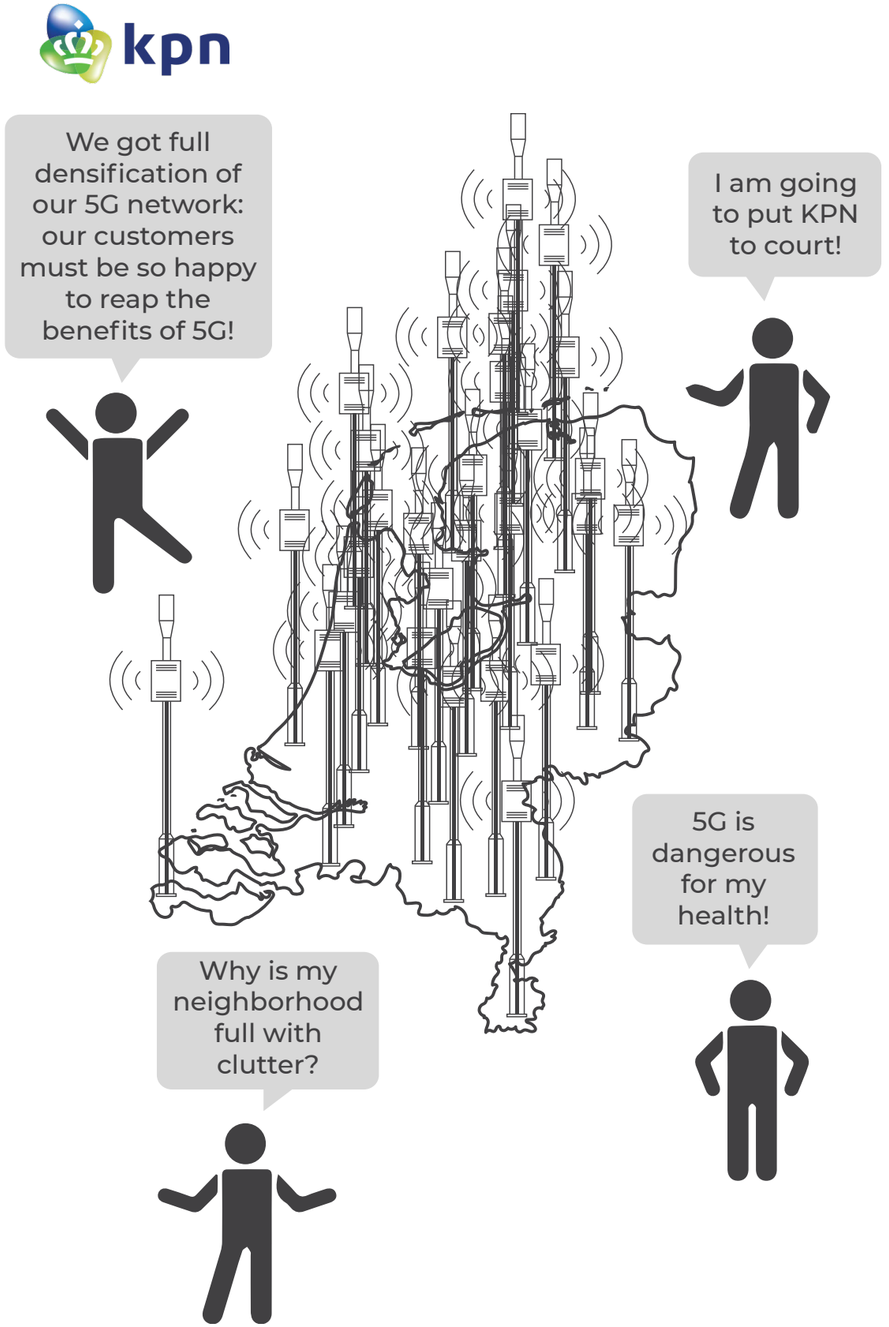
- Telecom laws that do not put any restrictions on mobile network operators regarding small cell rollout.
- Mobile network operators that do not want to have a shared network with other IoT devices.

Challenges to overcome

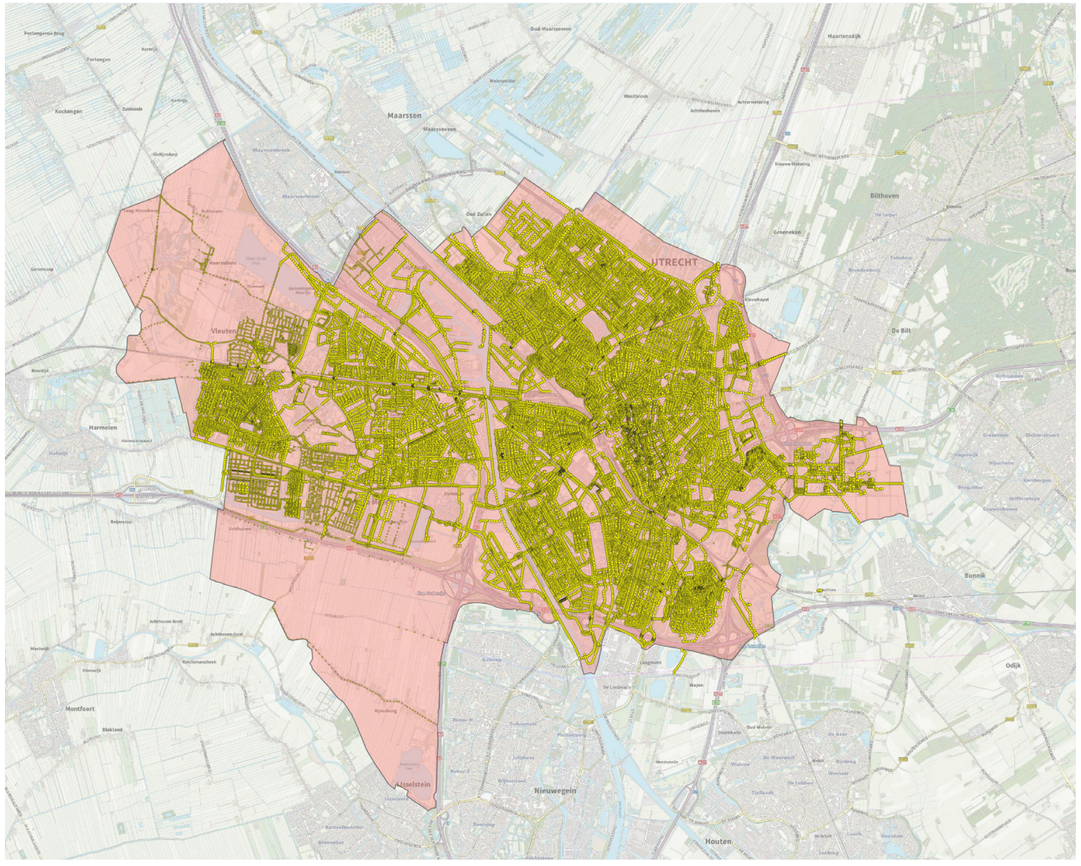
- There are different types of small cells. If BrightSites wants to implement this idea, they need to optimise this for various small cell types.
- The current small cells are too heavy, too big, and the amount of energy transferred per time unit is too high.
- What is the acceptance by the market to aesthetically integrate small cells into Luminaire fixtures?
- How much money can BrightSites generate by implementing this idea?
- What is BrightSites credibility and right to play in the market?
- The 5G small cells that can be aesthetically integrated into the luminaire need to be on the approved mobile network operators list.

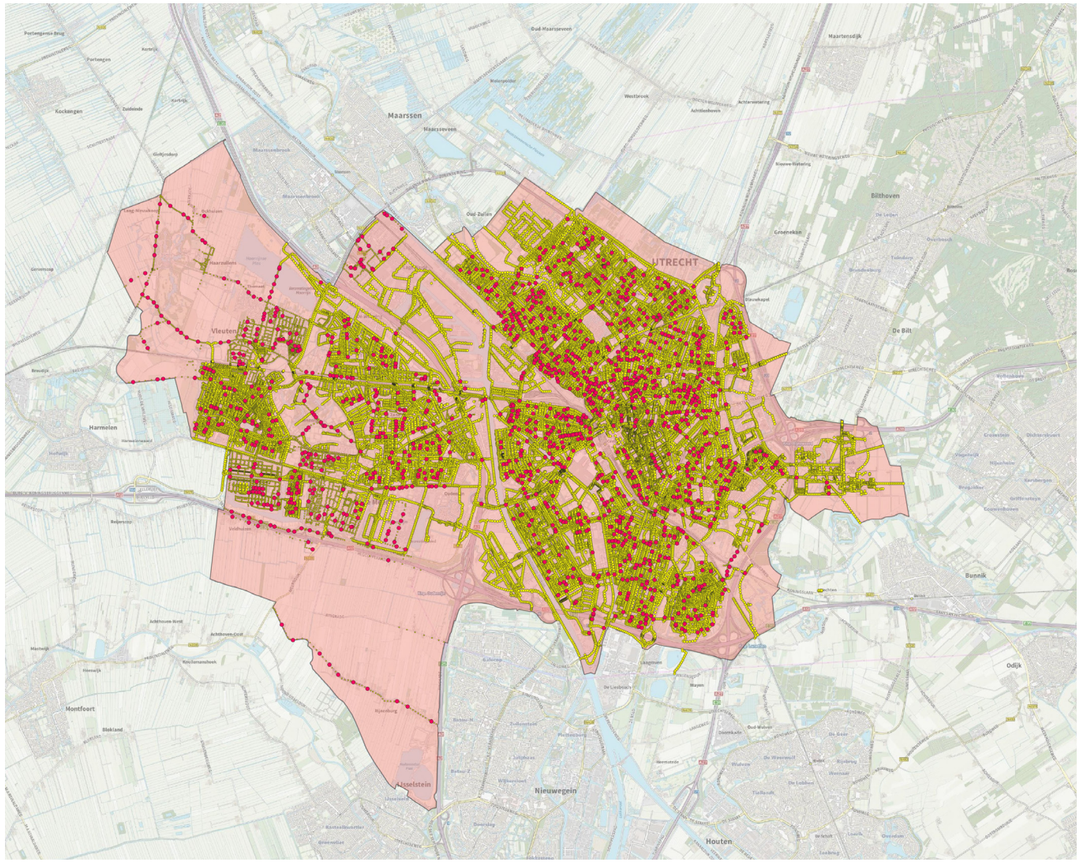
Strategies to overcome barriers and challenges

- BrightSites can use its power to get mobile network operators on board since they struggle with the best 5G rollout strategy.
- Pressure mobile network operators on the negative brand perception they will create if small cells clutter the urban environment.
- Develop a Gbit luminaire fixture that can host small cells with an optical fibre connection and wirelessly, giving mobile network operators the option to decide what fits their business and strategy.
- Focus on getting mobile network operators on board by visualising the negative brand perception they will create, the time they will save by negotiating with municipalities, and why collaboration is essential.
- With one partnership in the Netherlands and one mass small cell rollout project, e.g. 30.000 small cells aesthetically integrated into the luminaire, BrightSites can genuinely be impactful and set the industry standard.
- Technical challenges can only be overcome by joint partnerships with mobile network operators and seeking their technical input.



The Netherlands consists of approximately 3.500.000 light poles. The maps below show the existing light points in the city of Utrecht, plotted with QGIS, an open-source geographic system. The results show that Utrecht consists of approximately 60.000 existing light points, plotted with QGIS on the left picture below.





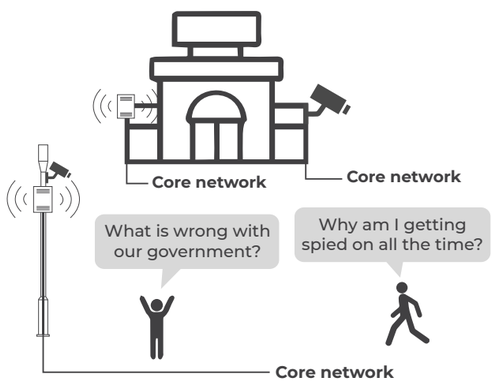
5G rollout

For the entire 5G rollout in the Netherlands, around 90.000 small cells have to be installed by all the three mobile network operators: KPN, T-mobile and Vodafone. A rough calculation shows the following effect on the city of Utrecht for the entire 5G rollout. If there are 3.500.000 light poles in the Netherlands, it could mean that one out of every 39 light poles requires a 5G small cell (3.500.000: 90.000 = 39). For the city of Utrecht, this will mean that 1538 light poles require a 5G small cell (60.000: 39 = 1538). This effect is visible in the picture on the right, where the red dots show the 5G small cell antenna locations.

Horizon 2: Beyond illumination (2026)

From the co-creation sessions, an interesting theme emerged: "the Spy society". The technology scouting analysis shows that more smart city IoT is becoming available for cities in the digitally connected city of the future. These IoT devices require a backhaul medium to transfer the data back to the core network. Based on the analysis of this research, high-bandwidth smart city IoT could run on 5G technology. However, based on the conversations with a T-Mobile expert, camera technologies running on telecommunication networks are troublesome since they require extremely high bandwidth. This makes the role of a wireless connectivity system via the lighting grid for cameras technically more interesting in the city of tomorrow. However, the question is whether the meaning of safety & security will be the same in 2026. In the future, the regulations regarding privacy and security by design for cameras will probably become stricter, and the look and feel of regular street cameras remain intimidating. BrightSites could offer value by incorporating 5G small cells and smart city IoT into the Gbit luminaire to decrease the level of intimidation that citizens perceive and increase the city's value.

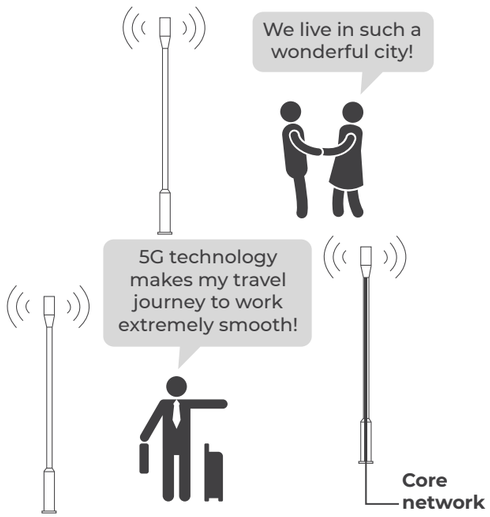
1: Current situation with Gbit luminaires



New value proposition

"BrightSites enables cities to transform the meaning of safety and security by identifying strategic IoT locations and incorporating high-bandwidth technologies of interest aesthetically into the Gbit luminaire."

2: With BrightSites (Gbit) luminaire small cell and IoT hosting fixture



Product-service offering

- Luminaire fixture that can aesthetically host small cells wirelessly but also with an optical fibre connection.
- Luminaire fixture that can aesthetically host smart city IoT, especially cameras.
- Online communication tool that can be used in the negotiation or sales process called the smart city IoT marketplace. The tool can be used to identify new strategic IoT locations based on one out of the five smart city themes. See appendix X for additional wireframes.

The second version of the marketplace tool will even become smarter than the first version. Next to identifying the existing optical fibre infrastructure and lighting infrastructure, the system can recognise existing IoT applications inside cities and recommend new smart city IoT applications that can be aesthetically integrated into the luminaire fixture.

The applications are divided into five different smart city themes:

- Safety & security applications, e.g. AI-based cameras
- Healthcare applications, e.g. Acoustic AI-cameras
- Economic development applications, e.g. People counting cameras
- Waste applications, e.g. Object detection cameras
- Mobility applications, e.g. LIDAR and CCTV cameras

Main need of municipalities

Help us to reduce polarization inside society by aesthetically concealing telco equipment and IoT devices.

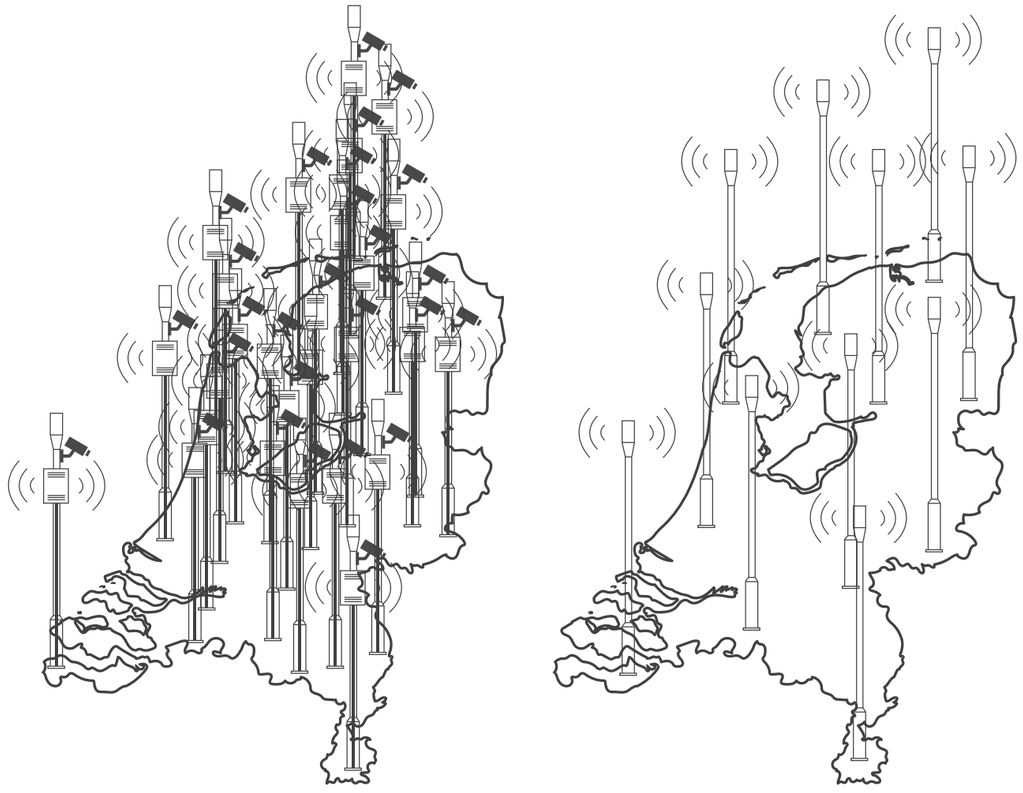
Challenges to overcome

- In 2026 there will be many smart city IoT devices, the main challenge is how to create a product that can host a wide range of devices that are of interest for the city.
- Corporate interest can never overwhelm the values of municipalities.

Strategies to overcome challenges

- Strategic alliances with a broad range of third party equipment suppliers for smart city IoT.
- Joint collaboration and R&D with municipalities, mobile network operators, third party equipments suppliers and Signify.

3: Effect on the urban environment



Horizon 3: Enlightening (2030)

Intelligent street lighting will become part of a much bigger and complex ecosystem than it is of today. While municipalities are now rather conservative and mainly take a facilitating role in the innovation process, cities need to rethink their role in the digitally connected city of the future. With more and more data transport and connected systems, cities will become even more interconnected. Likewise, intelligent street lighting will become more intertwined with other systems, from mobility to energy; therefore, a new approach to innovation and ecosystem understanding is required.

New value proposition

"BrightSites fosters ecosystem mapping in the intelligent street lighting industry and co-creates luminaire fixtures beyond the limits of the corporate organisation."

Product-service offering

- Intelligent street lighting that is co-created beyond the limits of the corporate organisation.
- Online ecosystem mapping tool for intelligent street lighting. The tool can show the existing street lighting ecosystem in a specific city and the connections with other ecosystems. See appendix XI for additional wireframes.

The online ecosystem mapping tool can show the existing street lighting ecosystem in a specific city and the connections with other ecosystems. Imagine a future in which cars can communicate and send data through light poles. Before BrightSites can become part of, for example, the mobility ecosystem, BrightSites first must understand how its own ecosystem intertwines with other systems. Only in this way BrightSites can truly be impactful and realise the full potential of intelligent street lighting.

Main need of municipalities

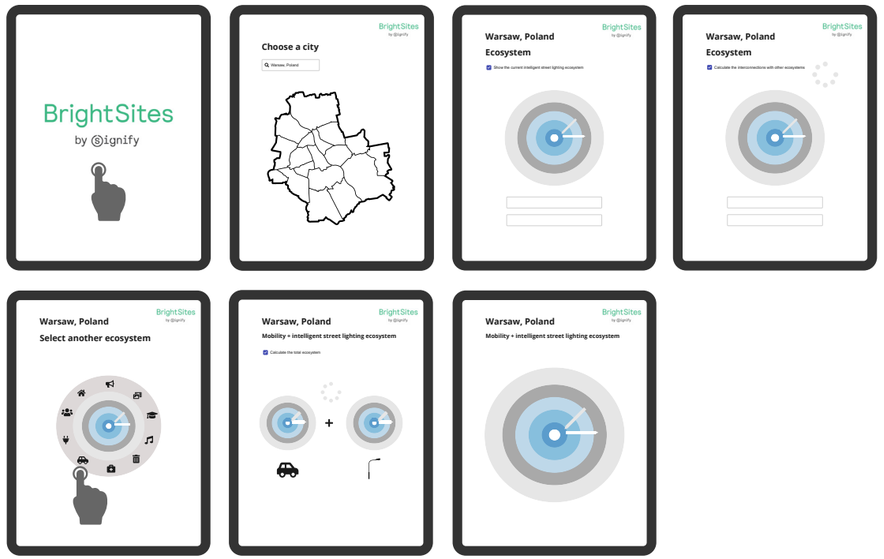
Help us to realise the full potential of intelligent street lighting in the digitally connected city.

Challenges to overcome

- Requires an extensive database of existing players and products.

Strategies to overcome challenges

- In 2030, data will be the new oil, meaning that data and information will be easier to process and attain. The competitive advantage BrightSites can create by making ecosystem mapping part of the core strategy is product optimisation.



Chapter 7

EVALUATION

7.0 // Evaluation

The final chapter of the strategic analysis provides the overall conclusion, limitations, recommendations and a personal reflection of the author. The main conclusion that can be drafted is that the product proposition should be perceived, developed and pitched from an ecosystem level. In addition, the author suggests that the (Gbit) luminaire should be positioned as a hosting solution rather than a wireless fibre extender. The main limitation of the research is that it is mainly taken from a shared desirability perspective. Still, many technical constraints have to be overcome to make the (Gbit) luminaire hosting fixture vision a reality. Likewise, the new product-service offering will require substantial research and development time, meaning that the idea can not be immediately put on the market. Moreover, the new product-service offering heavily relies on strategic alliances, which will also take time.

Furthermore, the recommendation advocates that BrightSites should focus on four pillars: 1. Focus on the common interest in the ecosystem, 2. Joint value creation, 3. Touch upon human emotions, and 4. Highlight the fit with existing business processes or city strategy.

7.1 // Conclusion

This research provides a basis for BrightSites to analyse further the role of Gbit luminaires in the digitally connected city of the future. The main conclusion that can be drawn is that placing a new product in a conservative ecosystem, in this case, the lighting department at municipalities is challenging and, in the process, can feel like a daunting task. Many design problems are complex, and through this research, it was observed that finding the product-market fit for Gbit luminaires in cities was no exception. A method that is being used to deal with the complexity of the project is to collaborate with and include external stakeholders in the process closely. The developed value flow framework shows how intertwined and dependent the product proposition is on other stakeholders. For this reason, it becomes key to understand how stakeholders can strengthen the ecosystem, but even more how they would like to be rewarded for doing so. Furthermore, the various design methods being used throughout this project cast a new light on the gaps in the Gbit luminaire ecosystem:

1. The value gap
2. The knowledge gap
3. The financial gap
4. The urgency gap

First and foremost, **the value gap** between municipalities and market players. While municipalities are actively looking for solutions that primarily carry social or environmental benefits, market players care less because of their financially driven nature. This becomes troublesome in the second gap: **the knowledge gap**. The data indicates that operating a data network is an entirely different line of work compared to managing a connected lighting system, and in some cases, even perceived as market-distorting. This requires a market player, such as a telecommunication infrastructure provider, fibre supplier, internet service provider or mobile network operator, to operate a network on behalf of the municipality. For doing the network operation in cities, they would like to be rewarded with either financial value or brand strength. Cities have to deal with budget constraints and market players would like to get paid, leading to the next gap: **the financial gap**.

A Gbit luminaire network infrastructure could create financial value or brand strength for market players by deploying fixed wireless access services, public Wi-Fi, camera technologies, and 5G small cells. Fixed wireless access could be a promising use case, but there has to be kept in mind that this depends on the scalability of providing fixed wireless access in the city or even to other cities. Nonetheless, even with a scalable outlook, market players could opt for separate mmWave radio placement onto light poles, making them solely focus on their core business: data networking. In addition, from a legal perspective, municipalities are not allowed to distort the market, and can thus only offer fixed wireless access services for their own buildings. Since they do not have the knowledge, expertise and interest for doing so, it is highly unlikely that this will happen in the short term.

The findings for public Wi-Fi show that many cities in Europe already offer free public Wi-Fi services, mainly being funded by the European Commission. Some experts even call public Wi-Fi outdated in European cities because of the rise of 5G and cheaper data bundles for consumers. The prediction is that public Wi-Fi will become irrelevant since it will cost less to get internet access, or it will either be fully present due to free fundings of the European Commission. For these reasons, fixed wireless access and public Wi-Fi are not considered as the use cases that will make the Gbit luminaire proposition profitable in the medium term.

Differently, cities all over Europe are looking and experimenting with smart city IoT use cases and 5G. A method being used in this project is to dive deeper into the coalition agreements of cities. The results indicate that there are three recurring themes of cities: sustainability, security and mobility. It is of immense value that the Gbit luminaire consists of LED lighting since shifting to a more energy-efficient lighting infrastructure is a key priority for every city in Europe. First, because the investment can be earned back in a few years and second, it aligns with the city's sustainability goals. However, adding extra functionalities to a luminaire means that companies can charge a higher price than a traditional luminaire. These costs need to be justified in either return on investment or significant social value.

From analysing the existing sensors that are present in cities, as of today, cameras are the only sensors that require high bandwidth and real transmission frequency. In the future, 5G chips could be placed into these cameras. However, expert analysis shows that the camera chip business is troublesome for mobile network operators as cameras take up extremely high bandwidth on the network. Therefore, a flexible wireless connectivity system via the lighting grid is considered as an excellent fit to support these camera technologies. In this thesis, various camera technologies are scouted. The prediction is that more and more camera technologies will become part of the city landscape that strongly align with cities' city goals concerning mobility and security.

The last use case a wireless connectivity system via the lighting grid could support is 5G backhaul for mobile network operators. A key finding is that mobile network operators, both KPN and T-Mobile in the Netherlands, do not want to make use of antenna sharing. This means that each mobile network operator prefers to use its own 5G small antenna and thus not share one single 5G small cell antenna with other mobile network operators. Furthermore, a shared network with other IoT devices from a security and maintenance perspective likewise sounds far from attractive.

An eye-opening finding, maybe even troublesome for the venture, is that the Gbit luminaire is perceived as a niche product. This created a new gap: **the urgency gap**. It is evident that connectivity is becoming more important and that in the digitally connected city of the future, an enormous amount of data traffic will occur. However, it is less clear how investing in a Gbit luminaire infrastructure fits with the existing business processes of market players or why they will need BrightSites to reach their strategic objectives. Especially, since market players will still require permission from cities to place their equipment in the public environment. It appears that BrightSites will need market players to bring the connectivity grid of the future to life, but to what extent do market players see urgency in becoming part of the Gbit luminaire ecosystem?

The goal for BrightSites is to close the perceived urgency gap between market players, cities and BrightSites. It is essential that every single stakeholder of the ecosystem feels that a concrete pain point is being solved. It can be stated that the greater the pain point and the higher the perceived urgency, the more likely it is for stakeholders to give access or invest in a wireless connectivity system via the lighting grid. Essentially, this applies to every business proposition, but what makes the Gbit luminaire ecosystem significantly different from any other business is the interdependence in the ecosystem. To illustrate, it could be of great value for cities in the Netherlands to connect 5G small cells wirelessly. Still, T-Mobile or KPN need to share the same vision. Otherwise, it will be impossible without any regulatory restrictions to hold them back. Likewise, a city could feel bothered by internet service providers that individually trench optical fibre; however, if cities do not want to operate their own municipal network, they can not force internet service providers to provide internet access services via the lighting grid. In the same way, a municipality could see great value in installing mobility camera technologies on the lighting grid. However, the whole ecosystem must cooperate, from providing a budget to citizens' acceptance to providing a 24/7 power supply.

To make the product proposition succeed in cities, it is thus essential to not look at the need of one single stakeholder but at the shared need inside the whole ecosystem. Considering the lessons that are learned from the literature review, many smart city initiatives fail because products only target individual needs, usually the needs of the paying customer, while ignoring the ecosystem the product proposition is part of.

Broadly translated the findings indicate that a sense of urgency needs to be created, so it will not just be a product to just experiment with. This urgency needs to be created in either the messaging to the market or a change in the product-service offering.

The outcome of this thesis is a design roadmap, which answers the following research question: what is the role of Gbit luminaires in the digitally connected city of the future? A design roadmap significantly differs from traditional technology or product roadmaps as it centres on the end-users values rather than the technology portfolio and organisational goals.

The design roadmap that is developed in this thesis advocates that the Gbit luminaire fixture should be positioned as a concealment and hosting solution for telecom and IoT devices rather than a wireless fibre extender. The current product offering can rapidly densify communication and IoT networks; however, it appears that it does not touch upon a shared pain point inside the whole ecosystem. In the new value proposition, BrightSites will need to provide a flexible product offering, meaning that it can offer optical fibre and wireless backhaul technology. In addition, to win sustainable business, an online tool is needed to stimulate collaboration and understanding among stakeholders.

Future research on the Gbit luminaire proposition could examine other shared needs inside the ecosystem. The product-service offering in the design roadmap is purposefully taken from a shared desirability perspective, as this will be the first trigger for stakeholders to get an "Aha" moment. In user experience the "Aha" moment is defined as the moment when a stakeholder will feel there is value in the product proposition.

Once the shared value is created, future research should be devoted to close collaboration with market players. Still, many technical challenges have to be solved for the aesthetic integration of small cells and smart city IoT. However, to get market players on board, the conversation can already be started today. Not with cost comparisons or trying to sell, but rather to show what can be jointly achieved and why BrightSites can positively influence the business processes of the market player.

BrightSites could use simple communication tools to create the "Aha" moment for stakeholders. Rather than telling what the product is, a better way would be to focus on the effect that the product can create. For product innovation, simple visualisations could be used to give stakeholders this first "Aha" moment, and cheap cardboard prototypes could be used to co-create with stakeholders. This does not have to cost thousands of euros, as this can be done with PowerPoint and office paper. In addition, more complicated geospatial data tools, such as QGIS, can map out existing infrastructures and help in the communication process. The advice would also be to touch more on human emotions and how a proposition can make people feel. This is very important in getting acceptance of cities, as they are always at the service of their residents.

Future research should also consider the potential effects of other backhaul technologies more carefully, for example, satellite internet constellations. In addition, the technological advancement of mmWave radios should be closely monitored. Now the length of these radios is around 24 centimetres; however, they could become smaller and aesthetically redesigned in the future. These potential threats and emerging technologies will shape the role of Gbit luminaires in the digitally connected city of the future.

To conclude, finding the right product-market fit for Gbit luminaires is a complex problem. These problems are usually characterised by not having many potential solutions, and often, people can take more perspectives to see the problem. The perspective of this thesis is purposefully taken from the key decision-maker, the municipality, as it will be inevitable to leave them out of the conversation, regardless if they are the paying customer or not. Based on the findings of this research, positioning the product from a hosting perspective will create a position for BrightSites in the digitally connected city of the future. In this way, BrightSites will act as the bridge between market players and cities. This will require a shift in the product-service offering, as well as a different messaging to the market.

Further work is certainly required, and it is observed that innovating in a conservative regulatory environment in an interdependent ecosystem is not easy. However, BrightSites is part of Signify, the world leader in lighting. BrightSites has thus the brand recognition and the innovation capability to make great things happen. However, there has to be kept in mind that seeing the product proposition from an ecosystem level is the only way to move forward.

7.2 // Limitations

The design roadmap that is developed is mainly taken from a desirability perspective. This is also considered as the main limitation of this research. The product-service offering of the design roadmap will require high research and development costs and can thus be considered as a high upfront investment. As a result, the proposed product-service offering will not lead to immediate sales. On the other hand, looking at a product proposition from a shared desirability perspective will lead to recognition of a shared pain point, which is essential due to the interdependency of the ecosystem. Furthermore, a telecommunication infrastructure provider or investment company needs to see value in buying the (Gbit) luminaire hosting fixtures, as cities do not have money to buy them, and mobile network operators prefer to rent the space inside the luminaire or pole. The likelihood that mobile network operators will make use of the hosting solution is high as long as they can put their own equipment into the luminaire fixture and that it can connect both optical fibre and wireless technology. Furthermore, the investor of the Gbit luminaire hosting fixtures should own many hosting fixtures in a country so that mobile network operators can place 5G small cells based on their own strategic objectives. Horizon 1 of the design roadmap also will require BrightSites to look more at countries that are frontrunners in the 5G rollout, as in the Netherlands, the entire 5G rollout will still take some years.

Moreover, the design roadmap heavily relies on strategic alliances. From a technical perspective incorporating small cells into luminaire fixtures requires complicated engineering input, as this has never been developed before. Another option would be to create a luminaire fixture that can host telecom equipment inside the pole, under the luminaire fixture. This is technically considered feasible; BrightSites is already doing something similar inside their smart poles. However, the challenge would be to make it still a plug-and-play solution and keep the costs relatively low.

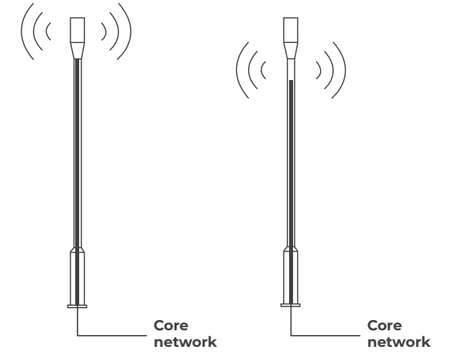


Figure 7.1 - (Gbit) luminaire small cell hosting fixture (left), (Gbit) luminaire fixtures with small cells incorporated under the luminaire (right)

The benefit for BrightSites is that there are only very few telecom equipment vendors that develop small cells worldwide. In the Netherlands, KPN mainly works together with Nokia, T-Mobile with Huawei and Vodafone with Ericsson. This means that luminaire hosting fixtures need to be optimised based on the existing partnerships of mobile network operators in a specific country. The advantage for BrightSites is that mobile network operators are highly unlikely to switch from equipment vendor as this is perceived as a 'marriage like' relationship. The disadvantage for BrightSites is that these telecom equipment vendors are influential. BrightSites will thus have to heavily rely on partnerships with these telecom equipment vendors to make the hosting vision a reality.

Figure 7.2 - The very few telecom equipment providers worldwide

7.3 // Final recommendations

BrightSites is currently targeting four key domains: 1. Fixed Wireless Access for buildings, 2. Backhaul connectivity for 5G networks, 3. Private networks for university campuses, businesses, industrial parks, ports and arenas; and 4. Smart cities. Below the key lessons learned from each domain are further motivated, along with my recommendations.

Fixed Wireless Access for buildings

The current target locations are homes, schools, communities and hospitals. The challenge observed with providing fixed wireless access to homes, communities and schools is that internet service providers are already deploying fixed wireless access services without aesthetic integration of the mmWave radio. Examples of big market players are Verizon and AT&T operating in the United States. For around 70 US dollars, these market players already bring 5G home internet. In Europe, Telia Estonia, the leading telecom service provider in the Baltic states, likewise provides fixed wireless access services without any aesthetic integration of mmWave radios on the lighting infrastructure. The main challenge I foresee is that internet service providers already have their own strategic objectives for network deployment. In addition, based on the lessons learned from KPN's telecommunication course, population density highly influences the communications network design for internet services. Meaning, that optical fibre roll-out is prioritised in the most densely populated areas.

Furthermore, providing fixed wireless access to buildings is a deliberate decision-making process of internet service providers. First, internet service providers build a network design based on their own business processes, not on a lower network deployment cost calculation of BrightSites. Based on expert input, internet service providers set up nationwide standards and use the same equipment nationwide.

To illustrate the challenge for BrightSites, see the scenario below:
Imagine BrightSites sees an opportunity to provide fixed wireless access via the lighting infrastructure in a residential area. The first thought an internet service provider will think of is how stepping into another domain, the lighting industry, fits their current business processes. Second, how this solution can be scaled to other residential areas and locations. It can be concluded that internet service providers do not care about aesthetics; they care about the services they can provide, the scalability and the homogeneity of their network devices.

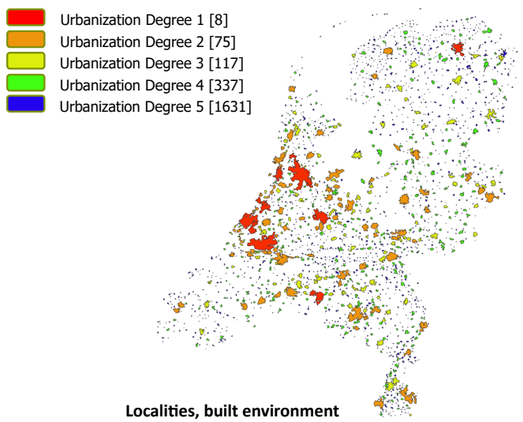


Figure 7.3 - Location density influences network design, source: ET4034 Telecom Business Architectures and Models course Tu Delft

This scenario shows that internet service providers need to see the fit with their current business processes and scalability over the country; without this fit and scalable outlook, it is doubtful that they will invest in a Gbit luminaire infrastructure.

Recommendations for providing fixed wireless access for buildings

Regarding sales and acquisition of customers:
- Create a map of existing internet service providers and their current view towards fixed wireless access. For example, in the Netherlands, fixed wireless access is not even part of internet service providers' corporate strategy. However, in the USA, for example, two large internet service providers, AT&T and Verizon, already offer fixed wireless access services.
- Create a map of the view of municipal networks. In the Netherlands, municipal networks are perceived as a market disruptive action. For cities in which municipal networks are legally allowed, the combination of providing fixed wireless access and aesthetic integration of mmWave radios on the lighting infrastructure could be attractive.
- It is critical to create in-depth customer profiles of existing market players, countries and cities.

Regarding network operation:
- Market players expect full integration of the dashboard with the more extensive management system.
- Municipalities prefer full integration of the dashboard with other smart city services for data-driven insights.

General recommendation:
- In hospitals, life and death occur; therefore, hospitals expect the most reliable backhaul technology, and therefore cost will not be an issue. In addition, network downtime is extremely harmful, so it is unlikely that wireless backhaul technology is the preferred solution for healthcare locations.
- Because of market players their financially driven nature, scalability of a solution is crucial. Therefore, by approaching market players the communication regarding deployment should always happen on a wide scale level, thus not on a single scenario.
- If fixed wireless access does not align with a market player's corporate strategy or network roll-out plan it is highly unlikely they will invest in a Gbit luminaire network infrastructure despite possible cost savings.

Backhaul connectivity for 5G networks

BrightSites luminaire infrastructure can provide the backhaul connectivity for future 5G networks. This wireless backhaul connectivity and aesthetic integration are mainly of interest for cities, as they dislike urban clutter and drilling optical fibre disrupts city life. However, without regulations holding market players back, they will continue placing their small cells on public assets. Based on the Dutch telecom law, municipalities need to make public assets available for telecom equipment. The same applies to mobile network operators as for internet service providers in that they prefer homogeneity of their network devices and backhaul technology. In addition, as of today, BrightSites can only host small cells in a smart pole in the current product proposition. Mobile network operators can not justify these costs, and lighting does not belong to their core business. If mobile network operators see the solution as solely a wireless fibre extender, they can offer the same capabilities with a separate mmWave radio. Based on KPN's telecommunication course, mobile network operators are still thinking of the best 5G roll-out strategy, but what is certain is that thousands of small cells need to be installed for the entire 5G roll-out. When this 5G roll-out happens is uncertain, but what is certain is that the regulations set by the central government are leading the 5G roll-out strategy of mobile network operators.

Recommendations for backhaul connectivity for 5G networks

Regarding sales and acquisition of customers:
- Create a map of existing mobile network operators and their view towards neutral host solutions and a shared network of IoT devices. From a maintenance, security and management perspective, it might conclude that certain mobile network operators do not want to have a shared network.

Regarding network operation:

- Create a map of existing mobile network operators and their view towards neutral host solutions and a shared network of IoT devices. Based on this research, mobile network operators that see the network infrastructure as part of their portfolio are less likely to hand over network operation to an external party.

General recommendation:

- Re-design the Gbit luminaires to host small cells for a lower buyer price than smart poles. Small cell roll-out will happen in large numbers; therefore, the costs of the hosting solution needs to be reasonable and able to be justified in a calculation of return on investment.
- Mobile network operators are struggling to find new antenna locations. At KPN alone, 70 people work daily to find new antenna locations. For companies that do not see potential in connecting small cells wirelessly, BrightSites could still be impactful by offering luminaires that can aesthetically host small cells with an optical fibre connection. Therefore, the following recommendation: develop Gbit luminaires that can host small cells into one fixture with the option for market players to use an optical fibre connection or a wireless backhaul technology.
- The power BrightSites has over mobile network operators is that they have access to the lighting infrastructure and innovation capability for aesthetic integration. Mobile network operators have two reasons to strengthen the ecosystem based on the developed value framework: financial rewards and increased brand strength. Even for mobile network operators who prefer a wired backhaul technology, BrightSites could still start the conversation by highlighting the negative brand perception for the mobile network operator if they are perceived as the ones cluttering the urban environment. Combined with a re-design of the Gbit luminaire that can host small cells with an optical fibre connection, BrightSites will satisfy the needs of both mobile network operators and cities.
- Focus on visualising the effect that BrightSites can bring to mobile network operators, not from a cost perspective but a human-centred perspective.

Private networks

BrightSites Gbit luminaire infrastructure can support private networks for university campuses, businesses, industrial parks, ports and arenas. These locations benefit both from energy-efficient LED lighting and high-speed connectivity; therefore, it is logical to have these locations as a target segment. The challenge, however, is that nowadays, the connectivity for these locations is either provided by fibre suppliers or internet service providers, and they do not care about aesthetic integration. They instead need to be convinced about the scalability of the Gbit luminaire infrastructure to other locations and the fit with existing network operation. It is doubtful that internet service providers or fibre suppliers will change their business processes for a single location.

Recommendations for private networks

Regarding sales and acquisition of customers:

- By stepping into a new product domain, internet service providers and fibre suppliers will need to change their current business processes. A recommendation for approaching the market would be to focus on scalability by mapping out multiple locations of interest. A single business case is never of interest to big market players. However, scalable solutions could be a reason to change current business processes and see potential in a Gbit luminaire network infrastructure.

Regarding network operation:

- Create a map of existing internet service providers and fibre suppliers and their view towards neutral host solutions and a shared network of IoT devices.

General recommendation:

- Collaboration with the owner of the infrastructure and the stakeholder who will operate the network is critical. Without this alignment, network rollout is impossible.
- Because of market players their financially driven nature, the scalability of a solution is crucial. Therefore, by approaching market players, the communication regarding deployment should always happen on a wide-scale level, thus not on a single scenario.
- If fixed wireless access does not align with a market player's corporate strategy or network rollout plan, it is doubtful they will invest in a Gbit luminaire network infrastructure despite possible cost savings.

Smart cities

The perspective of this research is purposefully taken from a municipal decision-maker perspective as it becomes inevitable to leave municipalities out of the conversation as they are most often the owners of the light poles in European cities. A wireless connectivity system on the lighting grid could offer backhaul technology for a wide range of smart city IoT. However, the only sensors that require high-bandwidth and real-time transmission frequency are cameras. Another use case a wireless connectivity system via the lighting grid could support is public Wi-Fi. A contradicting finding of interviewing Dutch municipalities is that public Wi-Fi is considered as an outdated vision. Therefore, more research regarding initiatives of public Wi-Fi was executed to understand the standpoints of other European cities.

Wi-Fi4EU is an initiative from the European Commission to provide free Wi-Fi to public spaces, including parks, libraries, schools and museums. Thirty countries participated in this initiative, and in total, 29261 EU municipalities registered for a free public Wi-Fi funding of the European Commission.

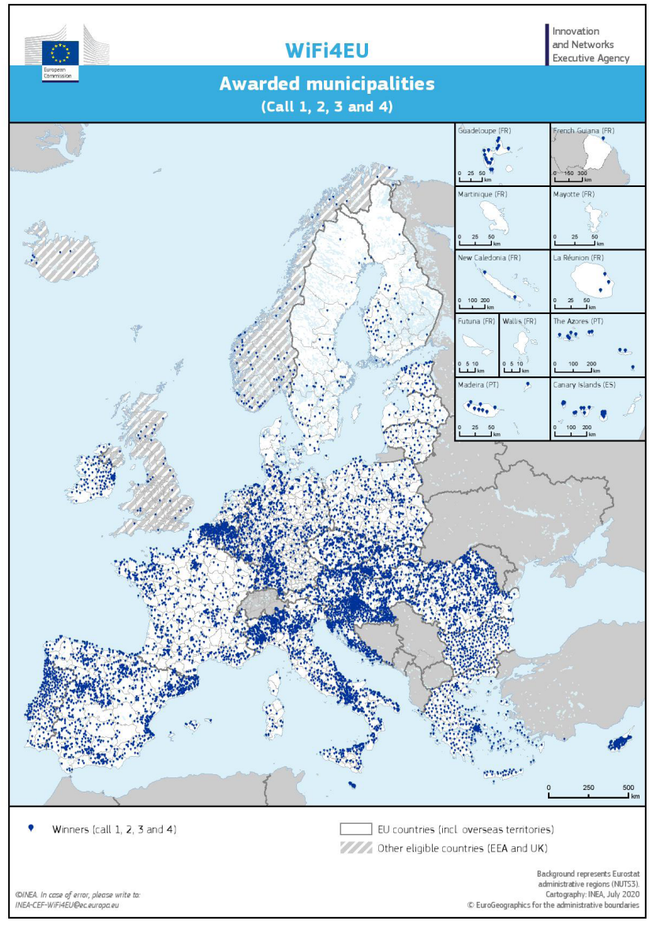


Figure 7.4 - WiFi4EU initiative (European Commission, 2020)

The findings show that many cities that had an interest in public Wi-Fi already applied for public Wi-Fi funding, which is now being installed every day across cities in Europe.

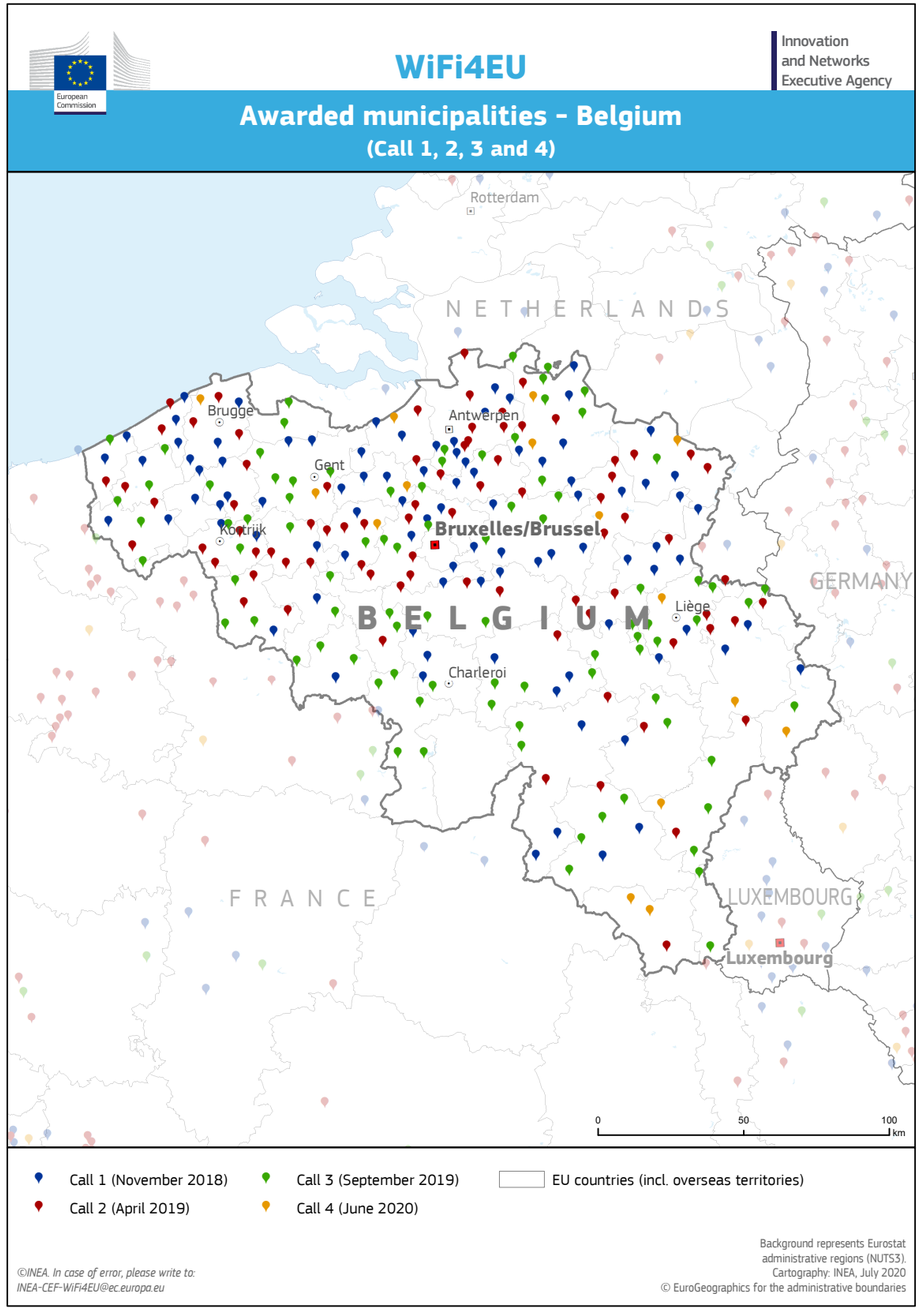


Figure 7.5 - WiFi4EU public Wi-Fi funding in the Netherlands and Belgium (European Commission, 2020)

Recommendations for smart cities

Regarding sales and acquisition of customers:

- Focus mainly on 5G rollout for smart cities and the bridge BrightSites can be in the negotiation process between cities and mobile network operators. See horizon 1 in the design roadmap. For the following reasons:
- Traditional street cameras are placed where it is needed from a safety & security perspective; therefore, it would not be the primary trigger to invest in such an infrastructure.
- In the future 5-10 years, more innovative cameras will become part of the city landscape that could benefit from such an infrastructure, such as AI-based traffic cameras. However, cities do not have the budget to invest in a future promise. In addition, a threat could be that most IoT smart city technologies will run on 5G telecommunication technologies in the future, making a wireless connectivity system on the lighting grid obsolete for cities.

Regarding network operation:

- Municipalities do not have the skills to operate a wireless connectivity system via the lighting grid.
- Mobile network operators, telecommunication infrastructure providers, internet service providers and fibre suppliers have the technical capabilities to operate such a system, however their motives need to align with city goals and regulations.

General recommendation:

- In order to become a relevant player in the smart city of tomorrow, a product proposition should always be viewed from an ecosystem level and not solely from a product level. It must be clear for every stakeholder involved what will change for this party to commit, access or invest in BrightSites' proposition. The value framework developed in this thesis could map out stakeholders and their value creation and capture mechanisms per business case. If this is not aligned or one party steps out of the ecosystem, the Gbit luminaire proposition will not go beyond a pilot project and come into danger.

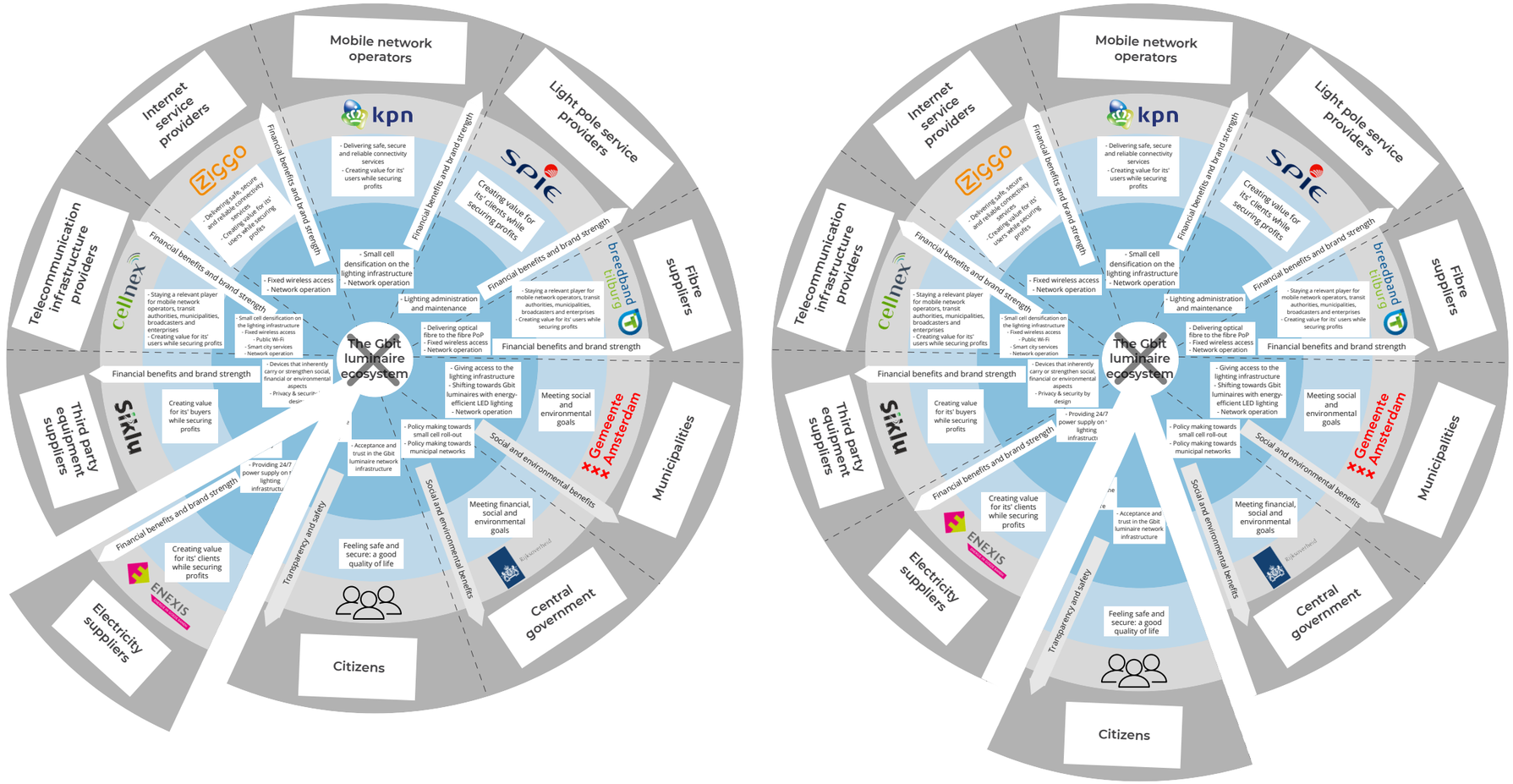
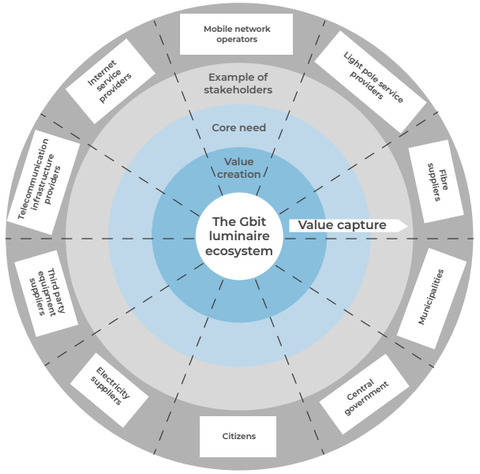


Figure 7.6 - Dependencies in the Gbit luminaire ecosystem

Messaging towards the market: A Wireless Connectivity System via the Lighting Grid

Regardless of the business case, the overall recommendation is based on four pillars. First, to focus on the common interest in the ecosystem. It is observed through this research that satisfying the needs of the paying customer will not automatically lead to widespread deployment. Second, embrace joint value creation. BrightSites has the innovation capability to make outstanding products. However, they will need the input from every stakeholder inside the Gbit luminaire ecosystem and recognise that this proposition needs to be positioned jointly. Third, to focus on human emotions. This might not be the most self-evident way to get customers on board for technology-driven ventures. However, note that market players and municipalities are always at the service of people. Stress the positive emotions the product proposition can create or the negative emotions the product proposition can eliminate. Fourth, highlight the fit with existing business processes or city strategy. Without a perceived fit, it is doubtful that a market player or city will invest or provide access to the lighting grid.



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Our 2021 – 2023 strategy

We live in an era of digital transformation. Driving demand for flexibility, autonomy and personalized experiences. That is why we increase our efforts to improve and digitalize the user experience of our products and services. We want to offer the best solutions for everyone; families or businesses, at home or on the move. Our solutions will give access to the best possibilities in the digital world. We will deliver premium converged services, which are simple, digital and flexible.

KPN has identified three key pillars underpinning its 'Accelerate to grow' strategy:

1. Leverage & expand superior network
2. Grow & strengthen customer footprint
3. Simplify & streamline operating model

With this strategy, KPN will continue its progressive dividend policy, covered by Free Cash Flow, and it will grow mass-market service revenues and EBITDA. It will also lead the Dutch digitalization wave to connect the Netherlands to a sustainable future.

Leverage & expand superior network

The Manchester Strategy

If you were one of the tens of thousands reached by our consultation on how to make Manchester into the place you'd want to live, work, play and do business in 2025, thank you for being part of such a huge, inspiring response.

The strategy is the culmination of that response. People's commitment to the city, and their desire to see its future success, shine through it, and it's a credit to all who contributed including:

- Manchester residents themselves, in their thousands
- the city's army of volunteers (our city has around 100,000) from tiny clubs to business-scale operations, and community activists
- a wide non-resident public – some of our city's biggest fans – who work in the city or visit to enjoy our varied culture and leisure
- business and civic leaders from the city and the city region who added their valuable insights, revealing the extent of their own crucial part in delivering Manchester's success.

Responses from across the city were many and varied, but a few themes came through again and again. People of Manchester share the desire to see the city do well, to see Manchester use and value its green spaces, to have a clean city with one of the best public transport systems in the world, to preserve its historic buildings and support those in need.

We've summed up our vision for Manchester and the strategy's five themes:

Our vision	A thriving and sustainable city	A highly skilled city
A progressive and equitable city	A liveable and low carbon city	A connected city

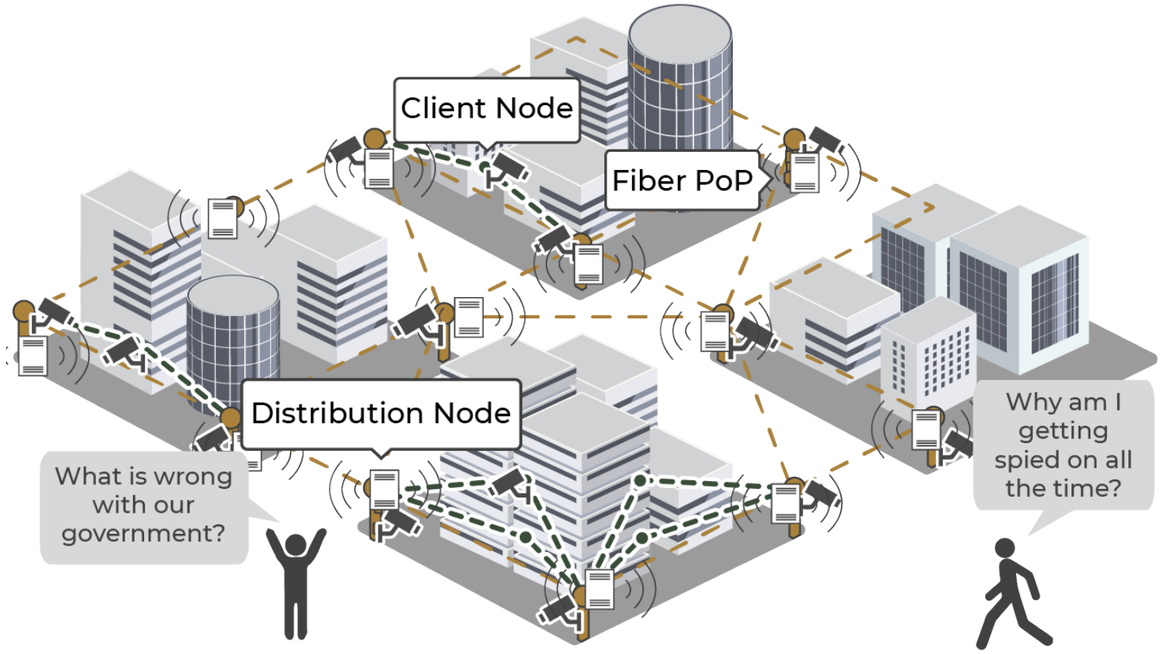
Focus on the common interest in the ecosystem

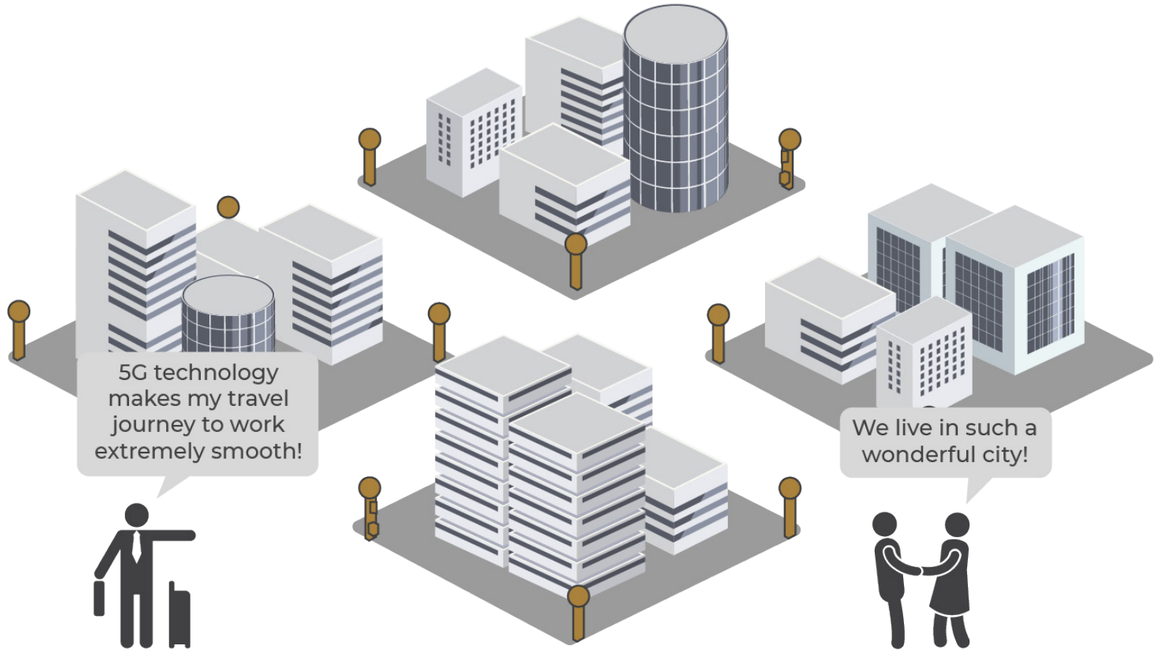
Joint value creation

Touch upon human emotions

Highlight the fit with existing business processes or city strategy

The pictures below show a fictional district in the digitally connected city of the future. The picture on the left shows the effect of the current proposition by Gbit luminaires. The picture on the right shows the effect if BrightSites offers (Gbit) luminaires that focus on hosting and concealment.





The (Gbit) luminaire offering

The problem with the existing Gbit luminaire proposition is that it is not touching upon a shared pain point or common desire in the ecosystem. The findings of this thesis show that by looking at the proposition from an ecosystem level, hosting and concealment is the domain BrightSites can be market-disruptive in, and as a result, thrive in the digitally connected city of the future.

7.4 // Personal reflection

Quote

"We do not learn from experience. We learn from reflecting on experience."
· John Dewey

As John Dewey stated: "We do not learn from experience. We learn from reflecting on experience." For this reason, I would like to reflect on my graduation journey at Signify, which has truly been a wonderful rollercoaster journey that I will not easily forget.

The industry

I can say from experience that graduating in the intelligent street lighting industry is challenging, especially with limited pre-knowledge. Yet, at the same time, I think it is the perfect industry where you can test your analytical skills and bring your strategic input as a designer by asking critical questions and using the right design methods.

When I started, I definitely underestimated the breadth of learning that is needed around BrightSites product proposition. The Gbit luminaire is not covering just one industry; it is covering multiple industries. It basically brings four industries together: lighting, data networking, IoT and telecommunications. It took approximately eight weeks to really understand what the venture was doing and trying to achieve. This was mainly due to the fact that I could not fully visualise the product in my head. From time to time, in the first weeks, I could feel bad about not being able to grasp the product proposition. Now that I look back, I do not understand why I blamed myself for feeling like that. Especially because the product was still in the early product development phase and the overflow of new terms of not one but four industries. I think what I would have done differently, if the situation would have allowed so during the pandemic, to ask if I could see the mmWave radio and luminaire in real life. I think that would have made a big difference for me to understand the product proposition faster. Learning about networking and telecom from all the industries felt the most complex, but it was critical to understand as half of the product proposition is about transferring data. Even though I followed physics classes in high school and university, the terms in networking and telecom are very industry-specific. I still remember that I was watching computer networks basics videos at Khan Academy in the first weeks. I had to take it step-by-step to get a certain base knowledge. Now, a few months later, my interest in these topics only grew over time. I realise that connectivity will only become more important, regardless of the industry. I am also happy that I could spend a large amount of my time as a student being engaged in a topic that will define the way people will live, interact and communicate in the future.

BrightSites, Signify

Executing my graduation project at BrightSites was really nice, exciting and educational. Even though I completed the graduation project from home, I never felt it was a dull topic or industry to work in. Even now I have finished my thesis, I still have many questions and topics I should learn more about, but I think that is the nice thing about working in a venture, that your way of working has to be very agile and adaptive as there is always the next thing to learn. I feel joining some of the team meetings has been very nice to watch, especially how the team sets goals and the way of working inside a venture. I mostly joined the meetings on Tuesday with the Shanghai team for software development. Even though I decided not to focus my graduation thesis on software, it helped me understand the technical side of the product better.

The graduation process

During the graduation process, I was the most stressed at the beginning of the project. This may sound strange to most people that this was not in the middle or end but at the very early start. I feel it was very easy to doubt myself knowing little, in a technology-driven venture, with a completely different way of working, on what I considered an important moment of my life. Therefore, I had to change my mindset to embrace the unknown, trust the process and remind myself that if you are the smartest in the room, you are probably in the wrong room. :)

I was part of the software team, which was very nice to learn about new product development for the Gbit luminaire. However, I did not feel writing my master thesis about the software would be truly meaningful from an academic and a company perspective. This was mainly due to the fact that the dashboard design had to look very similar to the existing Interact City dashboard. However, I did start interviews with cities and Interact City experts, which I could relate back to the software. I noticed that what people outside the company environment were saying were so different from what people inside the company were thinking about specific topics. Therefore, I spent around six weeks on software development and competitor analysis, and after that, I changed my research question to investigate the role of the Gbit luminaire inside cities.

One of the learning goals I set up was that I wanted to learn about new product development. What I learned is that it is super easy to trap into tunnel vision thinking in the new product development phase. I realised that I was also trapped in tunnel vision thinking for a while in the ideation process because the biggest question is to find the most addressable use case internally. Therefore, I started to spend much time scouting use cases through application technologies that mostly only address the needs of one customer. However, by thinking of the most addressable use case with application technologies, I was deviating from the developed value flow framework in this thesis that advocates that the product should be perceived from an ecosystem level. After I broke free from my tunnel vision, it put two questions in my head for ideation: 1. What can BrightSites offer that other players cannot? And 2. What is the shared pain point that the product proposition is solving in the ecosystem? These questions evolved from my research, and I think these are critical to answer for product success.

Now looking back, I feel I grew a lot as a person and a strategic designer. I had to overcome some hurdles, from shaping the project, learning a breadth industry and bundling contradicting visions. However, it was a fascinating industry to graduate in. I am happy with the end result and findings despite the hurdles and project complexity. I am also convinced of my findings and how I would position the Gbit luminaire in the digitally connected city of the future. I believe there is big market potential for BrightSites if they can evolve building on shared needs inside the ecosystem. This is also what I hope my thesis will bring about, that looking at the product proposition from most addressable use cases or buying customer perspective is probably not the way to go as this only serves the needs of one single stakeholder. Therefore, I hope ecosystem thinking will be part of every single step of the innovation process. From product development to serving customers, I think in this way, BrightSites will create many "Aha" moments for stakeholders, which will make luminaire fixtures thrive in the digitally connected city of the future.

For future graduates: everything will come okay in the end; just do your best, enjoy the journey, and if it is not okay, it is not the end. :)

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Appendix I: Connected lighting experts, Interact City

Experts:

- System Expert Public Segment Interact City cellular lighting
- System Expert Public Segment Interact City cellular lighting

Research objectives:

- Understanding the process towards monitoring, controlling and managing LED street lighting using Interact City
- Understanding the world of a lighting operator; empathising with the user of Interact City
- Understand the pain points of customers using Interact City
- Find out what features of Interact City are needed in the network operating tool of Brightsites

Key insights:

- Interact city is currently shifting from City Touch to a new Interact City interface.
- 99% of the customers still use the old City Touch platform, in terms of asset management it is 100% the same as the new Interact City UI.
- In May, Interact City will run the first pilot with the new Interact City dashboard in Europe.
- The main function of lighting operators in Interact City is fault and asset management.
- One of the most common faults is that the luminaires are not connected and thus can not be controlled remotely.
- The job of a lighting operator is not a job that requires a lot of thinking. Analysing light points is a completely different line of work compared to analysing a data network.
- One of the important day-to-day tasks of a lighting operator is to detect faults.
- Interact City shows an action plan in the dashboard, which makes it very easy for lighting operators to know which steps have to be made in order to solve a fault.

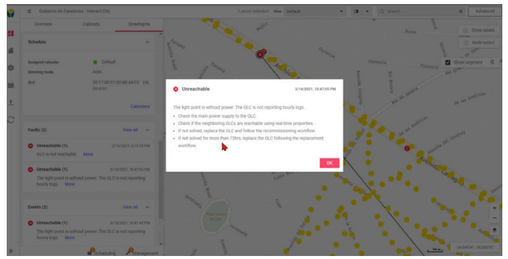


Figure 1: Action plan on how to solve faults using bullet points

- A growing number of Interact City customers are making use of the Global Operations Center in India to manage and monitor Interact City networks.
- Most of the faults in Interact City only get visible after 24 hours, this can take up to 48 hours, and only after 6 days the system registers it as a critical fault.
- The level of urgency in solving faults with regular luminaires is lower than with Gbit luminaires
- According to the experts, it does not contribute much for the lighting operator if they will receive information about the data networking part.
- Luminaires can be added to Interact using an excel file. There are no foreseen difficulties by merging Gbit luminaires with regular luminaires into the Interact City dashboard. In a combined dashboard Gbit luminaires could just have a different icon.
- Interact City has at the moment two plans for the future: environmental monitoring and incident detection. However, the dashboard at the moment only shows if a sensor is working or not.
- The Interact City expert assumes that the customers of Brightsites proposition are not just the regular lighting and network operators, but city administrators. The needs of these people go beyond lighting and data networking.
- In 2012 one interviewee worked on a project called city service beyond lighting: in this project he also worked on developing smart poles. This project never became a commercial success. The interviewee advised to look into the practical application for cities.

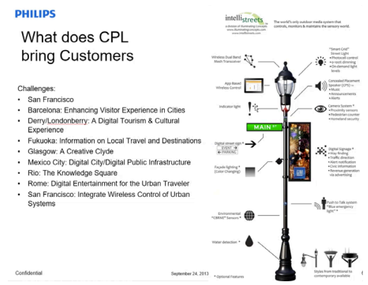


Figure 2: City service beyond lighting project

- One interviewee sees the revenue opportunities for cities mainly in the digital advertising screens.
- One interviewee prefers the old user interface of Citytouch regarding fault management. In the new UI of Interact city, the lighting operator only distinguishes between yellow = nothing is wrong and red = something is wrong circles. While in the old UI, there were different types of icons, making it easier for the lighting operator to understand which kind of mistake occurred. In the New UI, the lighting operator has to figure this out himself.

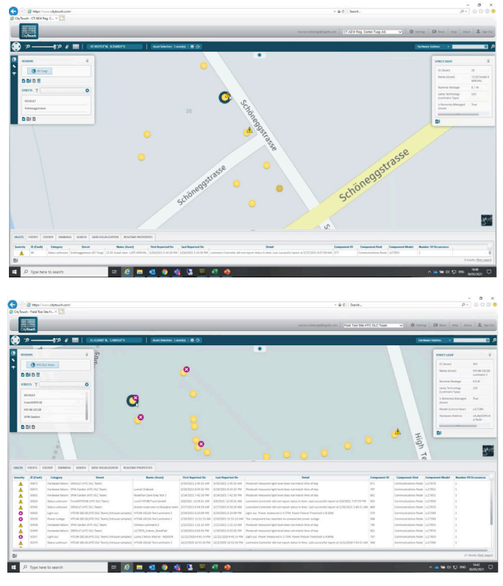


Figure 3: City Touch interface

- It is most important for lighting operators to look at a dashboard and understand immediately what to do. According to the Interact City expert, this became more difficult in the new Interact City interface.

What can Brightsites learn from Interact City?

- Clear action plan on how to solve problems does not require much technical understanding.
- Visualisation on dashboard, based on user profile the customer will see different dashboards.
- mmWave radios can easily be added to the Interact City dashboard by adding them into an excel file.
- mmWave radios can easily be added to the list of properties.
- Interact City's consistent style and branding strategy over different platforms; Interact City; Interact Hospitality; Interact Office; etc.
- Operating and managing a lighting network is not as complex as managing a data network with mmWave radios. Next to this, it is not as bad if a single luminaire is not working compared to having network downtime.
- It does not contribute much for the lighting operator if he will see information about the data networking part. However, for the Gbit luminaire it is a must to see if the device receives power.

Directions for exploration:

- What other platforms do municipalities use for asset management; how does Brightsites dashboard integrate with existing asset management platforms?
- How can the data of the operating phase result in new insights and services?
- What are the challenges of municipalities with building and handling digital infrastructures?

Appendix II: Data networking experts, BrightSites

Experts:
- Product architect
- Lead development engineer

Research objectives:
- Understanding the general attitudes towards operating a network
- Understanding the challenges of operating a network using Gbit luminaires
- Understanding the general attitudes towards existing network operating tools
- Find out what features are needed in a data network operating tool using Gbit nodes

Key insights:
- Network operators have certain expectations before setting up a network. The main goal of network operation is to check if a network is performing as expected.
- The application of this gigabit network differs: e.g. cellular backhaul versus fixed wireless access. Depending on the use case, certain features in a network operating tool would become more relevant. For example, latency is very important for a cellular network operator, but it could be irrelevant for someone delivering fixed wireless access for public purposes.
- This could also be a software implementation; for instance, when you start a project or your commission or set up a project, it could show more or less of these features.
- "In my view what we deliver to the customer is a kind of network addition or network expansion."
- I can imagine municipalities see the BrightSites proposition as a kind of means and it should be there working fine periods, we don't want to think about it just the same as you assume that if you have a home network connection to the Internet, you just assume it is there. And indeed for these kinds of customers, the dashboards could be really limited. The dashboard showing the gigabit network could just be status, okay, or status not okay and add some basic alarms, nothing more, nothing less.
- Steps of monitoring a network: 1. Check if the day-to-day performance is working as agreed on, 2. Check alarms, 3. Foresee future problems.
- Network operators do not have to be aware of the deep technical functionalities of the device. But, they have to be aware of network aspects, speeds, bandwidth, throughput, latency and being able to act upon this.
- There might be customers that would like to be pleased to have one single dashboard for all applications.
- The biggest fear of a network operator is network downtime. Networks with single fibre points are at the biggest risk of network downtime.
- For certain smart city applications, network downtime is disastrous, e.g. autonomous vehicles. We, as Brightsites, would have liability issues. Not much of a good promotion for Signify also.
- Before setting up agreements with municipalities, it is essential to understand how they look at Brightsites' proposition.
- If a link is very crucial inside a network, then the list of actions on how to solve a problem could be different.
- "I do not think we are in the position to provide real network management software to the operator."
- A future software tool could give information about third party devices. The current mmWave radio vendor will not give this type of information, at least not on the level that I think that will be useful for external stakeholders.
- Third parties have to pay to install their devices on the network. These devices require energy and data backhaul. At the moment there is a theory that companies can add their devices to the luminaire, but how do third parties know where their device is placed and for how long.
- I mean, in the end, lightning is managed by somebody, they do not have network knowledge. Furthermore, the network of operators care even less.
- How to send the relevant type of information to the relevant party, do not bother lighting operators with network operations, and vice versa. And for the third parties, they do not want to worry about the lighting and the networking, but they do worry on whether they get power and how much.

Appendix III: Planning phase software

Company: Siklu

Name of the product(s): MULTIHAUL tm TG TERMINAL UNIT T265	Name of the product(s): MULTIHAUL tm TG NODE N366 b base unit	Name of the software tool: Winde

Pro' s

- Clear process, the customer can anticipate on the next step of the network planning process.
- 2 type of viewing settings: roadmap view and satellite view
- Clear visual representation of unconfirmed LOS, confirmed LOS, no LOS & wired link. This information can easily be accessed in a legenda.
- Multiple area selection tools
- House detection feature
- 3 ways to import a network location: Manually by creating a new KML (keyhole markup language) file Existing Google earth KML/KMZ file Excel file (xlsx file)
- Network designs can be exported to multiple file types:
- Ease of adjusting an existing node
- Clear visual representation if its a PoP node / or not

Con' s

- The google earth functionality is not up-to-date compared to the Google Earth Pro app
- No option to design for a specific use case of the Terragraph technology:
  - Fixed wireless access
  - Mobile backhaul
  - Outdoor WiFi
  - Smart city services eg. cameras
- In the dashboard you can select if the node is a terminal unit or base unit. However, this is not visually clear in the dashboard. Base units and terminal units look the same visually.
- The dashboard only has a map view, the list view only becomes accessible after downloading to a CSV or XLSX file
- Advanced Design Configuration needs user manual
- Limited link info by clicking on the link, could be extended with extra information, see Google Earth
- The software tool does not identify existing fiber networks

Opportunities

- If the longitude and latitude of (existing) (smart) lighting poles is known then this could be an extra feature in the dashboard
- Coverage heat maps inside the planning dashboard with visual legenda, e.g. at Google network planner
- Fiber network identifier
  - important to know if it makes sense to deploy a GB luminaire or just a normal smart pole
  - Crucial to know where to place the PoP, this is the base unit which is connected with existing fiber
- Path profile of a link/ coverage and line of sight
- Show the population density: number of people living in area
- Selection area tool for luminaire identification/ fiber identification instead of housing detection only
- Show the amount of area covered with the mesh network
- Average current network speed per area
- Impact calculator
- Expected network speed per area

Company: facebook connectivity | Cambium Networks

Name of the software tool: Facebook advanced network planner and link planner	Name of the product(s): 60 GHz cnWave - distribution node - base unit	Name of the product(s): 60 GHz cnWave V1000 - client node - terminal unit	Name of the product(s): 60 GHz cnWave V3000 - client node - terminal unit	https://www.youtube.com/watch?v=MZlU3zrrdE84&t=478s

Pro' s

- Network plan and asset list
- Clear overview of status of plans and last created projects
- Compatibility with Google Earth
- Clear site list to adjust where each base unit or terminal unit is located and on which height
- Clear process, the customer can anticipate on the next step of the network planning process
- The circle with the i gives extra information about the feature, e.g. the boundary polygon is the area you want to cover in your design
- Pre-uploading function from Google Earth files: select existing file and upload a new file
- Information about user who created the .kml file
- Specify cost, capacity & demand parameters
- Visual representation of network
- Change settings of network plan e.g. with color
- User manual that can be accessed inside the software tool
- Report proposal generator
- Specific information about terminal unit and base unit
- Text file with optimized plan
- Optimization of network design

Con' s

- In the dashboard you can select if the node is a terminal unit or base unit. However, this is not visually clear in the dashboard. Base units and terminal units look the same visually.
- The link planner is not only suitable for Terragraph technology products but also other products
- Signal strength indicator legenda

Opportunities

- Showing assets in the final dashboard
- Report

Appendix IV: Stakeholder analysis

Municipality and smart city experts

Experts:
- Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht
- Process Director for the Living Environment, Municipality of Tilburg
- Infrastructure Engineer, Municipality of Delft
- Advisor Lighting, Innovation and IoT, Municipality of Eindhoven
- Advisor of Innovation and Digital Technology, Municipality of Breda
- Program Manager for Digital Connectivity, Municipality of Amsterdam

Clusters:
- Value of BrightSites proposition
- Imagining the future
- Challenges in Brightsites proposition
- Network management
- The current role of light poles
- Applications on the luminaire
- Task and needs of municipalities
- Current activities of municipalities
- Division of responsibility
- Current legislations
- Fit with existing infrastructure
- Lighting operation
- Position of a network operator
- Knowledge integration

Value of BrightSites proposition

- *"I think technologies like 5G and Brightsites technology are needed to meet the demands of municipalities in the future."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"It is important to look at how this technology has added value for municipalities. For example, I agree with the aesthetic value of Brightsites proposition."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"In the municipality of Utrecht, currently, 280 antennas are placed from different network operators. But because of the demand for data, more antennas are needed and municipalities do not like urban clutter."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"From a municipality perspective, the neutral host model is really appealing, that with one party you can manage the whole network. This is similar to managing utility services."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"It is a no-brainer for us that there is a need for cameras in the city."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I know that on one important point in the city, there are already 35 cameras installed."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"It is certain that the need for cameras will be growing. The question is where and when these cameras need to be placed."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I see the advantage of wireless camera connections, because I assume this will be cost-saving."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I believe there is much more possible in city with connectivity and sensors."*
  - *Process* Director for the Living Environment, Municipality of Tilburg

- *"I see a lot of value in BrightSites' proposition, because mobile network operators currently only base their operations on market demand. For inhabitants and municipalities, it is really disturbing if mobile network operators keep on drilling fiber. "*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"Eindhoven benefits from the City Beacon, since citizens can easily retrieve information about the city. We see the City Beacon as a multi-purpose object. This is added value from a marketing perspective for the city."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"The better the connectivity in a city, the better the economic value of a city."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"The municipality of Amsterdam wants to start a pilot, where we work with a neutral host solution, to investigate how small cell integration will have the least impact on the public environment, above and under the ground."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"Regarding climate goals, they say that 5G is more energy-efficient than previous telecommunication generations. But I think that the energy advantage correlates that more data traffic will occur."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"Regarding social goals, it is important that everyone is connected and that certain groups are not excluded from connectivity."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"Regarding economic goals, connectivity is essential for the city of Amsterdam; many tech start-ups are based in Amsterdam."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

Imagining the future

- *"Municipalities can not foresee how much data backhaul is needed at a specific location."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"It is essential to calculate how much data a use case needs. But nobody knows yet how much data capacity is required. The critical question is how much bandwidth does a city need for operation in a specific location."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"I think the need for connectivity is only going to grow."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"I do not expect that next year there will be a significant change compared to this year because this is dependent on the new frequency auctions. However, I believe that the upcoming years will change a lot; this will be dependent on the regulations, new technologies and the higher demand for connectivity. I believe that the municipality of Amsterdam wants to play a leading role so that they stay frontrunner on connectivity."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

Challenges in Brightsites proposition

- *"The stakeholder network from such a system is complex; I think that every party will see the value on the basis. But, how do you come to a common agreement that fits the existing business models of the company? Municipalities do not have a business model. But Signify, KPN, camera suppliers all have their own business models and this needs to match each other."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"It is essential to calculate how much it will cost for mobile network operators to use Brightsites technology compared to their own network rollout. This is also a playing field a municipality does not want to join in."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"I think that a municipality will never operate a digital network in the living environment for others. They can also not do this because this does not belong to their primary tasks."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *"The digital knowledge to think of managing a network is relatively low inside municipalities."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *"I do not see it happening that municipalities will roll out a basic network infrastructure for third party devices. It is the same as why would a municipality roll out a water supply network or gas network. The municipality will contribute to realising it, but they will not help in investing in it. "*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *"I think that the municipality of Utrecht will be open to this technology, but realising and maintaining it, is something I do not see happening. We will support the proposition, but we don't want to be responsible for it. I do not see it happening that the municipality will be responsible for 5G networks."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- Challenges of rolling out a new network infrastructure on the lighting grid: 1. Excavation work leads to nuisance in the city and capital destruction of existing assets, 2. Aesthetic fit, in general this is an issue and this even becomes more an issue inside historic city city centers. *Environment committees (commissie omgeving in Dutch) will decide if there is an aesthetic fit.* 3. The skepticism about radio waves. *A municipality needs to be able to give grounded answers to its citizens regarding these concerns.* 4. Legislation regarding 5G.
  - Process Director for the Living Environment, Municipality of Tilburg

- *"What is extremely important regarding the application of this infrastructure is whether mobile network operators take the access offered to them or if they can make their own choices in building out a network."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"We as a municipality see the added value of BrighSites' proposition, it is a beautiful and an important solution. However, the legal and financial aspects must be properly researched. Furthermore, the question is whether mobile network operators will use this solution eventually or if they will just roll out their own network. That is a very crucial question for us, whether we will invest as a municipality into an infrastructure nobody will use."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"The problems and challenges in the world are becoming more complex. Therefore, interdisciplinary collaboration is needed. I see that in the project I explicitly search for colleagues from the ICT department, legal affairs, financial department/deelnemingen. As a municipality, we can not just see this as a public space issue. It can be that I am talking with you and we make a nice project, but it can be that a colleague from the legal affairs department after 1.5 years will say this is not possible."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I think it is very important to remember that this pilot project and applications need a multidisciplinary approach to become a success." This can not become a success by just looking at the project from a public living environment perspective."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"Costs are a dominant factor for the municipality. If the system of Signify is much more expensive than digging fibre or other solutions then the municipality will still dig fibre."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"Firstly, the legal aspects are very important for the roll-out of such a wireless connectivity project of Brightsites. Secondly, if the telecom operators will actually use this system. It is important to take into account how the business model of telecom operators will fit with Signify's solution."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I think the line of sight aspect is a risky aspect. This means that I can use my light poles less flexibly in the urban environment. Eindhoven, currently also has a task to place more trees in the urban environment. If we would place more trees in the urban environment then we would also create more risk in terms of data communication, using this mmWave. The question I have is how such a solution would fit in the existing urban environment and its upcoming plans."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"BrightSites is a progressive company, and Signify is the world leader in lighting. But they will need other parties for their proposition and admit that they need to position this jointly."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"It is as important to create a network of other parties that want to make use of this infrastructure network, think of suppliers."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"The market must come up with hybrid solutions that fit into existing systems."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"As a municipality, we will wonder what such a network means for the rest of the city architecture."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"It is still a mystery when small cells will be widely deployed; according to research from Dialogic small cells will not be widely rolled out until 2027."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"As a municipality present-day, we will not roll out our own connectivity, e.g. rolling out fibre. We did this before in Amsterdam east, but this is actually not allowed (disrupting the market)."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"The fibre we own in the city is purely for our own business operations. We will not roll out fibre for our own citizens or cities."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"Cameras in the future might be able to be connected through a 5G chip."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"The municipality will not invest public money in increasing connectivity, and they also do not have the budget for this."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"Essential factors for municipalities: aesthetic fit, radio wave radiation (important theme!), management, continuity of the network, financial attractiveness, ownership, sustainability (from which material is the product made, how much energy does it use)."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

- *"Costs are an important aspect for municipalities; next to this, aesthetic fit with the urban environment."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

Network management

- *"As a municipality, I do not envision us to manage this network ourselves. The management should at least be carried out by another party. But this is something we should discover in the upcoming months, and also involve colleagues from (juridische zaken en deelnemingen)."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"An optical fibre company is currently managing the network infrastructure for cameras, these are mainly placed on parking places."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I do not see it happening that we will be a direct owner or administrator of this solution in a next phase."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"Our municipality is quite a large organization. We have a separate department that manages the ICT infrastructure, so the optical fibre networks but also the networks in our municipality offices. I think it is more likely that a ICT department will manage such a network than the public lighting management department of the municipality."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"I think that the management of such a network will not be the responsibility of the municipality because I do not see the municipality as the direct owner of such a network."*
  - Advisor of innovation and digital technology, Municipality of Breda

- *"Network management is a profession on its own and should just be done by market parties."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

The current role of light poles

- *"Municipalities primary responsibility is to deliver lighting to create a safe space for all citizens."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *"Light is very important for municipalities because it contributes to the safety of the environment."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

Applications on the luminaire

- *"A municipality will not say in this period that we will deploy a widespread Wi-Fi network. Why? Because Wi-Fi is already widely available, and there are already other technologies such as 4G and 5G. This is a vision municipalities had 10 years ago to stimulate digital communication inside cities; nowadays many people already have access to the internet."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *The decision if more cameras are needed are always taken from a safety perspective. Another part of the organisation makes these decisions. Signify will never be able to decide for municipalities where they can place a camera. If, from a safety perspective, it is important to place a camera at a certain location, then they will just place a camera on that location by digging fibre.*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"In the city center we already have cameras for public safety, these are all connected with optical fibre."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

Task and needs of municipalities

- *"It is important to look at the needs of municipalities, what needs arise from the municipality's task, and how the products of Signify play a role in this."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *"I think as a municipality we should really look at what is our role, what is the usefulness, and what is the need for organising such a system in our city. So what does such a system mean for our citizens and companies, but also for our own operations."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"As the municipality of Tilburg we want to be a facilitator, initiator and launching customer for these types of solutions."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"It is very important to look at the end user of such a system. The municipality is also an end-user, but it looks at the tasks they are responsible for, for example, safe traffic facilities."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"In the future municipalities will acquire cameras and sensors for creating a better living environment. However, they will go to a supplier, and they will tell them you need to deliver me a good camera that is privacy proof. Then the supplier will say, yes, I have this camera and they will put a 5G chip inside this camera. And if the data of these cameras is sent through a Vodafone, KPN or Brightsites network, municipalities will not care about."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"For municipalities, safety is very important. It would be interesting to put the luminaires in specific positions to identify where Brightsites proposition is most relevant."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *If we as a municipality would invest in such a project, then we should really have a story to tell. And this is going broader than just the business case. My colleagues will definitely ask me, is this investment necessary, is it legally possible? But we should also have a story to tell, on how this is gonna improve the city. Even if the business would be that Tilburg is gonna earn 10 million with this solution, what I financially would consider as a success then there are still a lot of other questions the municipality has to consider. For example, if we as a municipality invest in this solution how will this then affect the sport clubs or the aesthetics of the city center?*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I worked myself in a corporate organisation as well, simply said if one euro delivers more value than it costs, then there is already a business. But this is definitely not how it works from a government perspective. From a municipality perspective, there are many interests that do not express themselves financially."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"The municipality will always play a role in safeguarding the public interest."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"As a municipality, we do not only look at the investment costs, but also at the recurring yearly costs. We do not only look at the investment costs, but also at the total costs of ownership. This total cost of ownership is set against the total cost of value, which is the total added value for the municipality."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"Setting up a network for a municipality is the same as if we would create a new lighting fixture, this is also not a direct task of the municipality."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"A municipality is a fairly conservative organisation. There is an urge to innovate mainly in the big municipalities, but definitely not in every municipality."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"Public lighting certainly belongs to the conservative club."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"For municipalities it is very common to continue with what already exists. There must therefore be a substantial added value."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"Creating a business model is not the core business of a municipality."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"We as municipalities are just responsible for the city's safety. We may need a wireless connectivity system, which one doesn't really matter, as long as it is a technology that is widely accepted by everyone."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

Current activities of municipalities

- *"On data.eindhoven.nl citizens can look up information that is collected in the urban environment. We are currently working nationwide to create a register with all the sensors in the urban environment that shows where a sensor is hanging, what kind of data it is being collected, and who owns this sensor."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"In the municipality of Breda we are currently experimenting with the Lora network, this is a Long Range, Low Power IoT connection specially developed to exchange small amounts of information between objects and systems."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"In Breda, we also do not have continuous voltage on the lighting grid. However, we currently have a pilot running with enexis."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"The upcoming 10 years, we will spend 22 million euros to transition to LED lighting and make our lighting infrastructure connected."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"In the municipality, we are currently working on a pilot to detect vehicles with cameras using artificial intelligence algorithms."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"30% to 40% of the municipality of Breda already consists of optical fibre. There is currently an initiative, that will be implemented this year or next year, to roll out 65 km of optical fibre for a municipal network."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"In the municipality of Breda we are thinking of how we can make new revenue streams of our assets. For example, we are currently making advertising signs available for JCDecaux, these are million euro contracts."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

Division of responsibility

- *"As the luminaire owner, a municipality would require to know what is hanging inside the luminaire, from who it is and under which requirements."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *"Suppose a KPN or Vodafone wants to make use of the municipality's luminaire (asset). In that case, a municipality will say you can use this luminaire and pay me a certain fee because you are making use of something that I own. But there will come some requirements from the municipality. E.g. if there is a party who wants to add a device to this luminaire and something happens with this luminaire, e.g. it falls down then the municipality cares that not anybody will come into contact with the electricity. A municipality would expect then that a co-user of the luminaire is also responsible for creating a secure environment."*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

Current legislations

- *In the current legislation there is a written that municipalities are obliged to make available assets suitable for mobile network operators. The first question is when is an asset suitable? The second question is whether we should make these assets available or not. The issue is that we, as a municipality, do not want to pay for the electricity bill of these radios from KPN, Vodafone or Tele2.*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"The telecom law in the Netherlands gives mobile network operators much freedom. For example, if a telecom provider has a customer inquiry, they will just start digging."*
  - Process Director for the Living Environment, Municipality of Tilburg
  - *"A luminaire consists of two parts, the part under the switch block belongs to the net administrator (e.g. Liander), and the part above from the municipality. This is the agreement there is in the Netherlands."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"There is a different price in power supply for public duties versus corporate duties. For example, it is much more expensive to power supply a radio from KPN than a camera owned by the municipality."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"There is a clear line between market and government. A municipality does not want to provide fixed wireless access to office buildings, because they do not want to take the role of a mobile network operator. The government can take this task when the municipality sees this action as a socially important task, or when they are sure this is not a task for the market."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *I think for Signify, it is very important to look at the new telecommunication law. According to this law, there should be considered if there is a position for Signify. If the law shows that it is possible for mobile network operators to place their radios in a certain location, then they will just do this. In Dutch this is called: wetgeving rond 5G and this is an adjustment regarding the existing telecommunication law.*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"My advice for Signify would be to really investigate this law, especially chapter 5.2 and 5.3. I think that the success regarding this proposition, in the Netherlands at least, is dependent on this telecommunication law and the opinions regarding radio waves."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"Within NEN there is a smart city group that is occupied with smart city platforms."* https://www.nen.nl/normcommissie-smartcities
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"The municipality of Eindhoven has set up a Smart Society Charter with IoT Architecture principles and guidelines. Together with the municipality of Amsterdam, we have brought these to the attention of the ministry of internal affairs. These principles and guidelines then ended up at the VNG (=association of Dutch municipalities), and eventually, all Dutch municipalities started using these principles and guidelines."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *We as a municipality do not want clutter in the urban environment, but the current position of the municipality is that we must allow mobile network operators to place their antennas in the urban environment.*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"It has been determined on national level that municipalities must make infrastructure available for mobile network operators."*
  - Infrastructure engineer, Municipality of Delft

- *"In the Netherlands there is a guideline for public lighting, NPR 13201-1."*
  - Infrastructure engineer, Municipality of Delft

- *"As a municipality, we must make assets available for small cells. However, as a municipality, we still have a little guidance in this. Certainly, in the protected historic city center where we do not want to have antennas on every location, we can force mobile network operators to make use of this infrastructure."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"In the city centre, mobile network operators still have to require licenses for small cell deployments, for example, at monuments."*
  - Program Manager for Digital Connectivity, Municipality of Amsterdam

Fit with existing infrastructure

- *"Municipalities will wonder how these Gb luminaires can be integrated with existing luminaires and under which requirements?"*
  - Senior Advisor Digital Innovation Living Environment, Municipality of Utrecht

- *Neither Signify or the Municipality will decide where light points should be placed. There is already a certain direction and legislation, where light should be offered. In the Netherlands this is called a "openbaar verlichtingsontwerp/lichtplan."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *The city of Eindhoven has 50.000 light poles, without continuous voltage. The municipality will have to invest a few million euros to change the energy grid to continuous voltage.*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *More and more areas are being covered with optical fibre. The question is whether you only connect the residential areas with optical fibre or also the objects in the urban environment. In Strijp-S, we connected a light pole with optical fibre. In the city center, we are also working on connecting light poles with optical fibre.*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"The biggest challenge for rolling out an infrastructure on the lighting grid, is understanding the existing power supply infrastructure."*
  - Infrastructure engineer, Municipality of Delft

- *"In the municipality of Delft the luminaires do not receive any power during the day. This means that during the day, no other applications can be powered."*
  - Infrastructure engineer, Municipality of Delft

- *"Municipalities in the Netherlands already have a network of cameras. Therefore, municipalities will consider how this wireless network will fit with the existing cameras."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

Lighting operation

- *"We are also talking, as a municipality, with Signify that we want to make data in the public environment available for all. This means that we want data to be open and accessible for all. The question is how much this fits with the Interact City concept, where data is also very valuable from a company perspective."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"Citytouch is currently managed by the public lighting management department of the municipality."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"I think there will be a shift at the department of public lighting management, but then for the maintenance and management of sensors. For example, we have noise sensors now that are also installed on light poles, and these have to be monitored. This part I do not see happening by an ICT department, but by the department of lighting management."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

Position of a network operator

- *"Brightsites really should take into account that they do not put themselves in a position as a competitor of KPN or Vodafone! In essence, the same happens, the transport of data."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *A municipality can never have the same duties as a mobile network operator, this is a market disruptive action, even if we would like to do this, then it will not even be possible from a legal perspective.*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I foresee problems, if we put ourselves in the position of a network company."*
  - Process Director for the Living Environment, Municipality of Tilburg

- *"I talked with the head of government & public affairs of Signify as well, and propositions like this look like the government will be setting up a private network. The question is who is the one rolling out this network? Is that the municipality or will Signify do this in a sort of service level agreement? The question I have is how do you position such a network compared to other networks?"*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"A municipality benefits from good coverage, the question is who do you make responsible for that? In the Netherlands there are a few mobile network operators that are occupied with improving their own network infrastructure, from 4G we go to 5G and eventually to 6G."*
  - Advisor lighting, innovation and IoT, Municipality of Eindhoven

- *"As a municipality, we will keep our ears open for new technologies, such as the mmWave technology. But then we have to think of the position of the Municipality of Eindhoven. Will it then become a private network, owned by the municipality, that we will make available for the public. Next to this, we will also wonder what the operating costs of such a system will be."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"I can imagine that there will be certain places in the city where the data coverage is limited. I wonder then if municipalities will improve the data coverage on their own expenses or if they will go to a KPN and tell them that at a certain area the data coverage needs to be improved."*
  - Advisor Lighting, Innovation and IoT, Municipality of Eindhoven

- *"As a municipality we cannot be a network owner, but we can be a consumer of the network."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

- *"I do not think that as a municipality we will become the owner of such a network. In fact, it is a data network, just like an optical fibre network. And there are only a very few municipalities that own an optical fibre network. I know that the municipality of Tilburg and Helmond have their own optical fibre network."*
  - Advisor of Innovation and Digital Technology, Municipality of Breda

Knowledge integration

- *"Knowledge needs to be integrated: two worlds are becoming one. KPN/ Vodafone etc. is very good in operating networks and Signify is very good in producing light."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"Municipalities are not designed to manage a network. Municipalities are designed to perform public duties, e.g. ensuring that trash is picked up. The primary task of a municipality is not to deliver wireless connectivity; it is to take care of the citizens."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

- *"I think that KPN and other mobile network operators will be technically able to manage such networks."*
  - Senior Advisor Digital Innovation Living Environment, municipality of Utrecht

Mobile network operators/ telecommunication experts

Experts:
- Assistant Professor Tu Delft, Telecom Business Architecture and Models
- Technical Lead Industrial 5G Field Labs, KPN
- Fund Manager, Primevest Capital Partners

Clusters:
- Value of BrightSites proposition
- Imagining the future
- Challenges in Brightsites proposition
- Mobile backhaul
- Mobile network rollout
- Mobile network operation
- Task and needs of municipalities
- Current legislations
- Fit with existing infrastructure
- Lighting operation

Value of Brightsites proposition

- *"The technology is very interesting for us; we already use similar technologies to connect sites. The most significant advantage I see is that these technologies are built into light poles."*
  - Technical Lead Industrial 5G Field Labs, KPN

Challenges in Brightsites proposition

- *"There is a fragmented landscape between different actors: the government, manufacturers, telecommunications (MNO), the energy sector, advisors of the government (consultants) and construction companies."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"To realise the smart city of the future, actors can not only see their proposition as a business case, so what's in it for me, it is a value case what's in it for us."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"Smart cities are by definition trans-sectoral issues."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"If you are going to add smart cameras to the luminaire of Signify, then citizens will consider if they like this or trust this technology. If citizens do not want these cameras, then the municipality will have to deal with a lot of adversity."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"Citizens' confidence in Brightsites smart pole is important, since it will be placed in the public space."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"We want to have complete control over our network, and we do not want to use a shared network with cameras or Wi-Fi access points. Next to safety, we also have to guarantee enough bandwidth for each customer."*
  - Technical Lead Industrial 5G Field Labs, KPN expert

- *"KPN currently has sites where fibre roll-out is too expensive or where it is impossible to roll out fibre in the short term. For these sites, we use microwave links. However, it is our goal to link these sites to fibre eventually."*
  - Technical Lead Industrial 5G Field Labs, KPN expert

- *There will always be certain locations where fibre roll-out is not possible, and other backhaul technologies have to be used. However, fibre is our preferred choice.*
  - Technical Lead Industrial 5G Field Labs, KPN expert

Mobile backhaul

- *"In Apeldoorn, the Netherlands, a company (https://www.radioled.eu/) got permission to create a neutral 5G network with antennas, assuming that the mobile operators in the Netherlands will use it. The experience till present-day is that this is not going to happen. Why not? Because mobile network operators have their own proprietary technology and suppliers for this."*
  - Fund Manager, Primevest Capital Partners

- *"By looking at the current technology, all three operators will say, if I can place an antenna in your luminaire, then I want to have an optical fiber connection and not a mmWave backhaul. Why? Firstly, because it is not a proven technology. Secondly, no service levels can be agreed on this technology, which Mobile Network Operators have to communicate towards their customers"*
  - Fund Manager, Primevest Capital Partners

- *"Brightsites should just focus on creating space inside the pole for mobile network operators, a plug-and-play solution for mobile network operators. Something you should realise is that inside KPN already 70 people work in the department of site management. These people are working day in day out to find KPN antenna locations."*
  - Fund Manager, Primevest Capital Partners

- *"The telecom industry is shifting to a world where light becomes extremely important, in the telecom world there is a shift from an electrical world to an optical world. In terms of sustainability, this is also the way to go. Since, it is much more efficient to transfer data through light than through metal."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"Optical fibre is efficient and future-proof."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"It is more expensive to send data through the air, compared to sending data through a fixed medium. The only down-side from a fixed medium, is that mobile network operators have to dig in the ground for this. This is a complex cost issue dependent on the soil of the country."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"Capacity planning is extremely expensive for mobile network operators. KPN invests 1.2 billion euro on a yearly basis to increase their capacity and meet consumer demands."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"Connecting new sites is preferred with optical fibre because this is the most reliable, and the capacity is optimal. However, there are sites where this is not possible. For these sites, we currently use an 80 GHz backhaul technology."*
  - Technical Lead Industrial 5G Field Labs, KPN expert

Mobile network rollout

- *"Every mobile network operator sets requirements before rolling out a network. KPN will set out a national standard, and make national agreements for this and use the same equipment nationwide."*
  - Fund Manager, Primevest Capital Partners

Mobile network operation

- *"From a maintenance and management perspective, a mobile network operator does not want other parties inside their network."*
  - Fund Manager, Primevest Capital Partners

- *"Mobile network operators will never issue their operations to a party like Brightsites/Signify for managing or monitoring a mobile network. Why? In such a network, a lot of confidential data goes back and forth, and is sensitive for competition. This is the reason why mobile network operators also do not participate in antenna sharing. They do not want other mobile network operators to use the same antenna, because they are extremely scared that the other operator can see how congested their network is. It is a market that is extremely sensitive to competition, that does not want to reveal itself, and that is why mobile network operators make inefficient decisions."*
  - Fund Manager, Primevest Capital Partners

- *"The core activity of a mobile network operator is to offer a secure connection over which data can be sent, this is not the primary task of a manufacturer."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"Spotting peak demands in a network belongs to the daily task of a telecom operator."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

- *"We, as KPN, are convinced that our network needs to be safe and available; therefore, we do not want to hand out our operations to a third party."*
  - Technical Lead Industrial 5G Field Labs, KPN

- *"KPN buys network software tools from suppliers. However, access to this is only accessible by KPN."*
  - Technical Lead Industrial 5G Field Labs, KPN

- *We use microwave radio link technology to connect sites. The software from this device is from the supplier, but the interface fits our larger management system.*
  - Technical Lead Industrial 5G Field Labs, KPN

Task and needs of municipalities

- *"Network operation is not the core business of municipalities."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

Current legislations

- *"In the Dutch telekom wet, every Dutch MNO has the rights to roll out its network, and municipalities have an obligation to consent in the same law."*
  - Fund Manager, Primevest Capital Partners

- *"The telecom law is fundamental which must be taken into account."*
  - Fund Manager, Primevest Capital Partners

- *"355 municipalities in the Netherlands have signed a climate agreement and luminaires are becoming more important inside municipalities since this climate agreement mentions that municipalities need to save 50% of their energy streams by 2030. Most of the energy savings can be realised by LED lighting."*
  - Fund Manager, Primevest Capital Partners

- *"If you wanna become a telecom operator, you need to have a license, when you want to operate in the public environment with public spectrum, then you need to be legitimated to do so."*
  - Assistant Professor Tu Delft, Telecom Business Architecture and Models

Fit with existing infrastructure

- *According to TNO research, there are 3.5 million traditional luminaires in the Netherlands and 15% is LED. With these assets municipalities can provide a wide range of services. Providing that existing luminaires will be replaced, the backhaul for these services is optical fiber, and there is continuous power supply.*
  - Fund Manager, Primevest Capital Partners

Lighting operation

- *"There is a lot of negativity in the market regarding administration and management systems. Municipalities want open API's, so they can add extra functionalities to lighting systems."*
  - Fund Manager, Primevest Capital Partners

- *"The 5 biggest maintenance operators in the Netherlands are: Heijmans, Van Gelder, SPIE, CityTec and Dynniq. There is a shift in the landscape from operator to urban operator. In this job function, traditional lighting operators will also become responsible for reading out sensor data and communicating this back to the municipality."*
  - Fund Manager, Primevest Capital Partners

Fibre supplier expert

Expert:
- Director, Broadband Tilburg

Clusters:
- Commissioning
- Dashboard
- Network operation
- Product proposition

Commissioning
- Managing or commissioning the devices should be the responsibility of a lighting operator.

Dashboard
- For Broadband Tilburg, it would be better if the dashboard would fit their overall management system. However, since they are still small scale, it would also be ok if there would be a separate dashboard interface.
- Broadband Tilburg agrees that the software for mobile network operators should be integrated with their overall management system.

Network operation
- Broadband Tilburg thinks that managing the data flows is less critical, and this is also a key factor for project success because of the AVG law and ISO7001 and ISO27001. They only want to be responsible to see if the network is up and running.
- Broadband Tilburg sees themselves as a facilitator, so the system should work. However, they do not see themselves responsible for carefully managing how much data runs over such a network.

Product proposition
- In the current proposition, the income side for every stakeholder involved is less concrete than the cost and expenses.
- The proposition at the moment looks like a shift of internal costs.
- The challenge of this proposition is that it should become more than just a cost calculation compared to fibre rollout.
- The operating costs of digging fibre is probably cheaper than mmWave operation because fibre is lying in the ground and rarely gets damaged.
- Broadband Tilburg thinks it will take 3 to 4 hours to solve a network malfunction. It is difficult to arrange a service level agreement with four or five nines if the solution depends on a party BrightSites does not control.

Telecommunication infrastructure provider expert

Expert:
- Previous Global Head of Country Coordination, Cellnex telecom

Clusters:
- Main challenges
- Customers of Cellnex
- Reason why mobile network operators work with Cellnex
- Infrastructure ownership
- Distributed antenna systems (DAS)
- Network operation
- Small cells
- Requirements for successful network rollout

Main challenges

"As of today, I think the main challenge is consolidating all the growth that took place in a very short period of time. So in, I would say, five years. They went from one or two countries to twelve. And, even though things have been going on in parallel, there's a lot of consolidation and making sure that all those acquisitions that happen are part of the Cellnex story."

Customers of Cellnex

"Any mobile network operator that has 5G frequencies would be a customer, and any company that would have 5G frequencies that would deploy their own network would also be our customer."

Reason why mobile network operators work with Cellnex

"Operators a while back started thinking that owning a part of the infrastructure was not as critical for them and that they rather wanted to concentrate on other parts of their business, and they started selling the infrastructure. So, in this case a company like Cellnex comes into play and provides that part of the infrastructure that is needed for the operators to deploy their network and have their network functioning in an efficient way."

Infrastructure ownership

"KPN has not sold their infrastructure, as far as I know of today, they see that part of the infrastructure now as ownership. From players like this you can see that they have resistance in other parties to operate their network. Same goes for Vodafone, which actually has not sold any of its infrastructure, and they have in mind that they should own and control that. So, it depends on the player, whether they see the infrastructure as part of their portfolio or they have externalized that and have other companies like Cellnex."

"I would say, in some cases, it's no, I would say it's, it's more than 50 those that have outsourced the the infrastructure, but there is in some cases, still a mentality that that infrastructure is within the ownership even though they have sold it that they still have a lot to say about it."

"So you have operators that have that mentality that the infrastructure is mine, and I'm not going to sell it. And you have operators that don't mind because they see value in other services that they provide."

Distributed antenna systems (DAS)

For stadiums it is usually distributed antenna system deployment. And that's basically cellnex going on, and deploying the infrastructure for the operators to have the coverage and capacity provided at a stadium. And then operators only have to pay a rental fee for an infrastructure that's being deployed by somebody else. So they get to have the same service as they would if they'd done that on their own without having to do the investment.

Network operation

"If you're talking about the small cells, then there's not much to monitor, it's just hosting. Because it has to access the core network of the operator, and that part is still the borderline of where it comes from our company and where the operator begins, or vice versa.

"In the case of a DAS system, like I said, it's a little bit different, because from a certain point onwards, it is independent of the network."

Small cells

"So if you look at the networks of operators and you're really in touch with them, you know where they struggle in terms of capacity, or even coverage."

"Small cell deployment is always linked to the need of the operator."

"I think small cells will be wirelessly connected as soon as their deployment takes on a massive rollout. So once the rollout starts, surely there's going to be a need for networks transporting that traffic from the small cells at a street level without putting fibre there. But since the rollout of the small cells in a massive manner is not happening yet. Then the need for having that network is not coming for the meantime."

"You know, it's when you put a small cell somewhere, then there's a fibre that's connected to it at least in Europe, that's what they think."

Requirements for successful network rollout

"But as of today, unless it is very clear for a company like Cellnex, who is going to be paying them for the operation of this network?"

"I see clearly, that there's a need for who is going to pay Cellnex, to have that network operating and functioning."

"Because if, let's say there's a public entity that has cameras, and has money to pay for the use of those cameras on this gigabit network, and Cellnex is happy to operate the network for the traffic entity. Good. Fantastic. That works. But if the traffic entity does that, by themselves, Cellnex has no play."

The second thing I would say is that there has to be a clear path as to how that network will be implemented. Because we're going to find ourselves having to deal with different departments within municipalities, and we are addressing telecom needs, but we're doing that through equipment that has to be installed and the lighting needs. Okay. And these departments don't usually talk. So the agenda of the lighting department is going to be A, and the agenda of the communications department is going to be B. And they usually don't sit at the same table.

"We would have to have a more detailed list of what can go in the gigabit luminaire network and where the limits of its management are."

"We're having to serve at different levels of criticality. It's not the same for an operator to have its network not working at a certain point than it is for a traffic camera."

"I think we have a very powerful solution. But it's going to take time to educate the market and have people collaborating on different department levels. I would say, it's not going to be an easy task, and you know, public things depend on the country, but at least the ones I know in the south of Europe, they take their time."

Light pole service provider and smart city expert

Expert:
- Business Development Manager Smart City, SPIE Infratechniek B.V.

Clusters:
- About SPIE
- Insights of Dutch Municipalities
- Critical factors for success
- Competition
- View towards optical fibre
- View towards Gbit luminaires

SPIE
- SPIE is the biggest lighting operator in the Netherlands.
- SPIE is part of SMART-space, an European project for smart lighting. In this research project they are looking at how lighting matters or people can be influenced. For example, light intensity but also light color. What kind of effect does this, for example, have on a shopping street during Christmas.
- SPIE, for example, also contributes to product development, for example by sharing the knowledge regarding lighting to parties like Remoticom. Remoticom is a pioneer in the field of Internet of Things and sensor technology. In particular, they develop smart sensors that contribute to a safer, more sustainable and more comfortable living environment.
- The Network for the Rijkswaterstaat is maintained by SPIE.
- The municipality Utrechtse Heuvelrug is completely against wireless data communication.

Insights of Dutch municipalities
- Since 2015/2016 there's a lot of interesting projects going on in Dutch municipalities, but most of them remain pilots. Whether those are projects with intelligent lighting or independent solutions.
- SPIE is already trying for a few years with policy makers on how to get out of these pilot phases. But the only way for cities to scale is if there is a budget for doing so. The only way to get a budget within the municipality is for a policy point to go to the council. Only after the council decides on it, money is made available.
- The challenge is also that if one luminaire is changed last year, then the next 10-20 years they will not be changed anymore.
- Regarding the aesthetics of the luminaire, companies have to work with a legacy base, every city has a certain style of luminaires, and these luminaires have to fit the existing luminaire style.
- A government may not perform services competing with the market, this is a market disruptive action. If they want to do so, they have to ask permission from Brussel.
- Air quality monitoring has been a hot topic the past two years inside municipalities.
- What you have to do is to translate your products to the common themes in the municipality, or adjust the product to these themes.
- New luminaires need to adjust to the existing aesthetics of the light poles, especially in historic city centers such as Amsterdam. opportunity to recognise the current light poles in the city.
- A municipality is always at the service of its residents.
- Amsterdam, Utrecht and Groningen are governed by a left progressive board.
- The other big municipalities are mainly governed by a right liberal board.
- Cities have made a blueprint that shows how cities want to operate the city: 1. How do cities want to operate the city?, 2. How do cities want to spend their money?
- If your solution can cover crowd-management, then you have to pick the municipalities that have to solve that problem.
- Residents' commission can be concerned regarding radio waves.

Critical factors for success
- The decisive or most important issue lies at the policy. If you want to be successful in this business, you have to do a mass roll-out. And doing mass roll-out is extremely difficult in this world.

Competition
- Sustainder approaches lighting as an IoT object.
- Sustainder is a company that is built from people with a KPN telecommunication background. They bought the old factory of Philips in Emmen, and started to build their own luminaires. The first model they made was very smart, you could insert a cassette to use free Wi-Fi, you could add a cassette to measure air quality, only the lighting quality was not that good.
- Companies like Sustainder do not exist for very long, but even with these companies you see that they are struggling and that they are looking for niche locations.

View towards optical fibre
- "Optical fibre is one of the best investments that you can make."
- For short distances optical fibre can be splitted by means of splitters.
- According to the business manager of Smart Cities, fibre is not expensive, and the cheapest solution, he worked 25 years in the business.

View towards Gbit luminaires
- The Gbit luminaire is seen as a niche product, not as a mainstream product.
- A good question to ask is how you can make a Gbit luminaire a mainstream product?
- If you add value to your product, then you can also charge a higher price. Otherwise, you will be in the race to sell the lowest price of LED luminaires.
- If Signify wants to add cameras to the Gbit luminaire, then they will have to enter the world of law and regulations. And Brussel is becoming stricter on this in Europe, that you can not just hang cameras somewhere. In the Netherlands, this is called the AVG. A camera can, for example, be hacked. So regarding cybersecurity, there are also a lot of matters that must be met.

Appendix V: Customer profiles

"The use of cutting-edge technology and data is needed to improve the quality of life of our citizens, aid decision-making and tackle the complicated challenges that are part of the present day.

Paul Müller, 54
Municipality

Education Leadership in Digital Innovation
Occupation Chief Technology Officer
Location München, Germany
Values Growth, Connectedness, Transparency, Influence, Meaningful work

INNOVATIVE | CARING
INTELLIGENT | HONEST

Scenario

As CTO of the municipality of München, I am responsible for spotting new technologies that make our city more liveable. I believe that trans-sectoral collaboration is needed to bring these innovations to life. therefore, we closely work together with private companies, knowledge institutions and citizens to turn our smart city vision into reality.

Technology

SMART CITY APPLICATIONS
SMART LIGHTING
DATA NETWORK OPERATION

Goals

- To enhance the role of technology for a better city of tomorrow
- Safeguarding and understanding the public opinion of citizens
- Making privacy, security and transparency the fundamental factors to realize the smart city of the future

Frustrations

- The absence of a shared vision with private companies
- Lack of clear business models and division of responsibility
- Clutter and disturbance in the urban environment

Motivations

PRICE
PRIVACY & SECURITY BY DESIGN
TRANSPARENCY
SOCIAL & ENVIRONMENTAL BENEFITS

Considerations

FINANCIAL DRIVEN — VALUE DRIVEN
BACKHAUL TECHNOLOGY — SPECIFIC USE CASE
PRICE — AESTHETIC FIT
PRIVATE SECTOR OPINION — PUBLIC OPINION

Reasons to use the Gbit luminaire

- To avoid clutter in the urban environment and disturbance in the city centre
- To make use of the energy-efficient LED lighting
- To run smart city applications that require high-bandwidth connectivity

Reasons to buy the Gbit luminaire

- To meet social, environmental and social goals that positively impact the city
- To become the front-runner in connectivity and smart cities across the country
- To avoid chaos and disturbance in the city centre

BrightSites
by signify

“We continously scout new technologies to improve our services and modernize our networks for tomorrow’s connected society.

John Parker, 41

Mobile network operator

Education	Telecommunications
Occupation	Chief Technology Officer
Location	Paris, France
Values	Impact, Purpose, Security, Growth

INNOVATIVE | BIG-THINKING | INTELLIGENT | HONEST

Scenario

Ten years from now, the world will be different. Nobody knows how different. But, what we know for sure is that the world will be digital. We need to improve our networks and increase our capacity to keep up with the growing amounts of bandwidth to create the truly connected society of tomorrow with 5G as the foundation.

Goals

- To deliver the best experiences for our customers with 5G
- Leveraging and safeguarding our superior network
- Meeting customer demands and meeting well-defined service level agreements

Frustrations

- Competitive advantage is nowadays not only seen in network infrastructure
- Unable to monetize new use cases with 5G as foundation
- Big internet players and digital platforms move towards cloud services and might take over access services

Motivations

COSTS

MEETING CUSTOMER DEMAND

TRANSPARENCY

FINANCIAL BENEFITS

Considerations

FINANCIAL DRIVEN — VALUE DRIVEN

BACKHAUL TECHNOLOGY — SPECIFIC USE CASE

PRICE — AESTHETIC FIT

PRIVATE SECTOR OPINION — PUBLIC OPINION

Technology

SMART CITY APPLICATIONS

SMART LIGHTING

DATA NETWORK OPERATION

DAS SYSTEMS AND SMALL CELLS

Influencing factors

- The ability to communicate SLA’s to customers and meeting security standards
- The division of responsibility and the clarity of the business model
- The ability to monetize 5G use cases on the lighting grid

Reasons to buy the Gbit luminaire

- To run new 5G use cases that positively impact society
- To connect telco equipment wirelessly and aesthetically
- To increase brand strength

BrightSites
by Signify

"We understand that mobile network operators and municipalities face budget constraints. Therefore, we advocate for a neutral host model, where we operate and maintain the client's network.

William Evans, 48

Telecom infrastructure provider

Education Master of business administration
Occupation Chief Executive Officer
Location London, United Kingdom
Values Growth, Impact, Recognition, Competence

PERSUASIVE | PROGRESSIVE
INTELLIGENT | CRITICAL

Scenario

The Covid-19 pandemic exposed that connectivity is becoming the fourth utility, next to water, gas, and electricity. We want to provide the communication infrastructure that advances economies, enriches communities and brings people together all around the globe. With our extensive expertise, we can enable the digitally connected city of tomorrow.

Technology

SMART CITY APPLICATIONS
SMART LIGHTING
DATA NETWORKING AND OPERATION
DAS
SMALL CELLS

Goals

- Enabling cities with strong communication networks
- Advancing communities and economies all around the globe
- Satisfying clients and finding new revenue opportunities

Motivations

COSTS
SATISFYING CLIENTS
RELIABILITY
FINANCIAL BENEFITS

Influencing factors

- The demand of mobile network operators for small cells and DAS
- The view of clients towards mmWave backhaul technology
- The attractiveness of the business model
- A shared vision wth all stakeholders involved

Frustrations

- Being unable to consolidate the growth that took place in the last decade
- High permitting costs and concession rights to roll out networks
- Being unable to design, build and operate highly available communication networks

Considerations

FINANCIAL DRIVEN | VALUE DRIVEN
BACKHAUL TECHNOLOGY | SPECIFIC USE CASE
PRICE | AESTHETIC FIT
PRIVATE SECTOR OPINION | PUBLIC OPINION

Reasons to buy the Gbit luminaire

- To make use of a cost-saving and reliable backhaul technology to serve clients
- To monetize smart city services
- To increase brand strength

BrightSites
by signify

“The networks that we built today are shaping new digital experiences for the upcoming years. Our optical fibre is now used ar the core and transport-level and at the access and premise level to enable utra-low latency applications.

Eric Smith, 55

Fibre supplier

Education Engineering
Occupation Director
Location Utrecht, the Netherlands
Values Growth, Competence, Influence, Connectedness

INNOVATIVE | CARING
INTELLIGENT | HONEST

Scenario

High-speed connectivity is not just a luxury anymore; it is a necessity for the day to day. We believe that optical fibre is the most reliable and future-proof backhaul technology to initiate new digitalization opportunities. With optical fibre, we can enable cities and organizations to grow and open new opportunities through connectivity.

Goals

- To open new opportunities through extensive fiber roll-out
- To meet market demands and satisfy clients
- To deliver highly available, secure and reliable backhaul networks

Frustrations

- Expensive trenching costs for last-mile connectivity
- Time of deployment
- Lengthy conversations with municipalities

Motivations

COSTS
MEETING CUSTOMER DEMAND
TRANSPARENCY
FINANCIAL BENEFITS

Considerations

FINANCIAL DRIVEN — VALUE DRIVEN
BACKHAUL TECHNOLOGY — SPECIFIC USE CASE
PRICE — AESTHETIC FIT
PRIVATE SECTOR OPINION — PUBLIC OPINION

Technology

SMART CITY APPLICATIONS
SMART LIGHTING
DATA NETWORKING AND OPERATION

Influencing factors

- The ability to communicate SLA’s to customers
- Clarity in business model agreement and division of responsibility
- The demand from clients and their view towards mmWave technology

Reasons to buy the Gbit luminaire

- To make use of a cost-saving and reliable backhaul technology for last mile connectivity

BrightSites
by signify

Appendix VI: Needs and sub-needs

	Fundamental psychological needs	Sub-needs
1.	Autonomy	· Freedom of choice · Individuality · Creative expression · Self-reliance
2.	Beauty	· Unity & Order · Elegance & Finesse · Artistic experiences · Natural beauty
3.	Comfort	· Peace of mind · Convenience · Simplicity · Overview & Structure
4.	Community	· Social harmony · Affiliation & Group identity · Rooting (tradition, culture) · Conformity (fitting in)
5.	Competence	· Knowledge & understanding · Challenge · Environmental control · Skill progression
6.	Fitness	· Nourishment · Health · Energy & Strength · Hygiene
7.	Impact	· Influence · Contribution · Building something · Legacy
8.	Morality	· Have guiding principles · Acting virtuously · A just society · Fulfilling duties
9.	Purpose	· Life goals & direction · Meaningful activities · Personal growth · Spirituality
10.	Recognition	· Appreciation · Respect · Status & Prestige · Popularity
11.	Relatedness	· Love & Intimacy · Camaraderie · To nurture and care · Emotional support
12.	Security	· Physical safety · Financial security · Social stability · Conservation
13.	Stimulation	· Novelty · Variation · Play · Bodily pleasure

Source: (Desmet & Fokkinga, 2020)

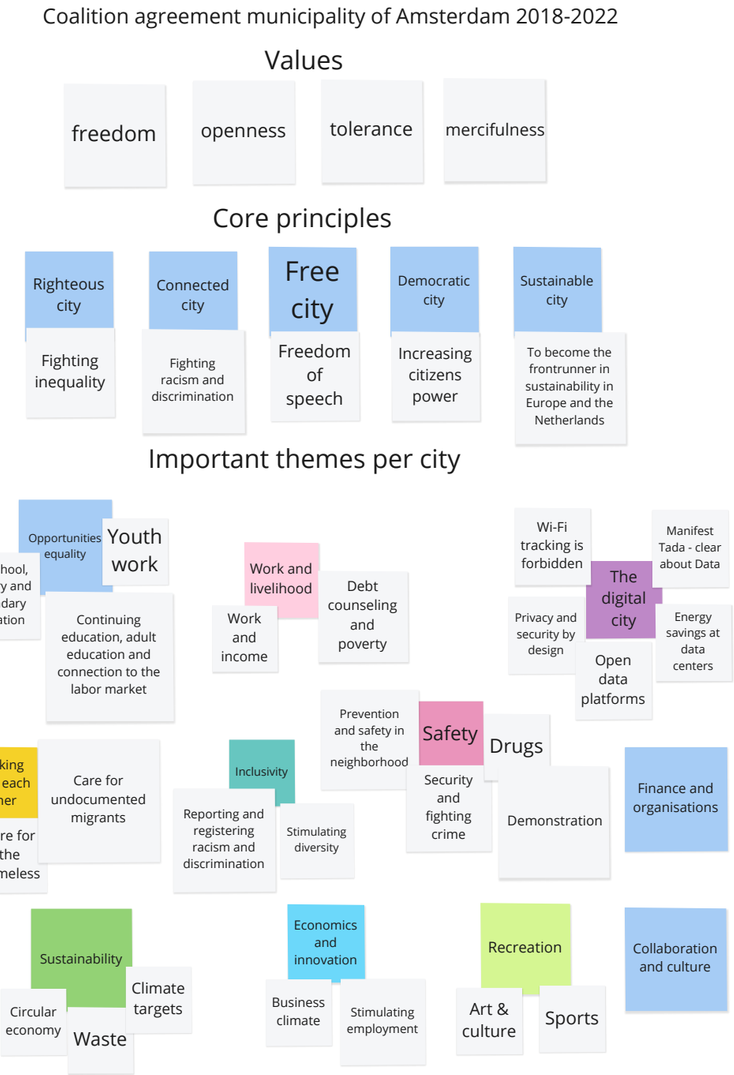
Appendix VII: Needs and sub-needs of the various stakeholders in the Gbit luminaire ecosystem

Stakeholder	Needs and sub-needs
Municipalities	Beauty · Unity & Order · Elegance & Finesse Community · Social harmony · Affiliation & group identity · Rooting (tradition, culture) · Conformity (fitting in) Impact · Influence · Contribution · Building something · Legacy Morality · Having guiding principles · Acting virtuously · A just society · Fulfilling duties Security · Physical safety · Social stability
Telecommunication infrastructure providers	Competence · Knowledge & Understanding · Challenge · Environmental control · Skill progression Impact · Influence · Contribution · Building something · Legacy
Mobile network operators	Competence · Knowledge & Understanding · Challenge · Environmental control · Skill progression
	Impact · Influence · Contribution · Building something · Legacy Stimulation · Novelty
Internet service providers	Competence · Knowledge & Understanding · Challenge · Environmental control · Skill progression Impact · Influence · Contribution · Building something · Legacy
Fibre suppliers	Competence · Knowledge & Understanding · Challenge · Environmental control · Skill progression Impact · Influence · Contribution · Building something · Legacy
Electricity suppliers	Competence · Knowledge & Understanding · Challenge · Environmental control · Skill progression Impact · Influence · Contribution · Building something · Legacy

Light pole service providers	Competence · Knowledge & Understanding · Challenge · Environmental control · Skill progression Impact · Influence · Contribution · Building something · Legacy
Citizens	Autonomy · Freedom of decision · Individuality · Creative expression · Self-reliance Comfort · Peace of mind · Convenience · Simplicity
3rd party equipment suppliers	Stimulation · Novelty Impact · Influence · Contribution · Building something · Legacy

Source: (Desmet & Fokkinga, 2020)

Appendix VIII: Coalition agreements of three cities in the Netherlands



Coalition agreement municipality of Utrecht 2018-2022

Core principles

- Utrecht: A place for everyone
- Utrecht: Growth for everyone
- Utrecht: The power of everyone

Important themes per city

- Equality in education and the labor market
- Education, youth & talent development
- Focus on children that are raised in poverty and youth that are in a vulnerable position
- Tackling teacher shortages
- Healthy living environment
- Investing in nature
- Environmental zone for zero-emission transport by 2030
- Supporting people who need to find a job
- Economy, business climate and labor market
- Focus on the creation of jobs
- Creating a healthy business climate
- Culture and events
- Making budget available for culture and events
- Collaboration with public and private partners
- Mobility
- Make Utrecht the number 1 bicycle city of the world
- Expanding and renewing public transport
- Neighborhood oriented
- The role of the district alderman is neighborhood-oriented and coordinating
- Income and approach of poverty
- Helping with approaching debt
- Stimulating social initiatives to tackle poverty
- Safety
- Focus on prevention
- Fighting radicalization and polarization
- Open municipality
- Privacy by design
- Open data
- Physical and social accessibility for everyone
- Fighting discrimination
- Freedom to choose partner and gender
- Improving routes for people with a disability
- Focus on becoming climate neutral
- Energy transition and the circular economy
- Meeting the Paris Agreements
- Citizen participation
- Organizing neighborhood talks
- Focusing on new ways of communication
- Spatial development and living
- Boosting the pace of new housing construction
- Focus on affordable living spaces
- Healthy society: sport, well-being, health and care
- Creating public spaces to play sports
- Investing in sport initiatives

Coalition agreement municipality of Tilburg 2018-2022

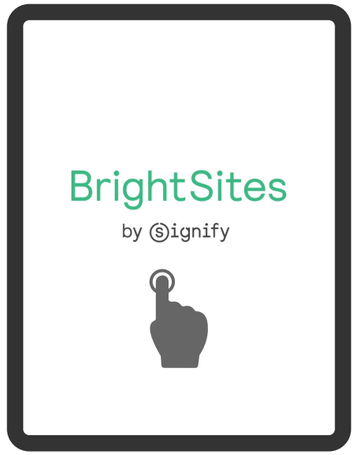
Core principles

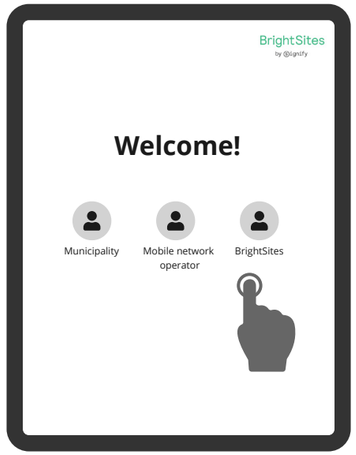
- Inclusive city
- Sustainable city
- Vital city
- Collaborative city

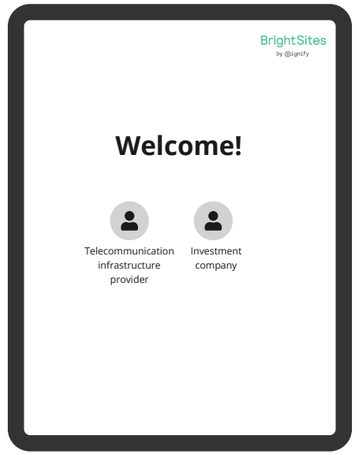
Important themes per city

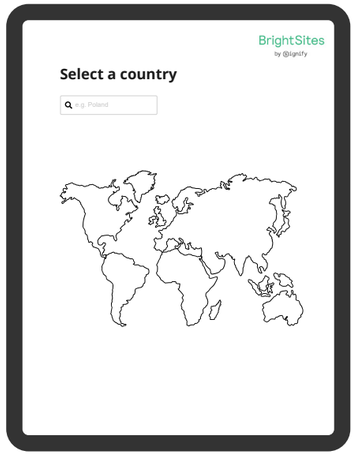
- Culture and events
- Making budget available for culture and events
- Youth care
- Less bureaucracy and less regulatory pressure inside the organization
- Well-being of elderly
- Providing them with care
- Providing them with care
- Talent development and education
- Nature and environment education
- Collaboration between educational institutes
- Collaboration
- Citizen participation
- Active in national and international networks
- Housing
- Sufficient supply of affordable housing
- Labor market
- Tackling youth unemployment
- Supporting refugees with finding a job
- Safety
- Neighborhood watch teams
- Fighting organized crime
- Sustainability
- Energy transition
- Circular economy
- Climate adaptation
- Mobility
- Smart mobility
- Electrical vehicles
- Sports
- Stimulating healthy living
- Strengthening social cohesion
- Poverty
- Initiating the debt offensive program

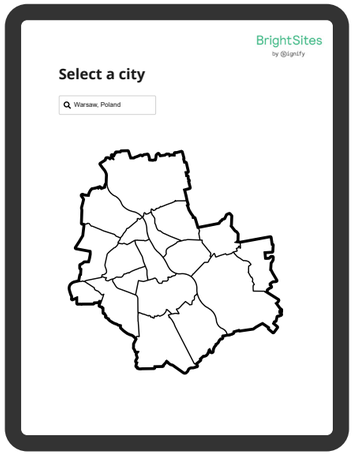
Appendix IX: Horizon 1 communication tool

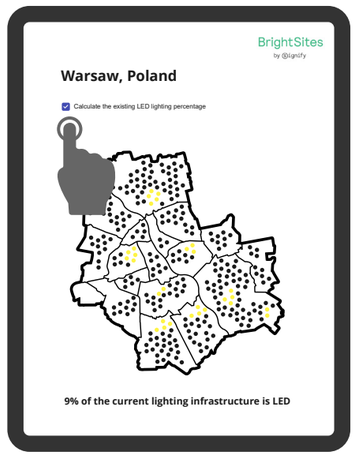


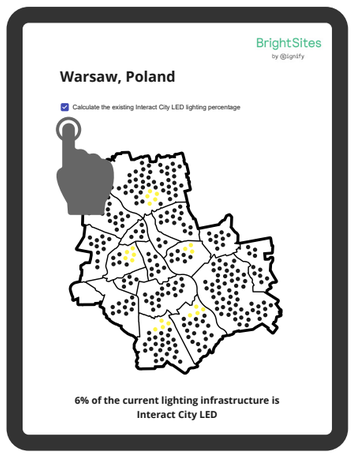


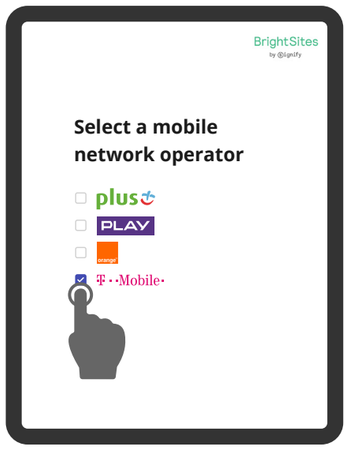


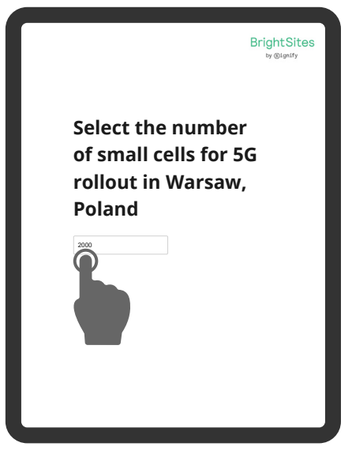


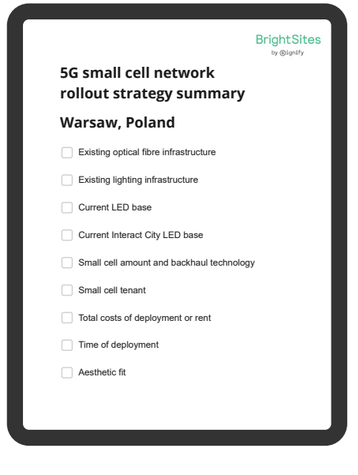




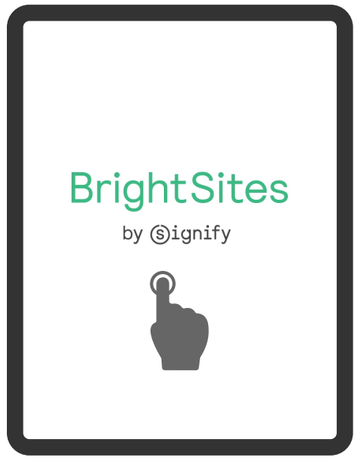


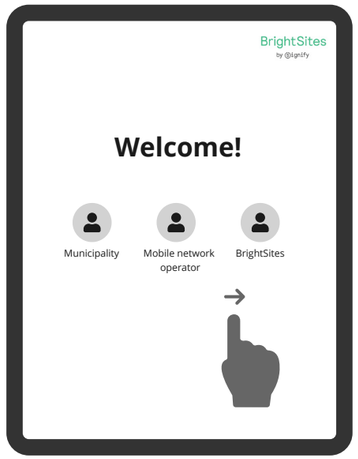


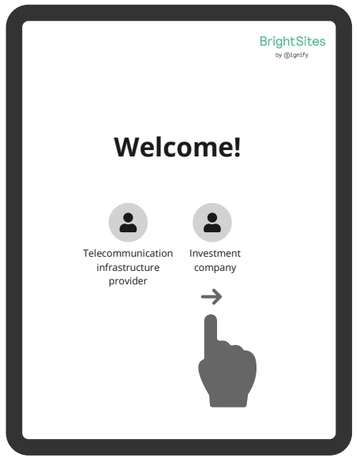


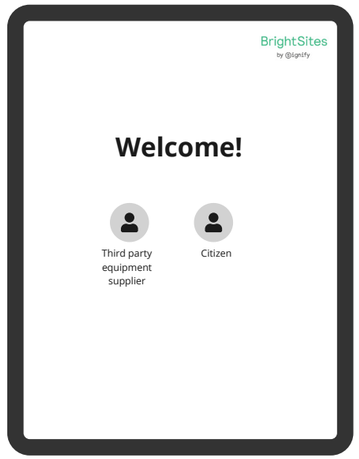


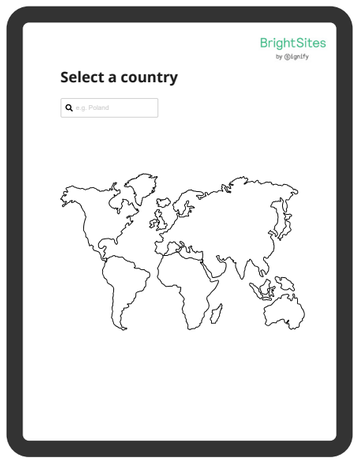
Appendix X: Horizon 2 communication tool

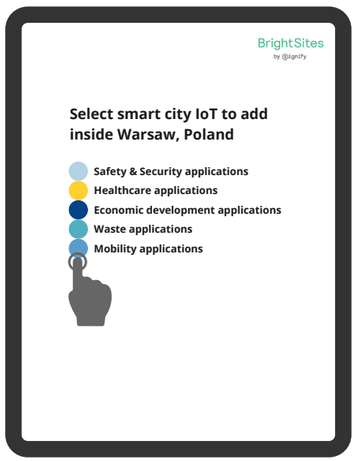


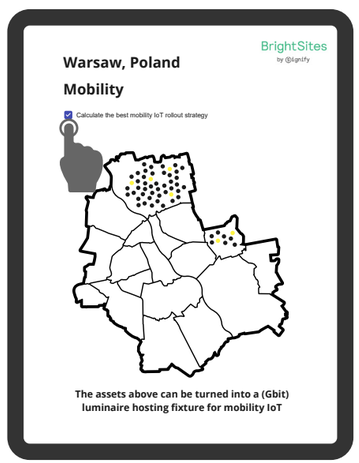




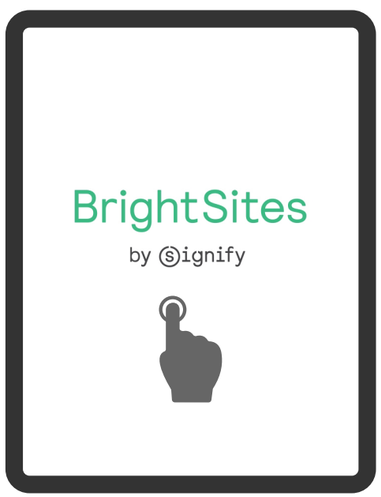


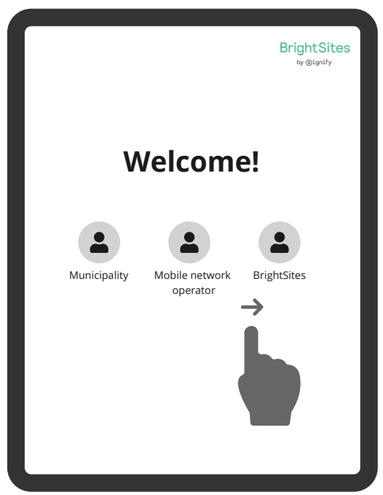


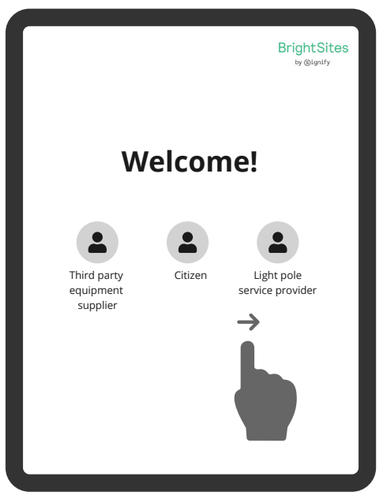


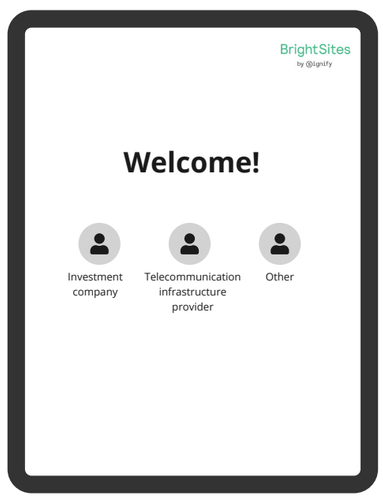


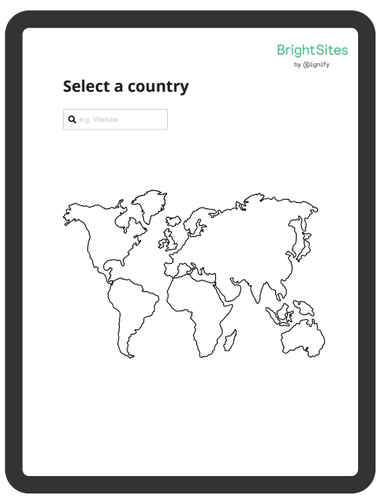
Appendix XI: Horizon 3 ecosystem mapping tool

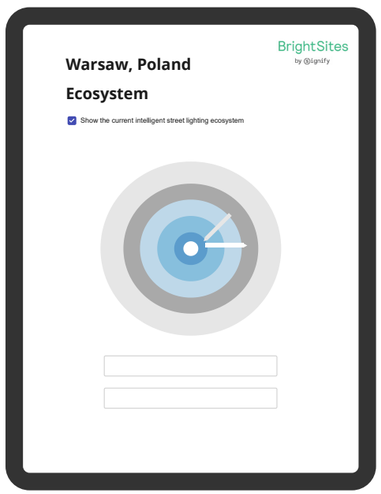


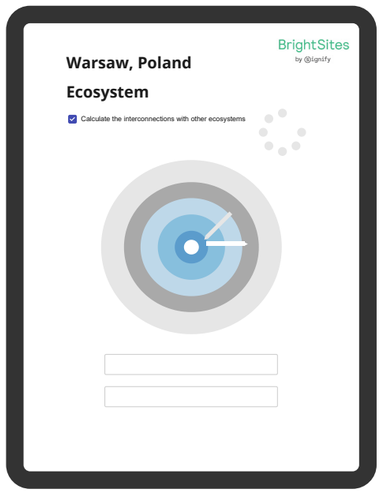


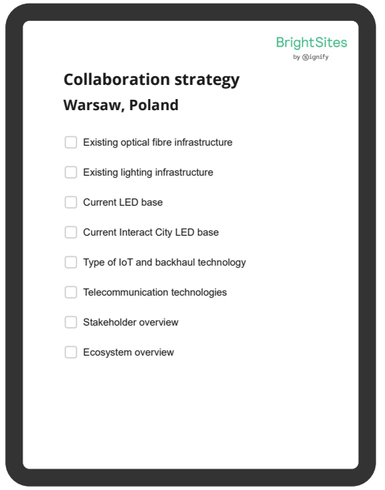












Master thesis

Strategic Product Design