CHAPTER III

Open Innovation 2.0: Smart Cities

Smart Lighting Solutions as a catalyst for Smart Cities: *Practical Challenges of Ambitious Innovation Partners*

Abstract

Cities strive to improve quality of life for their citizens and see opportunities in new ICT-based technologies. Public lighting and public lighting infrastructure can play a significant role as a stepping stone to achieve the ambitions of cities to become 'smart cities'. New technology enables cities to offer a wide range of intelligent and integrated services to benefit both individual citizens and society at large. The main challenge is how to create and implement new technology solutions serving the needs of people. This requires a paradigm shift towards the continuous innovation of services for people. Practical projects indicate four paradigm shifts: (1) from products to service; (2) from technology to people and society; (3) from individual products to adaptive platforms; and (4) from one-off results to continuous innovation.

Ambitious cities and projects encounter practical implementation problems that can only be overcome by radical new approaches and corresponding boundary conditions. Changing roles for all partners — industry, municipalities, knowledge organisations and citizens — can be identified. The technological development should aim to provide a platform in which all partial solutions can be integrated, and that is open to the development of applications. The starting point should be the people and other stakeholders who will benefit from the value created. A 'designerly' approach facilitates citizens in participating as experts on their own quality of life. The main challenge is in the co-creation process in the ecosystem: all partners will participate in the path of innovation, embracing the uncertainties in the outcome and jointly seeking opportunities that deliver the best value for all partners.

Introduction

Cities strive to improve quality of life for their citizens and see opportunities in new ICT-based technologies. At the same time companies are looking for ways to create a sustainable business in the smart city domain. Many companies approach cities to offer technology solutions, resulting in a large number of pilot projects for smart cities [1]. In many cases these solutions are only a part of the desired integrated system, e.g. the role out of extensive sensor networks to collect all kinds of data. However, for a truly smart city solution, just collecting data is insufficient. Smart solutions should have a real impact on quality of life by providing answers to real societal needs. Smart lighting projects have an advantage, since light adds an actuator to the system to influence quality of life. This means that public lighting and public lighting infrastructure can play a significant role as a stepping stone towards achieving the ambitions of cities in becoming smart cities. As we described in the previous yearbooks, the lighting domain is in a transition from a hardware and product-driven industry to a full solution and service-driven industry. The new, disruptive technology creates possibilities for adaptive lighting and smart services that have not been possible before. Technological developments include an upgrade of the public lighting infrastructure and system by connecting to ICT solutions. The resulting growth in the availability of data from sensors and controls creates many new service opportunities. This enables cities to offer a wide range of intelligent and integrated services that will benefit both individual citizens and society at large.

The main challenge is how to create and implement new technology solutions serving the needs of people. How can we ensure that the technology contributes to making the city an attractive place to live?

A change of paradigm

Moving beyond the functionality of products to providing value for citizens and society with service innovation not only needs technological developments, but especially it needs a change of mindset for all participants in the quadruple helix — a fundamental mind shift towards continuous innovation of services for people. This paradigm shift, also described by Curley and Salmelin [2], involves changing perspectives of all partners in the quadruple helix. However implementing such new working approaches is no easy task. In realising smart lighting projects as part of the implementation of the vision and roadmap urban lighting Eindhoven 2030 [3] the TU/e Intelligent Lighting Institute, the city of Eindhoven and industrial partners experienced new practical challenges. We will explain the change of paradigm through four mind shifts occurring in parallel, illustrated by practical projects.

A shift in focus: from products to service

The dominant business model in the lighting and ICT industry has mainly been hardware-based: selling products such as lighting posts, luminaires, sensor and routers. The innovation question focused on how to create new technology and new functional products. But today a shift is needed towards smart, ICT-based lighting as a value-adding service.

This shift from products to services will be illustrated by the Amsterdam Smart Lighting project, in which an adaptive lighting solution is designed and implemented for Hoekenrodeplein, a square in Amsterdam. This project is a collaboration between the city of Amsterdam, Philips, Cisco, Alliander, KPN and the TU/e Intelligent Lighting Institute. Hoekenrodeplein is located in ArenAPoort, and provides a unique environment with a diversity of entertainment, shops, sports, restaurants and bars. The Ajax football stadium, several music stages and a large cinema are just a few examples of event locations in ArenAPoort. Residential and business areas are also included.

In the redevelopment of Hoekenrodeplein, three ambitions were identified for the area: increasing sustainability, safety and hospitality. The proposed lighting solution is an adaptive lighting system that creates the right ambiance for any moment. The lighting scene adapts to time, weather, number of people, the spread of people, and their needs at the moment and the desired atmosphere.

The smart lighting system consists of a set of LED spotlights that enable different light scenes by adjusting the light levels for the individual light sources. The system uses cameras to count people on the square and monitor their locations. In this way the system can adapt the light scenes to the use of the square, for instance commuting during the morning and evening rush hour or leisure activities at weekend evenings. It can adapt by dimming the light when there is nobody around or by lighting up the areas in which people are present to create a pleasant atmosphere. During events the system provides an inviting light scene to attract people to come or to stay longer. When it is very busy the system can be geared up to a higher light level, enabling surveillance of the crowd for security reasons. The adaptive lighting system provides the service to create the right ambiance for any moment

Figure 1: Adaptive lighting at Hoekenrodeplein creates the right ambiance for any moment (designed by Philips)

The Amsterdam Smart Lighting project illustrates the mind shift towards service-driven thinking. Technically, the adaptive lighting system consists of lighting posts, luminaires, cameras, sensors and Wi-Fi connectivity. In functionality this enables any possible lighting scene, creating new design opportunities that address the innovation questions at different levels. If the system can create any desired ambiance for any moment, then what ambiance should be provided at what time? How can we turn ambiance creation into a meaningful application? Who are the users and other stakeholders, what are their needs and when do they experience them? And what ambiance suits these needs best? In other

words how can we develop meaningful solutions that add value to the (local) people?

For Hoekenrodeplein these challenges have been solved by realising the adaptive lighting system first, with a set of ambient lighting scenarios. After the installation, independent research is being carried out to validate the scenarios. Using the outcome of the research, the scenarios can then be tuned to achieve the desired impact on the defined criteria of sustainability, safety and hospitality. The shift in focus from products to services makes it possible to continuously innovate without further investments in the hardware infrastructure.

A shift in focus: from technology to people and societal needs

The changing focus to services requires a second mind shift to a focus on people and societal needs. There is a need to get a deeper understanding of the different stakeholders' needs in relation to good quality of life to enable the definition of meaningful solutions.

The shift towards a focus on people and societal needs is illustrated through the ENIGMA project [4]. ENIGMA is a European-funded project that aims to implement a joint transnational pre-commercial procurement (PCP) procedure in the field of public lighting. The project is coordinated by the City of Eindhoven, and has five partner municipalities (Eindhoven, Malmo, Stavanger, Espoo and Bassano del Grappa) cooperating on procuring innovation and testing innovative ICT-based lighting solutions in a real-life environment. The TU/e Intelligent Lighting Institute facilitated the first step in the project: defining the desired societal impact for the intelligent lighting system and the common and specific needs for the different pilot areas of the five cities.

The challenge in defining the societal needs and the desired societal impact is twofold. First of all, all cities appointed a specific pilot area in which the results of the project will be implemented. Each pilot area has its own dynamics, stakeholders and context. In-depth understanding of the specific needs of the stakeholders in the pilot area is needed, as well as good understanding of the city's policy with its strategic ambitions for the city as a whole. Secondly, all five pilot areas differ in functionality (a busy area near a railway station, a school area, a park in the city, a university campus and a historic city centre). For this project it is important to identify a common ground for all cities on which to define the specifications and desired societal impact, to be able to procure an innovative solution that meets all needs simultaneously.

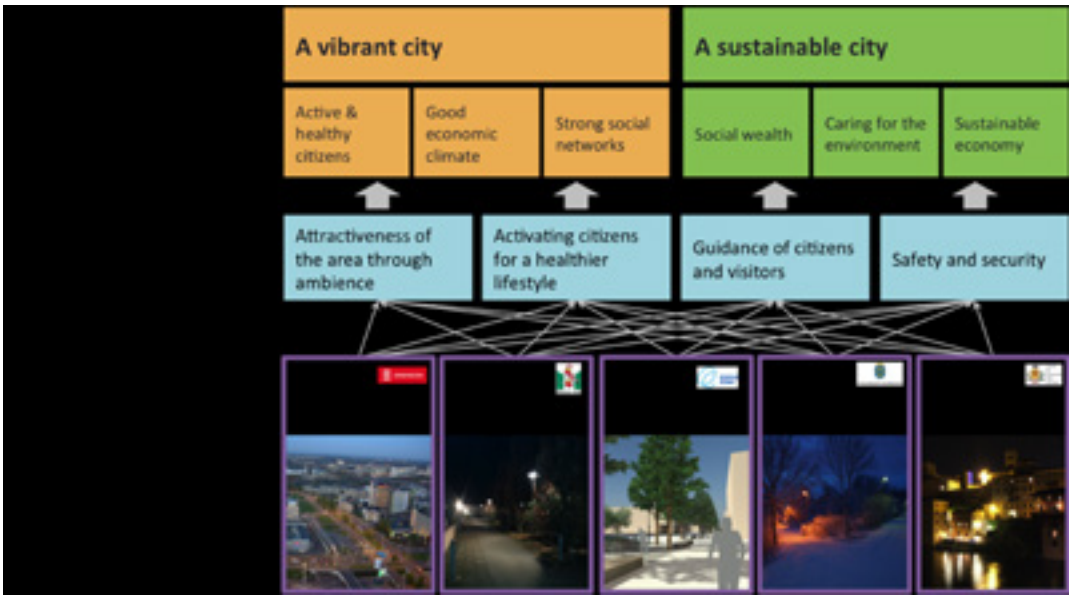
To gain an understanding of the strategic ambitions and societal needs in the pilot area, Deep Dive Workshops were organised in each of the five cities. These consisted of four sessions, as shown in Figure 2. External stakeholders included residents, police officers, employers, hotel owners, representatives of citizens, scholars etc. All information and insights from the four sessions were combined, and these led to a coherent overview of the desired stakeholder needs in relation to the cities' strategic ambition.

Figure 2: The identification of societal needs with all stakeholders in the ENIGMA project

With the coherent sets of needs for each city and its pilot area, the second challenge was to reach common ground for the five cities. At a strategic level the cities share a common ambition: becoming vibrant and sustainable cities. On a deeper level there are also shared societal needs. For example, one common need is 'guidance of citizens and visitors'. This can be defined in more detail for each

pilot area, e.g. for the university campus area in Espoo this translates into 'offering guidance between the public traffic lines (e.g. transition from metro to bus station, which lines leave from where, lighting indications showing when the next bus/train will arrive etc.)'. For the railway area in Eindhoven it means 'providing collective routing and guidance in case of special events and police request (crowd control)'. Or for the historic city centre 'dynamic and interactive lighting able to drive visitors and tourists through the city gems as well as providing services to residents (such as driving directions highlighting restricted car areas, car parks, cycle paths, the presence of bike sharing, ongoing events, services, commercial indications)'. Since the societal needs were described in the same way for each area, the cities had a shared language to discuss the specifics and commonalities. This catalysed the process of defining the right level of description for the common needs.

Figure 3: The step from societal needs to common societal needs and ambitions in the ENIGMA project



Traditionally cities would procure lighting systems by specifying the functional aspects of lighting (light levels, light distribution, colour temperature, light source technology, type of luminaire etc.). It is perceived as a great challenge to turn the process around and identify the societal needs. This leaves more space for creative solutions by designers and industry. The cities struggle with the process for different reasons: it is a new working approach, and it requires a different kind of thinking, but it also means that it is much less certain what solutions they will eventually get when creativity is allowed into the process. The ENIGMA project illustrates the mind shift to a focus on people and societal needs, to identify new possible and desired solutions for intelligent lighting systems, and not only taking technical (contemporary) solutions as a starting point. In the process it is important to engage all stakeholders and listen to their specific needs. However it is equally important to redefine the identified needs so they address the societal needs for the city above the individual preferences of stakeholders. The public interest has to be addressed at the right level.

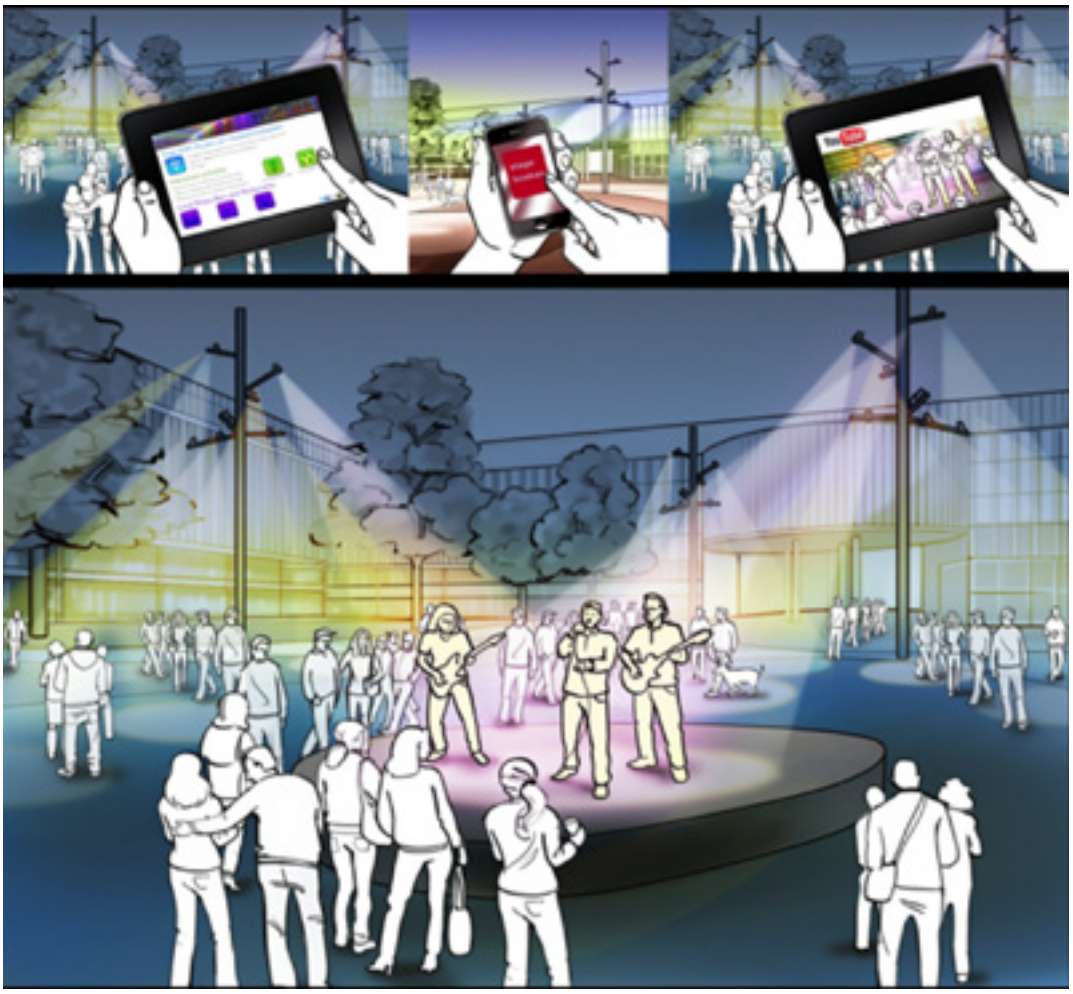
A shift from individual products to adaptive platforms

A market exploration of the current state-of-the-art in lighting and smart city solutions shows that increasing numbers of products are available. However, from the perspective of societal needs, they all offer only partial solutions. To really address societal needs and improve the quality of life in the city, all the partial solutions such as lighting, sensors, cameras etc. need to be integrated in a platform. Only then can innovations emerge that were not possible before.

What this means is illustrated by the Amsterdam Smart Lighting project. The adaptive lighting system installed consists of luminaires, cameras and Wi-Fi. But when looking at the societal need to improve the perceived hospitality in the square, more ideas could be generated based on the adaptive lighting system. A creative session on solutions to increase this hospitality level resulted in the idea of providing a virtual stage for street performers. This ties in closely with the context of the square in which large music events

are often held in the Ziggo Dome, Heineken Music Hall or Amsterdam ArenA. The presence of adaptive lighting technology enables the creation of such a street performance stage without extra investment in the infrastructure. This virtual stage provides a podium for local talent. Airtime can be booked on an app or portal, and will offer preselected time slots for performers on a real spot on the square, marked out by spotlights and at the same time being streamed online by the video cameras. This new service is interesting for the performers, and also time attracts crowds and increases the attractiveness of the area. It will therefore address the need of direct

Figure 4: The concept of a street performer's music stage at Hoekenrodeplein (designed by Philips)



users as well as the overall ambitions for the entire redevelopment project of the square.

The concept of the street performer's music stage of the Amsterdam Smart Lighting project illustrates the mind shift to the development of an adaptive platform for smart lighting and smart city solutions. Such an adaptive platform integrates the current fragmented solutions into a 'Lego-style' platform that enables the building of various systems, each dedicated to the specific context. The system is also upgradable to meet future needs — for example in the Hoekenrodeplein case, in which first the adaptive lighting is implemented, and later the virtual music stage will be added. Such a system requires open interfaces to allow other building blocks to be integrated.

At the same time the new services that can be designed on top of the platform introduce new business and new business models. The proposed street performers' music stage is of interest for performers, for the public, for entrepreneurs (such as café and restaurant owners) in the area, and for the municipality. The idea allows for a range of business models: bar owners can rent it for their customers, visitors to the square can pay a fee to use it, or organisers of larger music events can provide it as

a service to their customers. It is not clear (yet) who would be the logical operator of the new service; for example would this be one of the large companies involved in the project, or does it require a local entrepreneur? Or — in the start-up phase — could it be the municipality? It may well be that the municipality would have to operate it (temporarily) to facilitate the market launch, and to demonstrate the impact and viability of such a solution to the stakeholders before the market takes it up. Such a role to spark and promote the development and exploitation of new and innovative services falls outside their traditional responsibility (and comfort zone) of the municipality, but is important to achieve the goal of becoming a vibrant and sustainable city.

4. A shift from a one-off result to continuous innovation

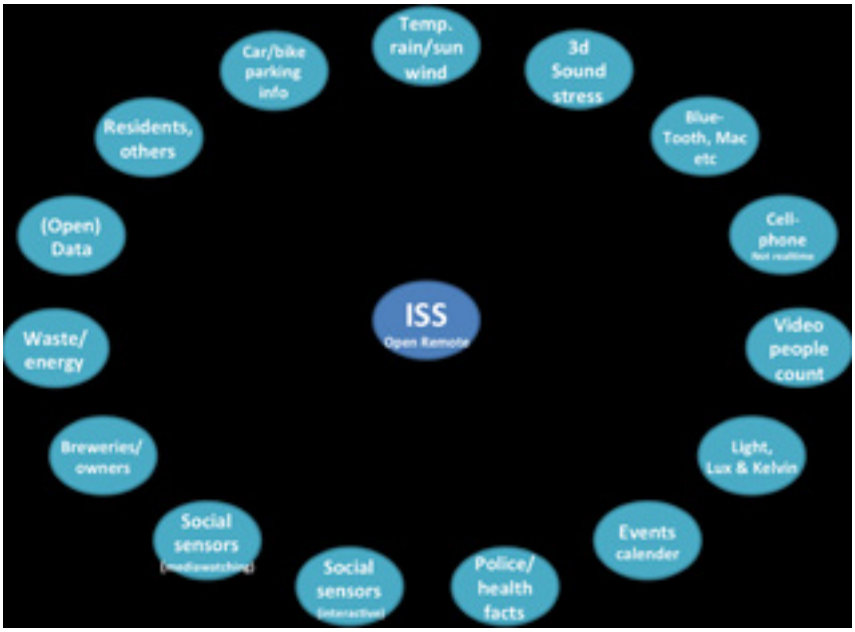
Smart lighting solutions are by their nature more flexible: the integration of ICT in an LED-based lighting system allows for dynamic lighting scenarios and interactivity through various sensors and controls. This is an important advantage, especially since the innovation process still involves high levels of uncertainty. Although artificial lighting has been available for over a century, it is only in the last few decades that the digitisation of lighting has enabled variations in light levels and colour. There has still been little research into the effects of varying lighting scenarios on human well-being and behaviour. So innovation processes that look for potential solutions that may influence well-being and behaviour are still highly uncertain. In addition, new hardware and software will become available over time allowing new functionalities. To ensure that the system has a sufficiently long economic lifetime, it will need to be able to include new and at present unknowable modules. Also the context of urban spaces will change over time. With aspired infrastructure life-cycles of well over a decade, it is uncertain what the future context will be. To embrace the uncertainty in this innovation process, there is a need to shape the solution in a way that it is flexible and adjustable, to enable continuous innovation based on progressive insights, changing contexts and new opportunities.

An example of a project that aims for a continuous learning environment to find ways to influence mood and social behaviour is the Stratumseind area, a large inner-city entertainment area in the city of Eindhoven in which a living lab has been set up to explore the opportunities for innovative lighting solutions that will improve the atmosphere and reduce the escalation of aggression. The project is part of the portfolio of projects to achieve the smart lighting ambition in Eindhoven [5]. In this living lab, a scientific research project called De-escalate aims to provide fundamental insights into human behaviour, but also to deliver lighting schemes that are applicable and effective in real-life conditions through evidence-based lighting design.

Figure 5: Dynamic lighting scenarios to influence people's mood and behaviour in the Stratumseind area

For this purpose a living lab has been set up in which Philips provides intelligent lighting hardware, Open Remote provides an open source software platform to integrate lighting and open data from various sources is used together with data from large numbers of sensors from various suppliers. The platform integrates solutions from multinationals and SMEs, as well as from small local start-ups. The resulting integrated sensor system allows for continuous monitoring and learning. And as it is built on the open source principle it also allows for the integration of new sensors as they become available on the market, for example solutions for mood sensing.

Figure 6: Sensor system integrating solutions from different suppliers to collect all kinds of data in the living lab



In the first phase of the project the emphasis has been on the realisation of the hardware and software infrastructure. In the second phase the system is used to explore the impact of different dynamic lighting scenarios on the mood and social behaviour of people, with the ultimate aim of increasing the atmosphere and perception of hospitality in the street and to reduce the number of incidents of aggression. Shorter experiments go hand-in-hand with longitudinal research to gain an understanding of the longer-term effects of different dynamic lighting scenarios.

Furthermore, next to the scientific research on the effects of lighting on behaviour, the living lab is also used to develop new lighting applications. For this purpose, 'hackathons' are organised in which visitors from the entertainment area are also invited to participate in the development of apps and lighting scenarios. The open set-up of the living lab enables easy exploration, using the ideas developed in the hackathon in real-life settings. This will speed the development of the best ideas in business, either by small (student) start-ups, in SMEs or even integrated in the platform by multinationals. Different business models can co-exist in such a platform, however since many of the partners have invested time and money in the set-up of the living lab, they have been granted priority in the exploitation process. Such arrangements to share investments and revenues are important in creating open ecosystems of this kind. Next to the challenges in finding sustainable and scalable business opportunities, there are also challenges in how to deal with privacy and ethics. Current regulations, such as those for the use of CCTV cameras, are insufficient for a multi-sensor, open data, public area living lab set-up. New ways of dealing with such challenges need to be developed along the way.

New organisational practices are needed

The described projects illustrate the paradigm shift that the urban lighting domain is currently experiencing. Ambitious cities and projects are encountering practical implementation problems that can only be overcome by radical new working approaches and corresponding boundary conditions. Moving towards continuous innovation of services for people, and for that purpose integrating a 'mash-up' of products and services from different organisations, require changes in the ecosystem for innovation as well as in the roles of all partners within the ecosystem simultaneously.

A changing ecosystem

Every player in the domain of urban lighting and smart city development is going through a change process towards new roles and responsibilities far beyond the traditional roles of the municipality as a customer and businesses as the suppliers of products. The ultimate aim is to offer more value to more stakeholders, thereby significantly improving the quality of life in cities through new innovations. Next to the aspect of putting the citizens at the core of the innovation process, as referred

to earlier, it also requires new thinking on investments and depreciation, maintenance contracts and product life-cycles, as well as respecting each other's business models and shared value creation. The key aspect in the new ecosystem is real co-creation. As referred to in the white paper by Curley and Salmelin [2], this requires a shift away from a focus on the performance of the organisation towards optimising both the performance of the organisation and the social conditions. It involves the creation of shared value, sustainable prosperity and improvements in human well-being. For this purpose, ecosystem-centric cross-organisational innovation has to take place. These ecosystems allow large and small businesses, governmental and public organisations, academia and private individuals to co-create novel products and services. The shifts described above also make it important to ensure that the business models support sustainable exploitation of the system by integrating societal and economic interests. Such business models need to be developed and implemented through a transition from the existing to the desired business model.

This quadruple helix innovation approach is most successful when there is a shared vision and shared value is created. The projects shown as examples demonstrate that starting from a societal need is a good way to create a common vision on the desired impact of an innovation. A joint aspiration enables the different partners to contribute from their own strengths and perspective. However, for this new ecosystem to develop and flourish, each partner is also going through a change process.

A changing role for industry

The industry, lighting as well as ICT, has traditionally focused on research into new technological solutions and the development of new products (e.g. light bulbs, luminaires, sensors, routers, software). The results of this technological innovation process were off-the-shelf products, fulfilling the regulations set by governmental and public organisations. In the European tendering processes, customers (such as municipalities) would indicate the functional requirements and the industry would then respond with tenders based on their existing products. But in the new ecosystem the industry is involved in the quadruple helix co-creation process, which starts by identifying the end-user needs, followed by the development of integrated solutions made up of products and services.

Starting from the end-user needs often leads to the co-creation of innovative solutions (products and services) that exceed the boundaries of contemporary lighting solutions and lead to lighting as a value-added service. This co-creation process drives structural changes far beyond the scope of what any one person or organisation could achieve alone. Moreover, these may very well include the development of an adaptive platform in which all partial solutions (from different organisations) are integrated.

Although this is often perceived as contra-intuitive, the development of such an open and adaptive platform is an enabler for companies in their business development. As the example projects show, the needs are very specific in their local contexts. To scale and develop a (world) market, there is a need for common service and application platforms that can be adapted locally, but that will still be affordable because of the broad application area. It also enables the integration of specific products from small and medium-size enterprises (SMEs) into a more common and globally scalable platform. Innovative SMEs often have dedicated high-tech solutions for specific functions (such as the 3D sound sensors or social media analysis algorithms in the Stratumseind example). The integration of such dedicated solutions enables new functionalities that are beyond the scope of traditional lighting system. An open, adaptive platform enables the rapid integration of new modules to provide new services.

The shift from a focus on products to integrated services also creates the opportunity for recurring revenues in service development. Services typically have shorter life-cycles than the supporting products and platforms. A combination of a flexible, adaptive platform with continuous service innovation enables simultaneous exploration and exploitation of new services. A smart system enables continuous monitoring and learning, dealing with the impact of the services on the quality of life in cities. As stated earlier, to create a sustainable ecosystem the business models should ensure the integration of the societal and economic interests of the different stakeholders.

The system integrator has an important role to play in the urban lighting ecosystem. As long as current industrial partners offer propositions from a single business perspective, there will be no integrated solution for the societal need. In the example projects there is a lack of a partner to take the responsibility for integrating the mash-up of products and services from different organisations into a total solution. In this situation, the partners in the projects will hesitate to take full responsibility for each other's products and services. Ideally, the ecosystem should include a partner that is independent of the different partial solutions, partial needs and involved organisations, and instead focuses exclusively on the successful

implementation of the best-value solution for the identified societal need.

An example of how collaboration in the quadruple helix also supports industry is the Green Deal. In the Green Deals, the Ministry of Economic Affairs in the Netherlands is taking concrete steps towards a sustainable economy. This will bring together more green energy with economic growth, and with projects that pay for themselves. The Green Deal helps to overcome obstacles (such as confusion about licences, lack of collaborative partners or ambiguous regulations) and achieve results quicker.

A changing role for municipalities

In urban lighting, municipalities traditionally focused on guidelines and specifications to enable them to choose the right products for their project. Their new primary, future-proof role is to safeguard the public interest in the co-creation process that starts by identifying the societal needs in different areas of the city. No other party in the urban lighting innovation process will safeguard the public interest. The city thereby acts as the representative of the citizens and society. There is a need for new citizen participation practices that acknowledge citizens as experienced experts on their own needs, and actively facilitates them in the design, and in thinking of new possibilities and future services.

Next, municipalities have an important role in creating lasting prosperity. The right policy decisions at this stage will accelerate the creation of both business and societal value through innovation. As indicated by Curley and Salmelin [2], the task of the public sector is to create the environment for Open Innovation 2.0, in which the mash-up of required components can happen in a frictionless environment, bringing in the fuel for the innovation process, for example by procuring innovative products and catalysing innovation and experimentation. The City of Eindhoven has a long tradition of open innovation and triple helix innovation in the Brainport region, and is actively opening living labs for smart lighting solutions. These will make space for innovation, enabling the desired paradigm shift [3]. The city also aims to create (economic) hotspots for smart lighting businesses.

In this role the municipality transforms itself in three ways: 1) from being a client, evaluating the bids in a tendering process for functional products; 2) to being a lead user, putting the city forward as a test bed for suppliers to pilot innovative products; and 3) to involvement in a full co-creation partnership. In the co-creation ecosystem, all partners are expected to participate, to take part in the responsibility and to jointly take risks in the uncertain route of innovation.

A changing role for knowledge organisations

Many relevant aspects in the relationship between open innovation and academia can be found in the context provided by the concept of 3rd Generation Universities. The framework of 3rd Generation Universities, as proposed by Wissema [6], describes the transition of Western (European) universities over the past millennium. He distinguished three generations of universities that are markedly different with respect to their positioning in society and their working approach. The first generation, starting with the universities of Bologna and Paris in the Middle Ages, was aimed at providing a kind of universal knowledge, defending the truth through education in Latin, provided by professionals in colleges that used methods from scholastics and arts. The second generation, starting at around 1700 and often referred to as Humboldtian universities, were aimed at exploring nature through research, conducted by mono-disciplinary professionals who applied scientific methods and were organised in faculties. For the last thirty years we have now had the concept of third-generation universities, which aim to generate value from knowledge by supporting multi-disciplinary academic entrepreneurs in turning knowledge into services and products that impact society.

The transition from one generation to the next can be described in terms of how knowledge is handled. The first generation transfers knowledge through education, the second generation in addition extends and expands knowledge through research, and the third generation in addition transfers knowledge into value. It is important to note that the subsequent generations build on the assets obtained by their predecessors. Third-generation universities combine education, research and value creation. However, the way they are organised and their positioning in society are markedly different. The first generation was open, but through the use of Latin only those who had mastered that language could participate. The second generation was limited to the scientific elite in every specific domain that could understand the often complex methods of investigation that were used. And the third generation again is open in its efforts to generate value for society. These universities consequently need to build on the insights gained from their target group, and in addition they need to understand how the academic knowledge can be effectively transferred to those who can create value from it. Many universities still operate at the level of the second generation. A true third-generation university applies a different approach to the working methods used by the previous generation.

Exploitation of knowledge should be a core business, and should become a third objective in addition to education and scientific research.

Universities should be eager to operate in an international and competitive market. They should be willing to collaborate with many partners and institutions at various levels, to use transdisciplinary research organised in institutes, and to run their business in a professional way, becoming less dependent on direct state financing and state interference.

As an example, Eindhoven University of Technology has expressed the wish to become a third-generation university. Its positioning in the Brainport region, which has been widely recognised as one of the 'Smartest Regions of the World', and its strong record in working together with industry provide the university with the knowledge and experience to make the required transition. In addition, the university is exploring ways to get more deeply involved in activities that take place at the level of the municipality of Eindhoven. Many of the newly defined projects relate to Smart Urban Life, and use the city or parts of it as genuine Living Labs. Multi-stakeholder concepts are applied to maximise the impact generated by the transferred knowledge. New business models are explored, and it can be safely stated that the municipality has moved from the role of facilitator to that of a participant in the Brainport innovation ecosystem. The most interesting asset resulting from this development is its amazing impact on young, talented people. We can safely state that it attracts a new breed of professionals who want to dedicate their talents to serving society with meaningful solutions, and this is a great facilitator in achieving open innovation.

In the new generation, knowledge institutes, citizens and other stakeholders are intensively involved in research and education with the aim of co-creating meaningful solutions. Although governmental policies such as the recently published vision on science of the Dutch Ministry of Education support these ideas, the associated transition also poses challenges to scientists and educators. For example, applying scientific rigour in such collaborative research projects in 'the outside world' is more challenging than when it takes place in traditional laboratories, and it is also more difficult to get multi-disciplinary scientific research published than mono-disciplinary. Knowledge institutes will need to adapt that their working approach benefits from and contribute to the ecosystem.

A changing role for citizens

Traditionally the role of citizens has been passive: the city, and with it their lives, was largely designed for that role. But today there is a strong drive towards participative citizenship at all levels of society. Especially when it comes to societal challenges, the notion that the involvement of citizens is required is now translated into participative processes, while sometimes solutions are even designed in co-creation processes. This is important because there are no blueprints for the desired solutions. It is also impossible to write clear specifications for the desired solution. So the only way to create a solution that fulfils the (often unarticulated) needs of the stakeholders is to jointly embark on a co-creation process to explore possible solution spaces. In this iterative process the needs become clear, when all participants play their roles in finding a synergetic solution that fits in the specific context. Each context is different, but as shown in the ENIGMA project, the solution (when adaptable and flexible) can be based on a common platform.

One very important advantage of the flexible and adaptive platforms referred to earlier is that they also allow the on-site co-creation process with citizens after the installation. As the example projects also show, the systems are flexible and very different lighting scenarios can be designed without changes to the infrastructure. The co-creation of desired lighting scenarios can therefore take place in real settings, in which different scenarios can be experienced once the systems are up and running.

As referred to above, in the quadruple helix model there is an important role for the citizens. They are experts on their own needs, but require facilitation in being involved in design, new possibilities and future services. Co-creation of meaningful innovations requires strong involvement by citizens, far beyond the frequently cited 'one-directional participation' in which ideas are simply presented to citizens. True involvement in dialogues to really understand the needs is a different process. New ICT solutions can enable further enrichment of the co-creation sessions, for example by offering virtual reality experiences of new dynamic lighting scenarios to citizens during the co-creation process. Technologies like this will enable citizens to experience solutions without large investments in technology infrastructure.

The role of municipalities is to serve the co-creation process. This implies making it possible, but also ensuring that the public interest is guarded in the process. It also requires from citizens that they take up their role and take responsibility for their environment. It is not sufficient to complain if something is not right: more and more citizens will need to be involved in actively developing alternative solutions that are in line with their needs.

New regulatory frameworks are needed

The new paradigm also requires a radical revision of the boundary conditions, including the technology frameworks. New regulatory frameworks are needed that not only acknowledge co-creation, but also facilitate it and help to address the inevitable need to deal with uncertainty.

Contemporary tendering processes and regulations are insufficient to support co-creation processes. Tendering processes emphasise risk management, based on rational problem-solving, stating that all information will be available in advance to support decision-making. In tendering processes, decision-making is based on a reduction to clear functional requirements. Even pre-commercial procurement processes, such as those applied in the ENIGMA project, are not really suitable for the more complex situations, such as those regarding the procurement of innovative smart lighting and smart city platforms and services that start from the desired societal impact.

Innovation inevitably introduces ambiguity based on reflective practice. The aspired societal impact may be clear, but how to achieve the desired result is not. Co-creation in the innovation ecosystem requires new regulatory frameworks that acknowledge the inevitable high uncertainty level, allow risk-taking and open up the dialogue needed to deal with them. The basis of the partnership must be trust and respect for each other's power to innovate. Award criteria on the outcome are difficult to set up, since the co-creation aims for a joint explorative process with an end-result that is not yet known.

Another topic to be reframed in a co-creation setting in which the partners innovate together is intellectual property (IP). Commercial partners often fear open innovation processes, in which the ownership of the IP may not be clear. Since current business models are often based on the ownership of IP, this hampers cooperation. As stated earlier, the creation of an adaptive platform for intelligent lighting and smart city solutions can create a platform which several businesses can use to scale their product or service. For such a platform to succeed, the building blocks can still contain IP for different organisations, but the interfaces between the building blocks need to be open. In the ENIGMA project the requirements for such a platform are identified as:

- Adaptability; the platform needs to be adaptable in order to enable changing the lighting settings according to the varying needs of diverse users and contexts. It provides the right light at the right place at the right time.
- Interactivity; the platform needs to be interactive in order to enable the people to control and 'play' with the light.
- Modifiability; the platform needs to be modifiable in order to upgrade or extend the system if needed to make it future-proof.
- Modularity; the platform needs to be modular in order to fit the design of the installation to specific needs and to facilitate the maintenance of the system.
- Openness; the platform needs to be open in order to connect it to other systems and to enable other systems to connect with the lighting system.

These adaptive platforms also require new technological concepts. There is a need for a city-wide 'plug and play' platform with generic modules (e.g. in the area of sensing, data storage and analysis, identification etc.). This platform needs to be open, with standardised interfaces to prohibit 'vendor lock-in'. Such a platform will allow all kinds of parties (both profit and non-profit organisations, but also citizens and students) to develop applications that can be plugged into the system. This will allow a wide range of solutions to use the system and available open data: from professional lighting solutions to simple neighbourhood applications.

The last challenge in the new paradigm is dealing with open data. Providing open data is attractive to invite organisations, companies and designers to create innovative new services to join the platform. But it will also inevitably raise questions of privacy and security. Dealing with the ownership of the data is an important aspect, as well as also concepts like 'privacy by design' and 'usable privacy'.

As stated earlier, the role of municipalities is to safeguard public interest. But this is no easy task. What is in the interest of the public? How to be objectively assessed? How can the effects of political interests be avoided? Here too, a 2.0 view will need to be developed along the way.

Realising smart cities

Experience from implementation projects in public lighting in practice reveal the challenges with the paradigm shift towards continuous innovation of services for people. This transition is currently taking place, and opens up new opportunities for the co-creation of shared value through innovation. Public lighting and public lighting infrastructure can play a significant role as a stepping stone towards achieving the ambitions of cities in their transition towards smart cities.

The core of the paradigm shift lies in co-creation within the urban lighting ecosystem in identifying societal needs and jointly enabling the development of meaningful solutions. The technological development should aim for a platform in which all partial solutions can be integrated, and that is open to the development of the applications superimposed on it. The starting point should be the people and other stakeholders who benefit from its value. A 'designerly' approach facilitates citizens in participating as experts on their own quality of life. The main challenge is in the co-creation process: all partners will participate in the path of innovation, embracing the uncertainties in the outcome and jointly seeking opportunities that offer the best value for the most partners.

To achieve a successful transition to open innovation 2.0 in the realisation of smart cities, new organisation practices are needed within all organisations, as well as for the ecosystem itself. New regulatory frameworks that support innovation and co-creation are also needed. There is still a lot to learn about this process, and there are many more challenges to explore in practical projects. It is only in this way that a big step forward can be taken in the realisation of smart cities that will offer a high quality of life for their citizens.

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The projects referred to here have been carried out in collaboration with various partners. For more information, please contact the authors through: www.ili-lighthouse.nl or www.tue.nl/ili

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