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Light the way for smart cities: Lessons from Philips Lighting

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ABSTRACT

Smart cities are one of the dominant manifestations of digitization with a multimillion dollar potential, where cities and companies alike are looking for ways to create and capture value. Technology-driven companies are key to making smart cities a reality, but their current product-centric business models do not meet the changing needs anymore. Based on an in-depth study at Philips Lighting of four smart city cases across a period of five years, our article illustrates four distinct business models that enable incumbent organizations to enter this smart city market. We develop and contrast the four types of business models on individual and joint value creation and value capture dimensions and show how each business model can be of value to an incumbent, depending on the project and ecosystem. We illustrate these business models with insights from Philips Lighting's transition from public lighting to smart cities and provide specific implementation suggestions for incumbent companies.

1. Introduction

Rome was not built in a day, and neither are smart cities. By 2050, nearly 70% of the world's population will live in urban areas (UNESA, 2015), creating both challenges and opportunities for municipalities and industries, leading to a widespread debate about the future of cities. Digital technology functions as a catalyst for urban transformation promising more efficient, livable, “smart” cities that improve the quality of life for citizens and visitors by leveraging smart services, systems, and solutions (The Economist, 2016). Frost & Sullivan estimate that the smart city market will be worth $1.6 trillion by 2020 with a wealth of locations claiming their status as smart cities, collaborating closely with industry experts and knowledge institutions (Frost & Sullivan, 2014; Snow et al., 2016). The rules of the game are changing, many new technology players from different disciplines are active in the smart city market. These companies range from new entrants to established players, which include such well-known names as Cisco, IBM, Huawei, Philips and Accenture. Although municipalities and businesses both seek to be at the forefront of these exciting developments, success in this cutting-edge domain is no small feat.

The path towards the future of smart cities is uncertain, as we do not yet know what an actual smart city looks like, beyond the mere pilot projects currently implemented. It has been argued that new technology in itself has limited value and that designing products and services around that technology does not guarantee firm success, competitive advantage, or societal value (Chesbrough, 2007). Business model innovation, on the other hand, can enable an organization to fully realize the commercial potential of a technological innovation and can lead to corporate transformation and renewal (Johnson et al., 2008; Zott et al., 2011; Zott and Amit, 2007). The general principle behind business models is based on representing connections between different actors or activities in order to create and capture value for all (i.e., customers, suppliers, complementors, partners and others) (Chesbrough, 2007; Doganova and Eyquem-Renault, 2009; Zott et al., 2011). Essentially, established companies entering the smart city market are looking for new business models, i.e. new ways to create and capture value (Amit and Zott, 2001, 2015; Osiyevskyy and Dewald, 2015; Sorescu et al., 2011). Value creation depends on whether such an incumbent is able to innovate successfully, while value capture is primarily concerned with bargaining the exchange value of products and services that result from value creation (Adner and Kapoor, 2010; Zott and Amit, 2010). More specifically, the business model determines a firm's bargaining power: the more value is created, the greater the bargaining power and the greater the amount of value to be captured (Zott and Amit, 2010).

Yet incumbents often struggle or fail to adapt and innovate their business model to create and capture the right products and services for newly emerging markets, due to their inertia and adherence to a dominant logic (Gilbert, 2005; Tripsas and Gavetti, 2000). Incumbents

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not only struggle internally with business model innovation, but challenges are also found in the firm's ecosystem. An ecosystem looks more closely at interdependent relationships with other organizations both up- and downstream, taking simultaneous cooperation and competition into account (Adner and Kapoor, 2010; Gulati et al., 2012; Moore, 1997). The main distinction here is that the business model only looks at the direct value exchanges from and to a focal organization, while the ecosystem takes a broader approach to include value exchanges beyond the focal organization, which are vital for the realization of smart city services and solutions (Adner, 2017). Whereas in the past, municipalities and incumbents used to solve problems in specific, isolated urban segments (e.g., lighting, waste, traffic), smart cities demand a combination of infrastructures across segments to facilitate a broader range of services (Cohen et al., 2016). This increasing complexity of smart city services and solutions demands a wider ecosystem of companies to create and capture value. As individual organizations are unable to develop and offer the necessary complexity on their own, they instead rely on a diverse set of partners to jointly create smart city innovations (Cohen et al., 2016; Porter and Heppelmann, 2014). To date it remains unclear however, how an incumbent can keep up with these urbanization and digitization developments and the increasing complexity of smart city innovations. Therefore, our research focuses on the following question: What kind of business models do incumbents apply in smart city ecosystems?

We focus specifically on the role of Philips Lighting, one of the largest lighting incumbents in the world, and the business model innovation challenges they faced during their digital transformation from lighting to smart cities. More specifically, through in-depth, longitudinal inductive case studies of four smart city projects at Philips Lighting, we explore what types of business model are relevant to the smart city market and how these can be implemented in a smart city ecosystem.

2. Methodology

According to Muñoz and Cohen (2016), major investments in a city's infrastructure are key to realizing smart city solutions (Muñoz and Cohen, 2016; Paroutis et al., 2014; Snow et al., 2016). We believe that the public lighting infrastructure is uniquely positioned to play a pivotal role in the transformation of the urban context, but in many cities it is outdated, demanding replacement with more economical, sustainable solutions. More specifically, connected, digital public lighting can provide several clear advantages (Den Ouden et al., 2015), where high energy savings already would justify the replacement of existing lighting infrastructures with LED. Moreover, connected, digital LED lighting can provide a basis for creating a dense network of sensors and actuators to enable smart city services. Such a networked lighting infrastructure (i.e., a smart lighting grid) enables the accessibility of additional real-time data on everything from traffic, crime, and pollution, and more, triggering the participation of the whole business ecosystem (Cohen et al., 2016; Graça and Camarinha-Matos, 2017). As prior research shows, lighting is not only functional; it also exerts a strong emotional impact, through its effects on ambiance, people's moods, and their sense of safety. Public lighting is also interwoven into a city's identity and character, such that it could facilitate city branding strategies. Essentially, installing a smart lighting network would allow a city to run more smoothly and at lower costs and create a broad range of innovation opportunities, which in turn puts remarkable pressure on the traditional, product-centric business models of incumbents (Øiestad and Bugge, 2014; The Economist, 2016).

More specifically, we focus on Philips Lighting, which has been a leader in public lighting for > 100 years. Nowadays it is rare that a company becomes this old by pro-actively adapting (Binns et al., 2014), as today's markets are put under a lot of pressure by new entrants, as examples of Airbnb and Uber have shown. Coming from a connected lighting background, Philips Lighting has been implementing several smart city projects and is entering the smart city market through their Internet of Things (IoT) enabled and enabling infrastructure approach. Unlike many other organizations in the smart city market, Philips understands how cities work, having collaborated with municipalities for more than a century. However, Philips Lighting is aware that lighting is not sufficient anymore and that they have to innovate their business model to go beyond pure illumination, if they want to remain competitive in the emerging smart city market. To go beyond lighting, Philips Lighting's focus now lies much more on commercializing embedded lighting and connectedness, while looking at the integration with other concepts that provide societal value, such as safety, crowd management, and open participative platforms (Chandy and Tellis, 2000; Chesbrough, 2010). Essentially, Philips Lighting faces a digital transformation from public lighting to smart city solutions, where public lighting and its infrastructure are seen as stepping stones towards smart city concepts (Den Ouden et al., 2015). This context and Philips Lighting provide a unique setting for our research to investigate what type of business models are relevant to emerging smart city ecosystems. To this end, we conducted an in-depth inductive, explorative study at Philips Lighting of four smart city cases. In the next section, we provide more background information on how and why the four cases were selected, including a short introduction to how the interest in developing intelligent lighting and smart city solutions started.

2.1. Case selection

Already in 2011, cities were increasingly interested in LED lighting to achieve their energy saving goals as declared in the Covenant of Mayors. In Eindhoven, the account manager of Philips Lighting took the initiative to make a proposal for the city to replace 21,000 of its traditional street lights with LED: an investment that would be earned back in under seven years. This proposal triggered a discussion in the Municipal Executive Council on the innovation ambitions of Eindhoven as 'the city of light'. Their concern was that, as LED lights would last for 25 years, they could potentially expect a lot of technology innovations based on LED and a smart city infrastructure. Yet, they can only invest once, so the investment should be future-proof. The vice-mayors initiated a co-creation process to develop a vision and a roadmap for urban lighting in 2030. Philips Lighting was one of the organizations that contributed to the roadmap from their own vision on future smart lighting and smart city developments. The resulting roadmap – aiming at a smart lighting grid that enables innovative solutions to continuously improve the quality of life in the city – was adopted as official policy document in 2012. As this also required rethinking the tendering procedure for public lighting, the decision was made to go for a competitive dialogue in which Philips Lighting was one of the participants. The Eindhoven tender was launched in 2014 and was granted in 2016 to the consortium led by Philips Lighting that proposed a smart lighting grid together with a continuous innovation process that involves end-users and other companies to identify needs and develop solutions.

At the same time, in October 2011, the vice-mayors of economic affairs representing the three major Dutch economic regions (Amsterdam, Rotterdam, and Eindhoven − also known as the E3) jointly wrote a letter to the ministry of economic affairs to make them aware of a number of key issues that needed to be addressed to improve their competitive position internationally. In this letter, the municipalities also pointed to the need to collaborate on the procurement of intelligent and sustainable public lighting to stimulate innovative lighting solutions in their respective cities, as light is one of the key infrastructures in a city. Within Philips Lighting, the account manager for these cities saw this letter as an opportunity to explore what innovative lighting solutions would be possible to go beyond the traditional product sales approach. The E3 Smart Lighting In Metropolitan areas (SLIM) project was developed as a response to the letter of the three municipalities. The cities selected Hoekenrodeplein in Amsterdam (to test how adaptive lighting can improve the perception of safety and

hospitality on a public square), and Stratumseind in Eindhoven (to experiment with dynamic lighting scenarios to diffuse aggressive behavior in an entertainment street) as interesting pilot areas.

In parallel, the same Philips Lighting account manager was approached by the area manager from Veghel that was facing similar problems to Rotterdam, Eindhoven, and Amsterdam, but who did not have the economies of scope of large municipalities and also was not part of such a consortium. Veghel was facing a decrease in visitors and shops in their areas and was interested in exploring intelligent lighting solutions in a pilot project to see whether these could improve the safety, attractiveness, and economic viability of their public spaces. The Philips Lighting account manager searched for actors within his organization that could respond to Veghel's needs. The main aim was to jointly develop innovative lighting solutions to test in the city center. Since there was little knowledge on the effects of light and how light can influence the atmosphere and people in a particular public space, Philips Lighting decided to invest in exploring also this opportunity further, including looking at different value creation and capture opportunities.

Thus, at that point in time, there were four projects ongoing within Philips Lighting that explored intelligent lighting innovations beyond mere lighting products and illumination, which demanded different business model types and ecosystem approaches (see Table 1). Moreover, we were granted access by Philips Lighting and the respective municipalities involved in the cases, which allowed us to gain in-depth insights. Following Yin's (2013) recommendations, we decided to include all four projects (Eindhoven, Amsterdam, Stratumseind, and Veghel) as separate cases in our study, to investigate how Philips Lighting approached business model innovation in the context of smart lighting and smart city ecosystems.

2.2. Data collection

We collected data on all four cases over a period of five years from 2012 to 2017 (see Table 1 for an overview of the four cases). In this period the projects were initiated and executed, with multiple value creation and capture activities both for Philips Lighting and the other ecosystem actors involved, including the municipalities. The primary source of data consists of participatory observations (i.e., quasi-participatory action) of both the primary and secondary author over the whole period of investigation. This is in line with suggestions from Tsoukas and Chia (2002), who state that “only by placing ourselves at the center of an unfolding phenomenon can we hope to know it from within” (p.571). As part of the participatory observations, both authors took part in numerous meetings discussing the progress and challenges of the four projects, which, combined, resulted in > 800 h of participant observations. In total, > 70 interviews were conducted with relevant actors to understand the dynamics of the projects, the interplay between the different ecosystem actors, and the implications for value creation and capture. Finally, for triangulation purposes, we collected documents, including archival documents, presentations, emails, and public documents. For the duration of the projects, the researchers took notes and discussed value creation and value capture activities with diverse representatives of the participating actors. With this approach, we gained a clear understanding of the evolution of the four cases, as well as the activities carried out by the different actors.

2.3. Data analysis

We are interested in how Philips Lighting explored business model innovation opportunities, while evolving from public lighting propositions to smart city propositions, and which types of business models are applicable to smart cities. This has been done through a comparative analysis of the four cases to determine the similarities and differences between these four polar types (Van de Ven and Poole, 2005; Yin, 2013). Our study draws on the insider-outsider approach, which stipulates the involvement of two distinct roles and perspectives (Bartunek and Louis, 1996). The two primary authors took the role of the ‘insiders’ by actively participating in the four projects, whereas the other authors were involved as ‘outsiders’. This approach has allowed us to gain more insights into the four cases, as individuals tend to talk more openly to insiders (Bartunek and Louis, 1996). At the same time, the outsiders were able to take an independent view, which stimulated a more systematic interpretation of the events.

The first step in our data analysis was to do a within-case analysis of Philips Lighting's value creation and value capture activities during each of the four projects, as well as the implications for the ecosystem. For this we created case descriptions of each case to identify an overall pattern of business model innovation (see Appendix 1) and identified the core and extended ecosystem for each case (Table 2). We explored the value creation and value capture activities of Philips Lighting in relation to their core ecosystem partners (see Table 3) and jointly discussed the developments within the author team. The combination of insider and outsider interpretations supported the move beyond conceptual representations, to uncover the dynamic nature of business models and the exchange of value between different ecosystem partners. The next step in the analysis was to contrast the four cases through a cross-case synthesis to find overlaps or discrepancies in their business models. This allowed us to develop a more general framework of business model innovation for smart cities (Fig. 1), which forms the basis of our results. Additionally, we created a list of actions that transcend the individual cases and that can provide valuable input to other incumbents looking to innovate their business model. We present this list in the Managerial implications section of this paper.

3. Results

Essentially, Philips Lighting is looking for new ways to create and capture value within different smart city ecosystems (Spieth et al., 2014). We find that the two relevant business model variables, value creation and value capture each consist of two possible forms.

Value creation took place in an individual or joint way. During the Amsterdam and Veghel case, Philips Lighting created value individually, by conducting its innovation activities in-house and cooperating with other parties primarily through traditional buyer–supplier relationships. The advantage was that Philips Lighting remains in control, reaps most of the profits, and is less vulnerable to competition. However, an implicit requirement demands that Philips Lighting maintains sufficient control and critical mass in the pertinent domain to succeed. Alternatively, during the Stratumseind and Eindhoven cases, Philips Lighting took a joint value creation approach, where they actively collaborated with external partners to leverage their distributed knowledge, skills, and resources, i.e. created value through an open innovation setting (Chesbrough, 2003; King and Lakhani, 2013). Generally, this participatory infrastructure was facilitated by a platform, with the overarching purpose of enabling value creation for all participants (Graça and Camarinha-Matos, 2017; Muñoz and Cohen, 2016; Parker et al., 2016). The greater variability in the resulting ideas also tended to increase the quality and value of the ultimate solution (King and Lakhani, 2013).

Similarly, Philips Lighting's value capture activities also entailed an individual and joint approach. During the individual approach in the Amsterdam and Stratumseind cases, the revenue streams were unidimensional product sales, usually involving a one-time transaction. In contrast, the joint value capture mechanisms of the Veghel and Eindhoven cases, rely on recurring income from multidimensional services and solutions, such as lighting consultancy or maintenance services, i.e. managed services (Baden-Fuller and Haefliger, 2013), where revenues can also be shared across different ecosystem actors. We combine these two dimensions into a matrix that consists of four business model types, the details of which will be described next.

Table 1
Overview of the four projects and their main goals.

	Timeline	Value proposition	Project budget	Expectations municipality	Expectations Philips Lighting
Amsterdam	- 2012: area development - 2013: E3 SLIM project - 2013: start project - 2014: opening area + lighting - 2016: opening area + adaptive lighting	Make the public space safer and more attractive through smart lighting	> 850,000 Euros municipality public lighting budget + investment from participating parties (Cisco, Philips, KPN, Alliander)	- Increase (social) safety - Create a vibrant atmosphere - Stimulate hospitality and local economy - Link area to other large spaces close by	- Learning (from other incumbents) - Customer relationship - Pilot project
Eindhoven	- 2012: Roadmap Urban Lighting 2030 - 2013: E3 SLIM project - 2014: start tendering process + open dialogue - 2015: receiving bid documents + announcing winner - 2016: contract signed - 2017: start installation smart light grid	Build a smart lighting grid to explore (lighting) innovations	> 1 million Euros municipality public lighting budget (incl. innovation, maintenance, energy)	- Build a smart lighting grid - Stimulate local economy - Improve quality of life for citizens - Strengthen reputation as the city of light	- Reputation - Sell more than just lighting products - Revenue
Stratumseind	- 2012: Light Poppers project - 2013: E3 SLIM project - 2013: NWO proposal accepted - 2013: Living Lab Stratumseind 2.0 - 2014: de-escalate project started (NWO funded)	Explore the use of smart lighting to manage crowds and provide safety	> 500,000 Euros NWO + investment from participating parties	- Explore impact of light on people in the city center - Increase public safety by diffusing escalating behavior - Revitalize entertainment street	- Learning from other organizations - Customer relationship - Pilot project
Veghel	- 2013: initiation project (Masterplan Veghel Center 2030) - 2013: 1st phase - 2013: opening ceremony 1st phase - 2015: 2nd phase - 2015: opening ceremony 2nd phase	Create a unique (lighting) experience in the city center to attract more visitors	> 1.2 million Euros municipality innovation budget	- Explore impact of light on people in the city center - Revitalize city center - Improve the economic viability of retailers	- Reputation - Pilot project 'revitalization' - Building an ecosystem of partners - Revenue

Table 2
Overview of the core and extended ecosystem parties from a Philips Lighting perspective.

	Core ecosystem	Extended ecosystem
	Parties working directly with Philips Lighting on creating and capturing value.	Parties involved with the municipality or indirectly with Philips Lighting.
Amsterdam		Municipality Amsterdam, Karres + Brand Architects, Cisco, Lichtvormgevers, KPN, Alliander, TU/e Intelligent Lighting Institute
Eindhoven	Heijmans, TU/e Intelligent Lighting Institute, municipality Eindhoven, citizens (and later also local SMEs and incumbents)	Ziut, Vialis, KPN
Stratumseind	Municipality Eindhoven, OpenRemote, ViNotion, TU/e Intelligent Lighting Institute, Police	LuxLab, Fontys, Icen, Mezuro/Goudappel, ProNorm, Munisence, De Oude Rechtbank, U-Approach, Tele-Event, Coosto, NHTV, Dutch Rose Media, DITSS, Geodan, Eindhoven 365
Veghel		Municipality Veghel, Erasmus University Rotterdam, ROC Leijgraaf, Greenm2, Stichting Centrum Management Veghel, Rabobank, Enexis

3.1. Marbles business model

In the Amsterdam case the city sought to increase the sense of hospitability, atmosphere, social safety, and cohesion in one of the most modern urban sections of the city – Hoekenrodeplein, which was selected as a pilot area for smart lighting solutions. With an adaptive lighting system, which accounts for the calendar of events and actual measures of the amount and dispersion of people on the square, it provides different atmospheres suited to the occasion, so that citizens and visitors feel more comfortable and safe. The partners in the project were Philips Lighting, Cisco Systems, KPN (one of the largest Dutch mobile network operators), Alliander (a major Dutch energy provider), and the municipality of Amsterdam. These incumbents all are leaders in their respective industries, but none of them had any experience working in a smart city ecosystem. The project began in 2013; the lighting was installed in 2014; and currently, further systems continue to be integrated to deliver more adaptive functionality. This lengthy process, together with a limited budget, has limited the chances of creating and implementing other interesting smart city propositions in that specific area. In addition, the project did not develop any new value capture mechanisms that might help recover the initial investments from the different actors and allow further investments. Both Philips Lighting and Cisco Systems focused on creating and capturing value through their individual product-oriented business models.

> "The adaptive lighting system consisted of so many complex and disparate elements, but there was no-one assuming responsibility for the integration of it all."
>
> [Project team member]

As a result, value creation for Philips Lighting was limited to an adaptive lighting system that serves the needs of the municipality of Amsterdam to reduce energy costs. As a consequence, Amsterdam has not fully met the needs of its citizens though (i.e., hospitability, safety), as these complex needs cannot be satisfied by a product offering alone. Because Philips Lighting did not go beyond selling products, i.e., luminaires, connectivity, and an asset management system, it was unable to explore more societal, human-centric innovation opportunities jointly with the extended ecosystem.

3.2. Tetris business model

In the smart city context, municipalities are no longer the sole customer of smart city services. Citizens and consumers have shifted, from being purely users to being customers and prosumers too. Nevertheless, the initial impact of communication technologies on cities often results in a growing number of vacant shops, whose tenants have been driven out by the attractiveness of online shopping. Such developments have had negative influences on retailers in Veghel, in the Netherlands, as well as on the livability and quality of life in the city. To counter these developments, the municipality initiated a project entitled "Veghel behind a digital city wall." In this case, Philips Lighting developed a two-step plan. First, it sought to create a lighting experience area, where colorful, dynamic lighting scenarios welcome and attract visitors to the city center. Second, they created an experience platform with an interactive lighting design for the two main shopping streets, initiating the project "Veghel turns the light on." The focus for the experience platform lay on changing lighting content that could invoke particular experiences in the city center. More specifically, Philips Lighting conducted an area analysis and designed both the luminaires as well as the lighting content for different atmospheres. Such lighting experiences improve the visibility of retailers in the city center; it also stabilizes the bond between the city and its citizens and attracts new visitors. By offering products and services (lighting consultancy, experience platform, and maintenance) Philips Lighting was able to diversify its revenue opportunities. Such a lighting platform can also serve as a basis for (external) apps to stimulate app-based revenue models, such as freemium/premium, affiliation, or subscription models. Although, Philips Lighting depended on other parties to for example deliver greenery or sensors, they were only part of the extended ecosystem, while Philips Lighting was in charge and created value in-house. The initial results look promising: there are 22 newly opened shops and 15% more visitors in the city center.

> "Actually visitors should experience a visit to the shopping area as an attractive, fun, cozy and surprising experience. They should spend a lot of time in the area through nice shops and restaurants. The longer a customer stays in the shopping area, the more money is spent. So focus on a longer duration of stay."
>
> [Project advisor]

For this case, Philips Lighting took on the keystone player role and created value, using its experience in lighting, while also exploring the new fields of platform development and a more human-centric approach. By taking control of the participative, extended ecosystem, it was able to enhance its own value creation. Furthermore, beyond product sales in the first phase, it was able to diversify its revenue model through an innovative platform, as well as lighting consultancy, and maintenance services.

3.3. Jenga business model

With the Stratumseind case we explore the open, collaborative living lab of Stratumseind, one of the largest and most popular entertainment areas in the Netherlands and Europe. Each weekend, 25,000 visitors head to Stratumseind; on any given Saturday night, there are roughly 850 incidents, 20 of which lead to arrests or detentions. The municipality believes that lighting might be pivotal for de-escalating aggressive behavior and reducing these incidents to increase public safety and the attractiveness of the area. Stratumseind thus offers a unique research and measurement center, where experiments test ways to make the area safer, more vibrant, and more attractive. Philips Lighting helped start up this living lab and initiated the development of an open platform. On this platform, small, medium, and large

Table 3
Cross-case comparison on value creation and value capture dimensions.

	Value creation	Value capture
Amsterdam	Philips Lighting: - Provide and install luminaires and asset management software - Identify user needs and develop use cases for the square (that make the public space safer and more attractive to citizens and support local entrepreneurs) - Create interface to connect cameras to the asset management software - Provide data collection Ecosystem Partners: - Decide which use cases to implement - Contribute cameras	Philips Lighting: - Product sales Ecosystem Partners: - Product sales
Eindhoven	Philips Lighting: - Contribute to creating a vision and roadmap for smart lighting in Eindhoven - Design an innovation process that stimulates continuous innovation using a quadruple helix construction - Build a smart lighting grid that serves as an open public utility for innovative lighting services Ecosystem Partners: - Heijmans contributed to all of the above - Use the smart lighting grid to explore (lighting) innovations with citizens, local SME's, and other incumbents	Philips Lighting: - Smart lighting grid (i.e., luminaires + asset management software) - Revenues through commercializing innovations on grid - Maintenance services Ecosystem Partners: - Revenues through commercializing innovations on grid - Maintenance services
Stratumseind	Philips Lighting: - Contribute to NWO grant application, to take a scientific approach to exploring the effect of light on de-escalating aggressive behavior - Design and install custom made luminaires to be able to provide full color dynamic lighting scenarios - Stimulate dashboard development and living lab set-up - Explore the use of smart lighting in an open innovation ecosystem to manage crowds and support local entrepreneurs - Create new value propositions on the effects of light on public safety Ecosystem Partners: - Experiment with and study visitor behavior in a living lab setting - Develop a dashboard that integrates different sensors as well as activates different light scenarios - Add new technologies and sensors to the dashboard	Philips Lighting: - (Customized) product sales Ecosystem Partners: - Product sales
Veghel	Philips Lighting: - Create a masterplan with a roadmap for the center of Veghel that would engage visitors through integrated lighting and technology - Designing use cases - Install interactive lighting system, including light, sound, and color - Design and install custom luminaires - Develop dynamic light content for luminaires, also making use of sound - Create an experience platform, for local entrepreneurs, retailers, or others to upload other lighting experiences Ecosystem Partners: - Install greenery for phase 1 - Develop app (by students from local education institution)	Philips Lighting: - Lighting consultancy (including area analysis, developing use cases, and creating lighting content) - (Customized) luminaires - Maintenance service Ecosystem Partners: - Product sales - Services

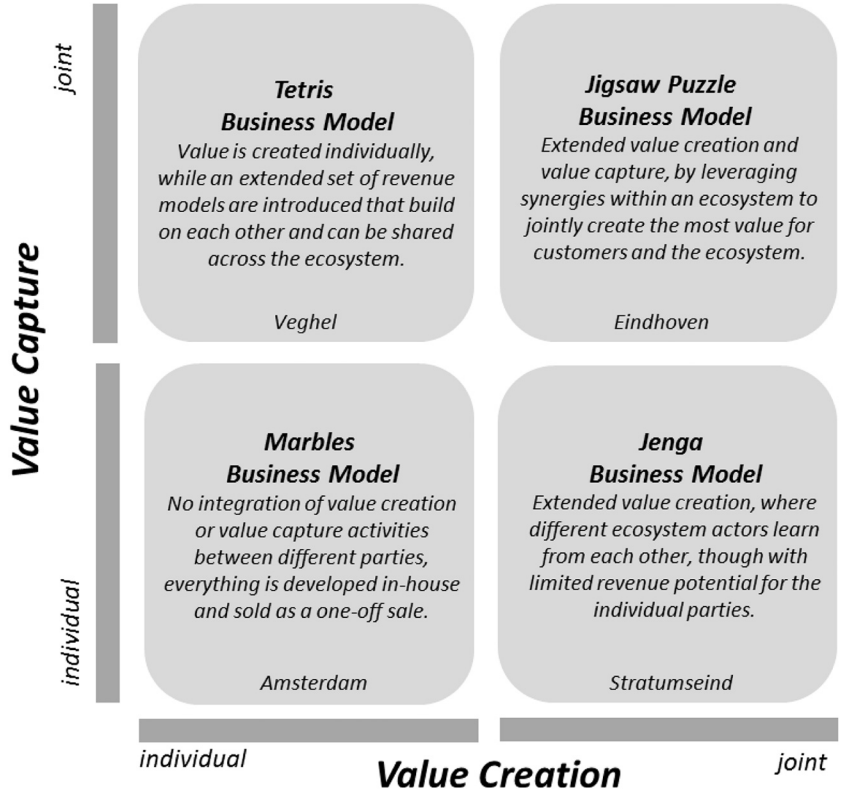

Fig. 1. Business model matrix with four distinct types of business models relevant to the smart city market.

enterprises as well as start-ups can propose and integrate their (partial) solutions, and test their impact in real-life circumstances with actual visitors. This ecosystem is highly complex, involving many different actors contributing to the improvement of the area. The Stratumseind case also reveals how a living lab can enable a large number of organizations to work together to jointly find smart city solutions. Although this living lab in Stratumseind has enabled experiments with various smart lighting and smart city opportunities, it offers very limited opportunities to capture the value created thus far.

> "The strong point of the Stratumseind living lab is its focus on crowd management and its open approach. Almost weekly companies approach us with technologies and modules that can be integrated in the system to better monitor or influence the crowd."
>
> [Living lab manager]

In this setting, Philips Lighting was part of a larger ecosystem; though not the keystone player. By creating value together with its ecosystem partners, Philips Lighting explored their products and services from an external perspective, while also diversifying its own offering according to the opportunities discovered through this joint value creation approach. The dominant Philips Lighting business model in this case remains dedicated to product sales to the municipality. However, the knowledge and value created through open innovation ultimately might be extrapolated and scaled to other cities and areas, where it could provide additional sources of income in the future.

3.4. Jigsaw puzzle business model

The smart city context can make it difficult to implement new and open business models, because many existing rules and regulations are linked to the old way of doing things. There is very limited room for innovation and flexibility. In the Eindhoven case, the municipality of Eindhoven acknowledged that it could not define all the requirements for innovative smart city proposals upfront, so it decided to enter into a competitive dialogue with industry and establish a best-value procurement process. The main aim was to develop a smart lighting grid (i.e., a platform) on which smart city services can be built to improve the quality of life in the city. A consortium of Philips Lighting and Heijmans (a Dutch maintenance and installation company) in turn developed an innovative offer that focused on continuous, human-centric services and solutions. These parties formed the core of an ecosystem, in which local entrepreneurs, small businesses, and other incumbent organizations jointly create smart city propositions for Eindhoven. The consortium is responsible for developing and providing a smart lighting grid that remains open to other parties. With a living labs approach, this project seeks to establish a platform that enables continuous, open innovation.

> "The project is very challenging, because we all need to change. But if we do, we will be able to address societal challenges with solutions that have a viable, scalable business. Each time when we are confronted with a misunderstanding in the project, we need to remember this – that keeps us going."
>
> [Project team member]

Due to the municipality's open, innovative approach to procurement, Philips Lighting was able to jointly explore a broad set of value creation opportunities during the open dialogue phase. In turn, it developed a long-term plan, in which the smart lighting grid and the platform provide foundations for extensive value creation that leverage external propositions, while also identifying joint value capture mechanisms across a smart city ecosystem. This open, cooperative approach stimulates scalability activities and helps diversify Philips Lighting's revenue model portfolio.

Overall, Philips Lighting applied four different business models in the smart lighting and smart city context that take different value creation and value capture approaches. In the next section, we will discuss these four types of business models in a larger theoretical context to identify the advantages and disadvantages of the business models and the related ecosystem approaches.

4. Discussion

Technological developments, changing customer demand and the arising market potential of smart cities put a lot of pressure on the current business models and ecosystems of incumbents. Radical technological innovations that conflict with the established business models have proven to be particularly challenging for incumbents (Teece, 2010; Tripsas and Gavetti, 2000). Examples, including Polaroid and Kodak (digital photography) (Tripsas and Gavetti, 2000), Nokia (smartphones) (Aspara et al., 2013) and the jet engine technology (aircraft industry) (Henderson and Clark, 1990), show that incumbents are often unsuccessful with business model innovations. Whereas start-up companies can design their new business model around a new technology from scratch, incumbents must innovate and transform their current business model and business processes to commercialize new technologies. In spite of that, the business model literature has mainly focused on start-up companies and new ventures (Amit and Zott, 2001; Andries and Debackere, 2013; Zott and Amit, 2007), with only a few studies focusing on incumbents, even though business model innovation there has a lot more intricate dynamics (Berends et al., 2016; Desyllas and Sako, 2013; Kindström, 2010). Therefore, in this study we focused on the incumbent Philips Lighting and how they explored the smart city market with four distinct business models and the related ecosystems. As Cohen et al. (2016) clearly state: "[…] the existence of business models that facilitate this [ecosystem] participation is essential for the success of these [smart city] endeavors. Effective business models are a critical aspect of open innovation." (p. 12). Our study contributes to the literature by illustrating four types of business models that are valuable in the smart city context, where the Marbles business model is related to the existing way of doing business in the lighting industry and the other three offer new business model innovation opportunities. Each business model comes with its own advantages, where there is not necessarily one model that should be considered better than the other. Instead, it depends on the project and the ecosystem constellation. In the next section we, first, discuss each business model individually and, second, consider the overarching business model and ecosystem implications for incumbents.

4.1. Marbles business model

The Marbles business model quadrant resembles the currently most common incumbent business model. Incumbents in various industries continue to apply this classical product sales model, such as when retailers of consumer electronics perform their value creation activities internally and sell the products through traditional channels, with some set margin. Interactions with other parties usually consist of competitive buyer–supplier relationships, with clearly defined, measurable targets and predictable outcomes. As we saw in the Amsterdam case, Philips Lighting did not create value together with other parties as part of a core ecosystem, but was still able to create interesting use cases and sell their products. However, Philips Lighting and Cisco were not able to go beyond their old, traditional product sales business model to integrate their innovation activities and create a more extensive adaptive lighting solution for Hoekenrodeplein, as both incumbents underestimated the effort required to create an integrated solution. Indeed, both incumbents were greatly influenced by their inherent industry structure and existing business model and could not adjust enough to create a joint solution (Adner and Kapoor, 2010). As Adner and Kapoor (2010) state, to successfully create value an incumbent must not only overcome internal innovation challenges, but their core ecosystem partners also need to overcome their own innovation challenges, which can be very time-consuming. Therefore, in certain contexts an incumbent can profit more from creating value individually, independent from the ecosystem's innovation activities, where similar to Marbles each have their own value. Instead other parties can be used in a supplier role in an extended ecosystem.

4.2. Tetris business model

In the Tetris business model quadrant, value capture has a more dominant role than value creation. Value creation continues to be done individually, in-house, but new commercialization opportunities are explored. The new revenue models might include consumers (e.g., crowdsourcing), other companies, or government institutions (e.g., public–private partnerships). The joint activities might take place in the fuzzy front end of innovation or during the final production or delivery processes (King and Lakhani, 2013). By creating value in-house, Philips Lighting was able to take on the keystone player role in the Veghel project and drive the project towards successful smart lighting innovations (Iansiti and Levien, 2004). By selling services, products, and a platform, Philips Lighting spread their revenue opportunities, while also allowing other companies to offer services on the lighting experience platform and capture value. This is also in line with research on ecosystems, that tends to focus on how exchange partners shape a firm's value capture (Adner and Kapoor, 2010). Such an approach is less risky to an incumbent organization, as there are fewer interdependencies (Adner, 2006). Through the keystone player role, Philips Lighting was able to leverage products from the extended ecosystem (such as greenery or an app), without the dependency on other incumbent's value creation, as experienced in the Amsterdam case.

4.3. Jenga business model

The Jenga business model describes new ways of creating value, using individual value capture mechanisms. Companies thus open their innovation activities to customers, end-users, and other companies, seeking to jointly develop and produce new products and services together. Such options are manifested in co-creation, crowdsourcing, and lead-user involvement. However, the product or service value continues to be captured with individual product sales approaches. In the Stratumseind case, we saw that the ecosystem actors were able to overcome their internal innovation challenges, to jointly 'build' on smart city solutions. By opening up their value creation activities the different ecosystem actors were able to share knowledge on how to use lighting to influence peoples' behavior. Such an ecosystem is necessary to jointly create value that no ecosystem actor could create on their own (Adner, 2006; King and Lakhani, 2013). If an actor would leave the core ecosystem the value creation activities would suffer greatly or might even break down, if no replacement is found, hence the Jenga tower analogy. However, in our context the value capture opportunities were limited to the individual actors, which in turn lead to some competition among actors with competing solutions for functions in the total system. If there is less competition, core ecosystem players are more likely to share their ideas and invest in joint knowledge creation, especially in contexts with high uncertainty, such as smart cities (Santos and Eisenhardt, 2009). Such knowledge can then be used for an incumbent's internal innovation activities and can, therefore, indirectly contribute to value capturing. However, the complexity of the interdependence between the ecosystem partners, can also become a bottleneck to a firm's value creation (Adner and Kapoor, 2010), but the implications and effects of (a lack of) competition in a joint value creation ecosystem, should be studied in more detail. Moreover, such an open innovation approach often demands compromises and adaptiveness from the different ecosystem partners, which can be quite time consuming (Adner, 2006). As King and Lakhani (2013) suggest, if companies want to capture value from their open innovation activities, they need a different business model (i.e., the Tetris or Jigsaw Puzzle business model).

4.4. Jigsaw puzzle business model

With the Jigsaw Puzzle business model, incumbents can jointly explore new territories and revenue models. With such a business

model, incumbents open up their innovation activities and invite other parties to contribute and share; they also jointly explore new revenue models. Both activities can reinforce each other. This connection often provides the economic justification for platforms that enable new value propositions. One party might provide a strong innovation platform, with specific use cases, and then other parties can leverage and contribute to the value of the platform in this value-sharing model. Like in a Jigsaw Puzzle all pieces add to a larger whole. As Cohen et al. (2016) stipulate, future city innovations will not depend on single tech organizations, but rather require collaboration and co-creation with local municipalities, incumbents, citizens, and even competitors from different industries. For this to become common practice, there needs to be a clear process to value creation and value capture among the core ecosystem actors. To commit to this future way of working, Philips Lighting designed a continuous innovation process that involves the quadruple helix actors (i.e., municipalities, knowledge institutions, businesses, and citizens). Through a continuous innovation approach a balance can be found between value creation and value capture, ensuring that all ecosystem actors will profit. Indeed, it becomes essential to provide clear and sufficient incentives for third parties to become involved in the core ecosystem (Cohen et al., 2016). However, from a Philips Lighting perspective, such an approach was quite risky, as it demanded a lot of resource investment and a more long-term approach to value capture in an uncertain market. Incumbents need to balance individual with joint value creation and capture, where individual activities are used for short-term profit and joint activities for continuous innovation and long-term success. In this study we present a dichotomy of openness and collaboration for business model innovation, while future research might investigate the degree of openness required for successful business model innovation. Moreover, future research should explore to what extent incumbents need to 'open up' their value creation and value capture activities to investigate also what kind of different open innovation forms might exist for new and diverse ecosystems (Cohen et al., 2016).

4.5. Overarching business model and ecosystem implications

Together, our four Philips Lighting cases show that by exploring a diverse set of business models in parallel, an incumbent can respond more flexibly to the rapidly changing smart city ecosystem. Instead of focusing on the procurement of a singular solution or isolated problems, smart cities demand more complex solutions from innovation ecosystems that also generate broader entrepreneurial opportunities. Opening up parts of the business model innovation process enables an incumbent to become more flexible. However, while open innovation literature suggests that open (i.e., joint) value creation goes hand in hand with open value capture (Chesbrough, 2003, 2006), we find that this does not necessarily have to be the case. Instead, joint value creation can also be combined with individual value capture and vice versa.

Moreover, business model innovation requires significant trial and error as well as openness towards experimentation and agility on behalf of the incumbent (Chesbrough, 2010; Doz and Kosonen, 2010; Sosna et al., 2010). Indeed, the appropriate business model cannot be anticipated in advance; it needs to progress continually and requires progressive fine-tuning (Andries and Debackere, 2013; Chesbrough and Rosenbloom, 2002; Demil and Lecocq, 2010). By being able to flexibly apply different models when reacting to changes in the markets or maturing of products, incumbents can save a lot of time and costs (Doz and Kosonen, 2010). More specifically, Sabatier et al. (2010) describe the approach to a business model portfolio as a strategic tool, where a company delivers different sorts of values into various markets at the same time through combining internal activities and external demands. They demonstrate that it is possible and beneficial to have multiple business models so that they can create and capture value at different stages in the value chain (Sabatier et al., 2010). With our study we extend these business model portfolio findings and demonstrate that incumbents can also explore several business models in one sector, depending on the project and ecosystem they operate in. A diverse set of business models in the same market can provide complementarities that ultimately can contribute to a more fine-grained overall business model. As our study focuses on only one incumbent and one market, future research should explore how a diverse set of business models within the same market develop further and whether and how different incumbents combine different models into one overall model as the market matures. However, such a diversification of activities can also be highly risky and may also lead to competition among two or more business models. As a consequence, an incumbent is faced with a conflict of interest between low-cost and differentiation strategies (Markides and Oyon, 2010). Future research should also explore in more detail the challenges of having multiple business models in the same industry.

Table 4
Overview of the seven actions for moving around the business model matrix.

		Actions	Example case
Move horizontally: from individual to joint value creation	1	Conduct value-driven business model innovation.	Amsterdam
	2	Consider customers, end users, and ecosystem partners in the business model innovation process.	Amsterdam
	3	Create value locally.	Eindhoven
Move vertically: from individual to joint value capture	4	Innovate across silos.	Stratumseind
	5	Capture value globally.	Eindhoven
	6	Take on a different role in the value network.	Veghel
	7	Innovate continuously.	Eindhoven

5. Managerial implications

The technological and financial benefits of smart cities are appealing, but the key to the success of a smart city is the promise of societal value, in the form of a better quality of life and a more human-centric approach to urban innovations (Albino et al., 2015). We find that in the smart city context these aspects are at the core of an incumbent's new business model. However, selecting, adjusting and/or improving business models can be quite a complex task to achieve (Teece, 2010). Typically a new business revises its business model up to four times before reaching profitability (Demil and Lecocq, 2010; Johnson et al., 2008). There are no clearly defined steps in business model literature that can be used to do so, as business models have mostly been analyzed at one point in time and not as a dynamic design. In this study, we go a step further and provide practical actions for business model transformation. Specifically, we ask, how can a company move from one business model quadrant to another? We extracted seven actions (Table 4) that suggest a practical approach for incumbents to compete effectively in smart cities.

5.1. Moving horizontally: from individual to joint value creation

The first three actions focus on how an incumbent can move from individual to joint value creation, which adds value to the company's offering by matching smart city–derived expectations.

1) *Conduct value-driven business model innovation.*

Technological developments, changing customer demands, and the rising market potential of smart cities have put a lot of pressure on current business models and ecosystems. Focusing on technology and products will lead back to a traditional product sales business model, in which profit gradually will decline. To change, it is necessary to shift

focus towards a more value-driven approach, to create and capture significant human-centric value in the smart city context. By taking a different approach to value creation, a company can proactively shape its role in the new ecosystem.

2) *Consider customers and end users in the business model innovation process*.

In smart cities customers and users are two distinct target groups. Traditionally, organizations negotiated and collaborated purely on a macro level, with the municipality. However, the micro, consumer perspective becomes more critical, so organizations and municipalities alike need to reconsider. For innovative smart city services to succeed, the value of the solution must be specified according to its desired societal impact. Smart city solutions should start with end-users, putting their needs at the core of the value proposition. A quadruple helix approach, actively involving the end-user, the municipality, businesses, and knowledge institutions, may be of great value (European Commission, 2015).

3) *Create value locally*.

To apply a human-centric value creation perspective to smart city innovations, it is essential to understand the needs of the citizens and visitors of a specific city in-depth. These needs will differ across cities, countries, and user groups, so only local insights can produce valuable smart city propositions that are likely to be adopted and used for an extended period. A living lab approach provides a pertinent means to identify latent value propositions, through co-creation and testing in the actual, local setting (Almirall and Wareham, 2011; Cohen et al., 2016; ENoLL, 2016).

5.2. Moving vertically: from individual to joint value capture

The next four actions involve moving from individual to joint value capture, to increase the scalability of smart city opportunities, which is key for remaining successful as an incumbent.

4) *Innovate across silos*.

Traditionally, value is created and captured within specific silos, with little overlap between them, especially in a municipality (The Economist, 2016). When moving towards smart city services though, value creation must span the different silos: Value created in one silo could be captured in a different silo. For example, imagine that with a specific lighting functionality, crime can be reduced in a certain area. In turn, fewer police men are needed to patrol that area, which would reduce the costs for the police department and the municipality overall. The challenge is to make such value capture transparent and tangible for all the parties involved.

5) *Capture value globally*.

Creating living labs and investigating local needs will result in stronger value creation, so the next step is to move value capture to a higher level. Platforms have become essential for capturing value efficiently and can be described as the business model of the Internet of Things (Parker et al., 2016). A platform can easily be transferred to new settings to create new value locally, but the challenge is to expand from single business cases to multiple value cases, to recuperate the platform investments and achieve global scale.

6) *Take on a different role in the value network*.

Stand-alone strategies do not work in a smart city context. A value network or ecosystem is necessary for an incumbent's success. Incumbents must take a broader approach and involve a wide set of partners and suppliers that can provide high-quality, citizen-centered services. In particular, a keystone strategy can put an incumbent company in a central hub position, such that other actors rely on it (Iansiti and Levien, 2004; Weill and Woerner, 2015). Incremental change will not move the organization to the center of the emerging value networks and ecosystems; rather, such a firm would likely find itself in a mere supplier role. Radical change is needed to become a key player in a smart city. Collaboration with other incumbents that create and capture similar value will lead to conflict, if not mediated by an integrator or keystone player. Taking the keystone player role in a value network puts a company in control of value creation and capture, while leaving the vast majority of the value creation effort to the wider network.

7) *Innovate continuously*.

By providing a platform on which numerous ideas can be submitted for additional open value creation, whether from citizens, municipalities, or businesses, the keystone player increases its access to ideas and value propositions. In addition, a continuous innovation process can ultimately benefit all parties and justify the initial platform investments. Yet, the keystone player also remains responsible for taking along its customers, to demonstrate the breadth of possibilities and the less tangible revenue streams and/or cost savings available to them.

6. Conclusion

Smart cities have emerged as a dominant digitization trend in recent years. New products and services enter the market and take off at a much faster pace than in the past, so lengthy discussions and contested agreements, as found in traditional procurement processes, instead hinder innovation. Therefore, smart cities, as a widely adopted buzzword, cited by policymakers, politicians, and companies alike, force us to wonder: Are smart cities a true trend for the future or just a hype? To realize the potential of smart cities in the modern, digitized reality, organizations and municipalities must shift their (centralized) mindsets and take actions that go beyond pilot projects, so that they can apply their lessons and innovations on a larger scale. Cities need to focus on designing structures that facilitate innovation ecosystems to be able to create the necessary smart city innovations. To adapt quickly, incumbents need to be able to adopt roles that do not always fit their traditional core competencies. Overall, the future of urban innovations demands collaborations and co-creation with municipalities, incumbents, citizens, as well as competitors across a range of industries.

From four cases involving Philips Lighting, we saw that smart city services can be achieved only through internal alignment and external collaboration. Incumbents must innovate across sales, business, and R&D while also opening up to external partners. Traditional inside-the-box thinking cannot achieve the breadth, depth, and complexity required for smart city innovations. As Philips Lighting highlighted: smart cities are not built in Philips Lighting but around it. Therefore, companies must find ways to work together across their departments, to think outside the box and deliver on the massive promise of smart cities. This requires a shift, away from a prevalent product mindset that reflects decades of product sales (i.e., “the product business model is broken” according to Marshall Van Alstyne), to a more process- or service system-oriented approach. Through a business model portfolio approach, an incumbent can experiment with different value creation and value capture approach in uncertain markets. An incumbent is then more flexible to responding to changes in the market or the ecosystem, until the market and the business models mature.

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Appendix 1

Case description – Amsterdam

Context

Hoekenrodeplein is part of a larger project of the municipality of Amsterdam that aims at redeveloping the south east central area of the city. Hoekenrodeplein is a square between the shopping area 'Winkelcentrum' Amsterdam Poort, the ArenA boulevard, the Bijlmer railway station, and residential areas. The area hosts the Amsterdam ArenA football stadium, several large music halls, as well as hotels, shops, and restaurants, and attracts many visitors throughout the year. Each day hundreds of commuters pass through the square to reach the local train station or to visit one of the facilities on the other side of the square. As the human traffic flow focuses on the west side of the station few people actually linger on the east side, including Hoekenrodeplein, as it is perceived as dark and uninviting.

Therefore, the main aim of the municipality was to improve the quality and function of the square, by focusing on (1) quality of life (safety, hospitality), (2) cost effectiveness (energy, maintenance), (3) sustainability (energy, CO_2). Next to the functional redesign of the square, Hoekenrodeplein was selected as a pilot area for an intelligent lighting project as part of E3 SLIM collaboration. More specifically, lampposts would be fitted with cameras, a public WiFi network, and an adaptive lighting system to stimulate and explore compelling use cases tiered towards smart cities.

Value creation and capture activities

In 2012, the municipality of Amsterdam gave the order to Karres + Brand architects to create a design for the whole urban space and a specific design for Hoekenrodeplein. This design focused on making the open space more attractive and hospitable, to retain more people in the area and stimulate the local entrepreneurs. The re-development of the area was seen as a starting point that would connect Hoekenrodeplein to the other areas, facilitate pedestrian routing, create places to stay and meet both during the day and evening, and stimulate a good atmosphere for small and large crowds. Additionally, a lighting design company called Lichtvormgevers was involved to create a lighting plan and design luminaires for the square. The final design resembles trees with birds, making use of Philips Lighting LED products. Additionally, Philips Lighting provided the asset management software to be able to control the separate lights.

Aside from the landscaping ambitions, the municipality, inspired by the discussions in the E3 SLIM project in 2013, was looking into the possibilities of organizing a pilot project on intelligent lighting and smart city solutions. Therefore, the municipality of Amsterdam asked the companies involved in the E3 SLIM project (Alliander – a Dutch network operator, Cisco and Philips Lighting) to develop and install the required technology to explore the viability of smart lighting and smart city solutions in a real-life setting, as these were still in their infancy then. Eindhoven University of Technology's (TU/e) LightHouse was responsible for developing a proposal to investigate the impact of smart lighting on hospitality, safety, and sustainability for the Hoekenrodeplein square.

While the square was being rebuilt and the lighting system installed, Philips Lighting focused on exploring possible use cases that would rely on an intelligent lighting system. The use case team conducted interviews with the people from the area (including residents, office workers, tourists, event visitors, and shoppers), generated insights and articulated use cases that could leverage an adaptive lighting infrastructure. Three common themes were identified, which were in line with the city's ambitions: (i) hospitality, (ii) livability, (iii) sustainability. Together with the extended ecosystem actors a decision was made on which use cases would be implemented first on the Hoekenrodeplein square: an adaptive lighting system that would change according to the use of the square and the amount of people on it. More specifically, such a light-on-demand system could provide an attractive atmosphere, safety lighting in calamity situations, reduced light pollution, and reduced energy usage through LED and adaptive light.

After the renovations were complete, Hoekenrodeplein was officially opened in June 2014, but at that point still only with limited functionality: only a few static lighting scenarios were available that were activated on predefined time-intervals through the asset management system. To be able to provide an adaptive lighting system, more than just lighting and an asset management software from Philips Lighting was needed. As there would be different types of scenes that would match different scenarios of usage of the square, e.g. for entertainment purposes, for commuters, or for football fans, cameras would be needed to detect the amount and distribution of people on the square. Cisco was responsible for providing WiFi connectivity and installing the cameras on the light poles on the square that would then be integrated with the lights.

However, the parties involved were confronted with two main issues. First, the budget for the project was very limited, allowing only the installation of four cameras that would only partially cover the square. Second, the asset management software from Philips Lighting that controls the LED lights, was at that point in time very closed, making it difficult to integrate external systems and sensors, such as cameras. None of the project partners felt responsible for the system integration, which, in the end, delayed the process of implementing the adaptive lighting system. However, through several rounds of intense negotiation, Philips Lighting developed the required additional software for the connectivity of the system to the cameras. Cisco installed the four cameras, which were then connected to the lighting system. KPN (a large Dutch network provider) became partner in the project to provide the data connections for the cameras and to operate the WiFi network for public use. KPN also took the initiative to create a simple control app to demonstrate the lighting scenarios. The municipality then organized the second opening in March 2016, where the adaptive lighting system was officially introduced. As the cameras only cover a very limited area of the square, the usability and effectiveness of the adaptive lighting system is virtually non-existent. Although there are still ideas and use cases that build on the adaptive lighting structure and create additional value, there is no more funding from the municipality, the parties involved or from new sources of revenue. The companies have all invested significant resources into this pilot project with little return on their investment and as there are more and more new smart lighting and smart city projects emerging, they have little incentive to invest even more in Hoekenrodeplein.

Ecosystem

Philips Lighting was initially approached for Hoekenrodeplein only to supply LED spotlights and asset management software through a traditional product sales business model. The project became a 'smart lighting project' when Hoekenrodeplein was selected as pilot for the E3 SLIM project, which resulted in an extended ecosystem involving the cities of Eindhoven and Rotterdam, TU/e LightHouse – as part of the Intelligent Lighting Institute of the Eindhoven University of Technology with the role to research the impact of smart lighting –, Cisco – having its European headquarters in Amsterdam and already involved in smart city discussions in Amsterdam – and Alliander – the local grid operator, who was needed to provide 24/7 power to the public lighting system. Philips developed the use cases, and in the realization of the solution each company brought in their own products and services. Throughout

the project process it became apparent that the ecosystem of partners lacked certain competencies, e.g. a network provider – so KPN became involved.

Conclusion

The Hoekenrodeplein project showed that the organizations involved from the beginning onwards were very eager to explore smart lighting solutions, to learn how lighting can be implemented in a larger context of smart cities. Although Philips Lighting was able to create interesting use cases that could be explored in the Amsterdam context, the parties involved struggled to develop and follow through on those ideas. Especially Cisco and Philips Lighting were unable to agree on system integrations and adhered strongly to their incumbent business model of selling products, while the other partners involved had very little knowledge of lighting and smart cities and could, therefore, not take the role of an intermediary or strong project manager. Although a localized approach is key to developing solutions that are scalable and replicable, it remains a challenge to involve all the actors in the process to jointly create value and a societal contribution that goes beyond their individual value capture goals.

Case description – Eindhoven

Context

Eindhoven is the technology capital of the Netherlands and home to many large multinational companies that have produced many (technological) innovations. More specifically, Eindhoven hosts the headquarters of Philips Lighting, ASML, DAF, and NXP as well as their major research facilities. As a consequence, the city and the surrounding region of North Brabant have been declared #1 most inventive city and innovative region by Forbes. The companies in this area produce > 22 patents per 10.000 employees, nearly three times more than the follow-up San Diego (OECD, 2013); while the European Commission declared Eindhoven to be the front runner for smart lighting (European Commission, 2013). By combining both its strong technology and design foundation, Eindhoven wants to live up to its reputation and also be at the forefront of the ongoing smart city developments. The city of Eindhoven has dedicated itself to installing a smart lighting grid to provide a strong basis for smart city services that will improve the quality of life for Eindhoven's citizens and visitors.

Value creation and capture activities

The account manager of Philips Lighting was aware of the fact that many luminaires in Eindhoven were approaching or even beyond their economic and technological lifetime. Moreover, the municipality showed ambition in the field of sustainability, by signing the Covenant of Mayors and the Lighting Urban Community International (LUCI) charter on urban lighting (LUCI Association, 2015). Therefore, in 2011 he took the initiative to make a proposal for the city to replace 21,000 of its traditional street lights with LED: an investment that would be earned back in under seven years and would contribute to major reductions in CO_2 emissions. This proposal triggered a discussion among the deputy mayors responsible for innovation, public lighting and spatial planning on the innovation ambitions of Eindhoven as 'the city of light'. Their concern was that these LED lights would last for 25 years and in this timeframe a lot of technology innovations are to be expected, which would then no longer be an option as the budget can only be used once. The vice-mayors decided to give an assignment to TU/e LightHouse – which was just founded to disclose the expertise of the Intelligent Lighting Institute (ILI) of the Eindhoven University of Technology – to create a vision for urban lighting in Eindhoven in 2030, and an accompanying roadmap to indicate available and future technologies to realize an urban lighting vision. With this roadmap they aimed to ensure future-proof decision making in the transition from conventional lighting to LED and smart city solutions. The project followed a co-creation process in which different departments of the municipality were involved, but also various companies and knowledge institutions. Philips Lighting was one of the companies that contributed to the roadmap from their own vision on future developments in connected lighting and smart cities. The resulting Vision and Roadmap Urban Lighting Eindhoven 2030 envisions a smart lighting grid that enables innovative solutions to continuously improve quality of life in the city (Den Ouden and Valkenburg, 2012). The roadmap was discussed in the Municipal Executive and city council and adopted as official policy document in 2012.

After establishing the vision and roadmap as official policy, the city of Eindhoven realized they would need a more innovative approach to procuring public lighting for their city. They gained insights in options through the knowledge sharing sessions of the E3 SLIM project. Two important decisions needed to be made: (1) cover the whole city lighting infrastructure at once or focus on specific areas first and (2) how to integrate the aspect of innovation in a public lighting tender. To answer both decision points the municipality team chose for a competitive dialogue phase, a procedure ideal for complex tasks, and combined it with a best value procurement approach in the final phase of the dialogue phase. A competitive dialogue is a flexible procurement procedure that enables the contracting authority to discuss an assignment with potential bidders (EPEC, 2010). This procedure can be linked to the notion of Public Private Partnerships (PPP), while the focus at that moment was on joint value creation and less on joint value capture (Burnett, 2009).

To start the process, the municipality organized a market consultancy session in 2013 that was open to any interested party. A large range of companies participated, including Philips Lighting. However, many parties did not follow through and were not involved in the following dialogue activities. The municipality later reflected that the threshold was probably too high for (smaller and international) companies, as this tender goes beyond their current budget and/or (language) capabilities, which also limited the possibility of forming a consortium. After the consultation session eight parties were invited to a one-on-one meeting with the municipality. All were very positive about the innovative approach of the municipality of Eindhoven and four consortia qualified and were selected for the dialogue sessions, one of which consisted of Philips Lighting and Heijmans (a Dutch infrastructure installation company). The intended goal of the dialogue phase was to focus on the 'why' and the 'what' questions and less on the 'how' questions. Information sharing, determined beforehand by the municipality, was done through formal contact moments. In total there were three official dialogue rounds, covering a timespan of one and a half years. Three key elements were taken into account during the dialogue sessions: innovation, organization and market potential (business potential). After these sessions the consortia received feedback from the municipality to sharpen their offer. Next to this, also expert meetings were planned focusing on specific topics such as 'open data' and 'governance' to get more detailed information on what was not covered during the dialogue sessions or which needed more clarification. This process helped the municipality to learn from the different consortia, while the consortia got the opportunity to understand the needs of the municipality in greater depth. Through this open sharing approach both sides were clear on each other's expectations and reached an additional level of understanding.

Overall, the municipality of Eindhoven had two primary goals in mind that were formulated at the beginning of the dialogues:

1) A smart lighting grid should facilitate data and services that will stimulate creative applications to improve the quality of life in the city, while continuous innovation results in new insights and services.
2) For the economic viability of the city the municipality wants to stimulate an ecosystem that develops new lighting solutions, including hardware and services that will be ultimately developed and realized by existing and new companies.

Key to achieving these goals is the implementation of a quadruple helix collaboration.[1] Philips Lighting is used to involving the end-user perspective in their research and design processes for new products, but working in a quadruple helix setting with end-users and other companies to create smart city services was new to them. The solution that Philips Lighting/Heijmans proposed was a process to complement the implementation of connected lighting as the foundation of a smart lighting grid. They designed a process to help structure the continuous innovation process for propositions that leverage the smart lighting grid. This process captures the different actors, their roles and how the quadruple helix can go from identifying needs, to open innovation and finally implementation.

After a careful consideration of the three bid documents, the Philips/Heijmans consortium scored the best overall and was awarded the Eindhoven tender contract in 2015. Next to the high quality product and service offering of the Philips/Heijmans consortium, the consortium stood out with its smart city continuous innovation process, which allows other companies to develop services on top of the smart lighting grid. The contract was signed in 2016.

Ecosystem

From the beginning Philips Lighting worked closely together with the municipality, TU/e LightHouse and the Intelligent Lighting Institute to develop the smart lighting roadmap for the city of Eindhoven. During the open dialogue phase several organizations formed consortia to compete in the tender. There were three consortia involved until the end of the process: (1) Philips Lighting and Heijmans, (2) Vialis and KPN, (3) Ziut. Although only one consortium won, all the parties involved shaped the process and the results. The smart lighting grid is an open grid that also offers opportunities to other companies, including those involved in the dialogue phase, to implement their smart city innovations.

Conclusion

While we observed a change in mind-set and way-of-working for both municipality and consortia, there are two separate key learnings for each of the two. For the municipality this whole project was a search for the optimal approach and process for creating and implementing smart lighting and smart city solutions for Eindhoven going beyond mere pilot projects. Especially the first part of the process, including developing and co-creating the roadmap and going through the open dialogue process provided the greatest insights. Through the open discussions, the Philips/Heijmans consortium was able to develop an innovative offering going further than any company could have developed on its own. It is safe to say that this procurement procedure was key in the development of the continuous innovation process, which will facilitate innovations beyond lighting. For Philips Lighting it became clear that smart city services can only be achieved through internal alignment and external collaboration. We saw a shift from the prevalent product mindset of Philips Lighting, which finds it origins in > 120 years of product sales, to a more process- and service-oriented approach. Innovation should become a more value-driven process, facilitated through an open innovation and co-creation approach. In line with this, value capture within smart city services demands a more long-term orientation, as opposed to the more short-term oriented product value capture focus.

[1] "[In] a quadruple helix model, government, industry, academia and civil participants work together to co-create the future and drive structural changes far beyond the scope of what any one organization or person could do alone. This model encompasses also user-oriented innovation models to take full advantage of ideas' cross-fertilization leading to experimentation and prototyping in real world setting." (European Commission, 2015).

Case description – Stratumseind

Context

Stratumseind is the main entertainment area of Eindhoven, where each weekend, 25,000 visitors come to have drinks and party. On any given Saturday night, there are roughly 850 incidents, 20 of which lead to arrests or detentions. Indeed, many situations escalate, as intoxicated individuals or groups get agitated or frustrated, which often leads to verbal and physical aggressions. Such aggressive behavior does not only impact the atmosphere of the entertainment street, but also affects the safety and health of visitors, local employees and security people, as well as emergency service providers. Additionally, due to the lack of (positive) atmosphere, fewer people have been visiting the local bars and cafes, and as a consequence many of those have closed, causing the atmosphere to deteriorate even more. Triggered by the development of the Roadmap Urban Lighting 2030, the municipality was interested in increasing the public safety and the attractiveness of that area by exploring the potential of lighting to de-escalate aggressive behavior. They believed that by making Stratumseind safer and more appealing, they could attract more visitors, have them stay longer and spend more, reduce the police and health costs, while being able to cut down on energy, security, and waste costs. As a consequence, the real-estate prices would increase as well as the revenue for Stratumseind and the city.

Value creation and value capture activities

In 2012, the municipality of Eindhoven was facing these issues and was discussing together with TU/e LightHouse what role lighting could play to resolve those. They considered it an opportunity to experiment with the ideas of the Roadmap Urban Lighting 2030. The LuxLab, a lighting consultancy from Eindhoven, picked up on this opportunity and wrote a proposal called 'Licht Poppers' to study the effects of light on people in Stratumseind. The main aim of that proposal was to conduct an explorative research and test light concepts in the public space that could positively influence the visitors' experience. The LuxLab joined forces with TU/e LightHouse and set up a temporary lighting installation in Stratumseind to evaluate how people reacted towards them. Overall the Light Poppers project was a success, where initial results revealed that people's mood and behavior could be influenced by lighting. At the same time, they also acknowledged that there are many other factors that play a role in such a public setting, such as weather, time of the month, or events that could also influence the results and which would need closer investigation.

In parallel, the municipality initiated a discussion on installing a living lab in Stratumseind to explore the promising results from the Light Poppers project in more detail over a longer period of time. In other words, they wanted a more structural approach to studying the effects of dynamic lighting scenarios on people in an entertainment street. Reacting on these opportunities a professor of human technology interaction (focusing specifically on light) from the Eindhoven University of Technology applied for a Dutch scientific grant (i.e., NWO proposal). The LuxLab and the account manager of Philips Lighting were involved in the 'De-escalating behavior through light' proposal. They were awarded the grant in 2013 and the project was initiated. The main aim of that proposal was to install adaptive lighting in Stratumseind, with which the effects of dynamic lighting scenarios with different light colors and intensities on visitors could be tested. The account manager arranged for the specially designed luminaires to be built and installed in Stratumseind, which was partly covered by the awarded grant money. In the process, a PhD student was hired to conduct the field experiments. In parallel, there were several companies that were already working in the Stratumseind context to explore crowd behavior and management during specific events. For example, ViNotion, a specialist in automated video content analysis, conducted an experiment during King's Day to track people's movement. Moreover, the municipality had a contract with Vodafone to find out from which cities visitors of the Glow festival came from, to be able to

offer more targeted marketing in the next year. So, aside from the more scientific project funded by NWO, many other companies were already exploring visitor behavior at Stratumseind.

Although Philips Lighting provided the luminaires, more hardware and software was needed to integrate all the different sensors, data and dynamic lighting control software for the PhD student to be able to run her experiments. For this, OpenRemote, a small company specialized in integrating different protocols and solutions, developed a dashboard with which different light scenarios could be activated, with the possibility of also adding other sensors. The costs for the dashboard were covered by the Intelligent Lighting Institute, the municipality, and Philips Lighting, as this was not budgeted for in advance.

This dashboard also opened up many more opportunities for integrating other sensors and systems to be able to collect more data. Essentially, this triggered the start of the Stratumseind 2.0 project, making the entertainment street a living lab for a large ecosystem of companies to experiment with new technologies. The main goal of this Stratumseind 2.0 project was to "structurally improve the economic and societal functioning of Stratumseind, together with other parties, including entrepreneurs, breweries, real-estate owners and the municipality (together with the police)". The structural improvement should focus on three main themes: (1) livability, (2) safety, and (3) attractiveness. The project gained significant attention in local and national media and attracted many smaller and larger companies that brought in additional hard- and software. Unfortunately, due to a lack of funding the participation is all on voluntary basis. As a consequence, the progress and the results from the project are limited. Also, the data that is being generated through the installed sensors is also not explored structurally, neither by the companies nor the Eindhoven University of Technology. Moreover, the PhD student, specifically focusing on the effects of lighting on de-escalating aggressive behavior, was unable to control for external factors that could also influence aggressive behavior, making data collection and analysis problematic and unreliable. In other word, less aggressive behavior could not be solely attributed to a certain lighting setting.

Ecosystem

The Stratumseind 2.0 project clearly stated in their mission that many parties should be involved to jointly explore how Stratumseind could be improved. Although Philips Lighting laid the groundwork for the Stratumseind 2.0 project by installing the luminaires and OpenRemote designed the dashboard to control those luminaires, many more parties got involved to add and test their own technology in the entertainment street. Through this more open and collaborative approach, Philips Lighting got pushed more and more towards the background of the project, but could still learn from the experiments and findings from the living lab. Indeed, Philips Lighting Research was able to develop new value propositions for their lighting products outside of the Living Lab setting. The propositions were tested together with the municipality and the police in Eindhoven and later added to Philips Lighting's asset management software.

Conclusion

The Stratumseind project was and still is one of the first to tackle the complex issue of how lighting can influence people's behavior in a public space. While in offices and homes it is possible to control factors such as amount of people, temperature, atmosphere, in a public space many more (uncontrollable) factors play a role that are outside of a researcher's scope. Though many organizations were and still are very interested in exploring the opportunities related to lighting and de-escalating behavior further, there is still too little knowledge on how to study its effects. Through the Living Lab setting and the involvement of the Eindhoven University of Technology a more explorative research setting was stimulated to create value. However, no company took the lead in creating a fully functioning integrated sensor system, which would have enabled a broader set of research questions and value capture opportunities. Philips Lighting is still involved in this project and the PhD project to learn from others and is still integrating such insights into their own products and services, but so far was not able to commercialize more than lighting products for the Stratumseind project.

Case description – Veghel

Context

Veghel is a small city in the Netherlands, situated close to other larger cities, such as 's-Hertogenbosch, Nijmegen and Eindhoven. A local study found that only 35% of residents were shopping in the city center, as many locals go to the larger cities close by, where a more attractive shopping experience with a more diverse selection of shops is offered. Additionally, through the emergence and developments of e-commerce, fewer people tend to visit physical shops to buy their necessary items. As a consequence, there has been a steady decline of sales through the traditional bricks and mortar retail channels, with many retailers closing. This is a particular prominent situation in smaller cities, where the increasing amount of vacant shops is more apparent, which leads to an unwelcome atmosphere and a negative shopping experience. To go against this negative spiral the municipality of Veghel was looking to invest in a facelift and renovation of their city center to improve the perceived atmosphere and support the existence of local retailers. In other words, they want to revitalize their city center to attract more people and stimulate the economic viability of their retailers.

Value creation and value capture activities

The municipality of Veghel was aware of these issues in their city and developed a Master Plan Veghel Center 2030 that would help revitalize their city to create a better quality of life for their residents. As part of this plan the municipality made a reservation of 10 million euros that could be invested in innovation. The Veghel project, which was part of our analysis, was paid through this budget. Based on the vision for the future of retail from professor Cor Molenaar from the Erasmus University of Rotterdam, the Veghel municipality and center management jointly developed the plan "Veghel behind digital walls". The main idea was to create an experience for the people in the city center by stimulating their senses and coloring walking routes, which should encourage visitors to spend more time and money in the area.

To explore the practical implementation of making Veghel more attractive the municipality of Veghel contacted Philips Lighting, market leader in designing and implementing lighting experiences. The overall ambition was to create interactivity with residents and visitors, where the surroundings needed to react to the people and not vice versa. Additionally, through the introduction of LED the municipality saw the potential to save energy, while also being able to create an attractive experience through light and beyond illumination with an online platform. Philips Lighting created a master plan with a roadmap for the center of Veghel that would engage visitors through integrated lighting and technology. More specifically, the master plan consisted of two phases. In the first phase the focus would lay on getting people towards the city center, while the implementation of the second phase would stimulate visitors to remain longer in the city center.

First phase

The first phase focused on the alley that connects the main parking spot in Veghel to the city center and which is used by most people to visit the shopping facilities. Philips Lighting designed a lighting system that activates people's senses through light, sound, and color, to give them a feeling of festivity. The main aim from the Philips Lighting point of view was to drive the local economy via a connected lighting grid that would attract and direct human traffic and increase the footfall into the city. In 2013, Philips Lighting installed the lighting system and Greenm2 the landscaping in 'het steegje' (the alley) and the

municipality officially opened it in October 2013. Essentially, the lighting system can be seen as a light curtain, where sensors react to people in the alley, so that sound and light move with the people.

Although the lighting has a limited impact during the day, the municipality and center management believe that in the future, shopping could be shifted towards the evening hours, to attract even more people. After one year, the municipality announced that there were 22 new shops and 15% more visitors, which convinced them to invest more and continue with the second phase of the Philips Lighting master plan.

Second phase

While the lighting in the alley way provides a more attractive atmosphere, the lighting dynamics and impact on the actual buying behavior of visitors are limited. But building on the experience of this pilot project the municipality of Veghel decided to expand the interactive lighting design to the two main shopping streets, initiating the project "Veghel turns the light on". The focus for the second part lay on developing changing lighting content that could invoke particular experiences, which would attract people towards certain stores or bars and restaurants. This idea also included the use of special lighting and sound algorithms to generate dynamic light content. The center manager would be able to adjust the light settings according to the weather or to specific events. Next to designing the luminaires and the basic lighting content, Philips Lighting created an experience platform, for local entrepreneurs, retailers, or others to upload other lighting experiences. Moreover, to appeal to the so-called hybrid buying behavior (using online and offline sales) a Veghel Center App was developed by students from the ROC de Leijgraaf, which would connect retailers to the visitors. The interactive lighting, with sound, and new landscaping for the main shopping streets were officially revealed in November 2015.

Ecosystem

At the very beginning the municipality involved many different parties, including Stichting Centrum Management Veghel (responsible for commercial activities in the city center, including real-estate and retailers), Rabobank, Greenm2 (a local landscaping company), ROC de Leijgraaf (an education knowledge institution), and Philips Lighting, to explore the practical implementation of making Veghel more attractive. Although the municipality clearly went for a multidisciplinary approach, involving many other partners, from a Philips Lighting perspective they did the conceptualization, development, and installation on their own, as the other parties lacked experience with smart lighting projects. Aside from the parties that were involved in the beginning, there was one other party that was important to the project, but not involved in the conceptual parts, namely Enexis, a Dutch network operator. They became involved due to the fact that in the Netherlands you have to pay the network operator if you want to interfere with public lighting. In the case of Veghel, Philips Lighting took down the whole lighting on the street and to do this they had to pay 200€/luminaire to Enexis. This is also one of the reasons why the installation costs in Veghel were more expensive and Philips Lighting was driven to diversifying their revenue options, by offering lighting consultancy services and a platform for others to upload lighting content.

Conclusion

Although Philips Lighting worked together with several other parties during the course of this project, they were in the lead and the driver behind the design and installation of the dynamic lighting system, where the other parties fulfilled a supplier role. They were able to leverage several sources of income, where they sold products, the service of maintenance and support for the software for the next five years, and the lighting consultancy (including area analysis, developing use cases, and creating lighting content). However, as so many ideas and products had to be developed from scratch, specifically for the Veghel context, the margins for Philips Lighting were quite small, especially compared to purely selling of-the-shelf products. Moreover, working together with a municipality costs a lot of time and patience for an incumbent such as Philips Lighting. The Veghel project took > 3 years, including a change in municipality, which delayed the project for six months, as the new project members had to be convinced of the benefits of such a lighting project. However, the results so far look promising, with increasing visitor numbers, and the municipality hopes that Veghel can become a center of knowledge on how to improve an unappealing shopping atmosphere due to many closed shops.

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