LIGHT HOUSE

Experience in …

… **Smart Lighting** and **Smart Cities**

REFERENCE **MODEL** …

Taking full advantage
of innovations and
smart lighting solutions

Choosing an ambition level

Realising goals

Applying the reference model

… SMART URBAN **LIGHTING**

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY
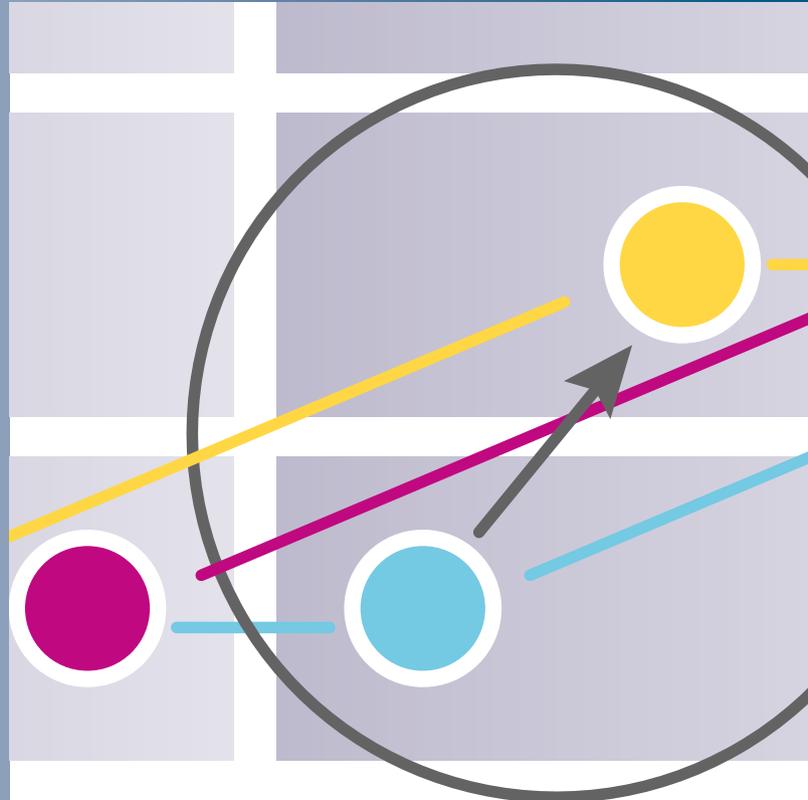
Making the **right choice**

Many municipalities are adopting LED for public lighting as a means to save energy while replacing light points during maintenance. At the same time LED offers the possibility to upgrade the lighting system by integrating it with ICT technology. The resulting 'smart lighting grid' can be a platform for many applications: far beyond the traditional function of lighting – like many smart city applications.

Cities see great opportunities in the newest technologies. At the same time these lighting technologies are developing at a very rapid pace. Cities are confronted with a fast changing and increasing amount of new products and new business models with solutions and services. They experience difficulty in making the right decisions, keeping in mind the costs, sustainability and social responsibility on the short and longer term.

LightHouse has developed a reference model for Smart Urban Lighting to provide insight in what is necessary to take the most advantage of innovative solutions.

Providing insight

The reference model provides insight in the decision processes and considerations in the transition to smart urban lighting. It offers municipalities insight in their current way of working, what they would like to achieve, and how to get there.

Offering framework

The reference model offers a framework for municipalities to learn from each other by exchanging knowledge and experience in successful implementations and challenges.

The reference model for Smart Urban Lighting is co-developed with the city of Eindhoven, and is piloted in the PLUS project with 11 European cities. For more information: www2.luciassociation.org/more-about-plus.html

Three **principles** are key

Everybody chooses his own ambition and learning path

Not all municipalities have the same ambition and the same possibilities. Some have the aspiration to be a frontrunner with innovative solutions, while others prefer less risky options. The model supports in choosing a suitable ambition level, and can be used for a self-assessment to see which practical steps are needed to achieve the ambition.

Knowledge exchange between municipalities

The model can also be used in peer-reviews with other municipalities to identify best practices. Municipalities can also select another municipality for a specific exchange of ways of working.

Collaboration with other organisations

On higher ambition levels the collaboration becomes more important: with other public organisations, bigger and smaller companies, knowledge institutes, citizens and other stakeholders. The reference model offers a framework to support the collaboration in the quadruple helix.

1
Ad-hoc - unaware
Informal and individual

Objectives are defined on individual level and the organisation often relies on experienced key persons ('heroes'). Knowledge is implicit and activities are planned on ad-hoc basis. Most things are arranged through informal networks.

2
Aware - explorative
Projects in single departments

Objectives are defined on project level. Employees recognise opportunities for improvements in projects and have room to take action. There is good collaboration within departments. A project-based approach enables reuse of ways of working and methodologies.

3
Depth - defined
Programs across organisation

Objectives are defined on organisational level, based on internal expertise. The objectives are translated into a program of projects in which the whole organisation collaborates across departments. The realisation of objectives is monitored, and when necessary projects are adjusted.

4
Embedded - adoptive
Proactive in total chain

Objectives are driven by the needs of end-users and society at large (outside-in). Objectives are realised through a pro-active attitude and data is shared to enable continuous improvement. The organisation collaborates wit the total supply chain.

5
Visionary - adaptive
Innovating in the quadruple helix

A boundary spanning vision – defined with the quadruple helix (public and private organisations, knowledge institutes, citizens and other stakeholders) – drives innovation. Together a platform is developed to continuously innovate with products and services to improve quality of life.

The **five levels**
of the model

The reference models uses five levels to distinguish different ways of working in organisations – see also the image below. On the first level (1) individual insights define the informal way of working. Organisations on this level can be very successful, because they rely on the expertise of a few experienced key persons.
On level 5 there is clearly defined long term vision with a roadmap of projects. Not just the own organisation with all strengths of different departments, but also diverse stakeholders contribute to realise the vision. Most organisations are somewhere between these two extremes.

The **use**
of the model

The reference model is a matrix in which for each of the five levels is indicated what should be in place in the different (sub)processes (see next pages for the complete matrix).
In the image below is indicated how the matrix can be used for a self-assessment, choosing an ambition level and comparison with other municipalities to identify learning opportunities.

Applying the reference model for evaluation of the current way of working, defining ambitions and comparison with other municipalities.

Policy development	Design	Realisation	Maintenance	
				5
				4
				3
				2
				1

ambition to improve to level 3: municipality B offers learning opportunities

ambition to improve to level 2

- Current level municipality A
- Ambition level municipality A
- Current level municipality B
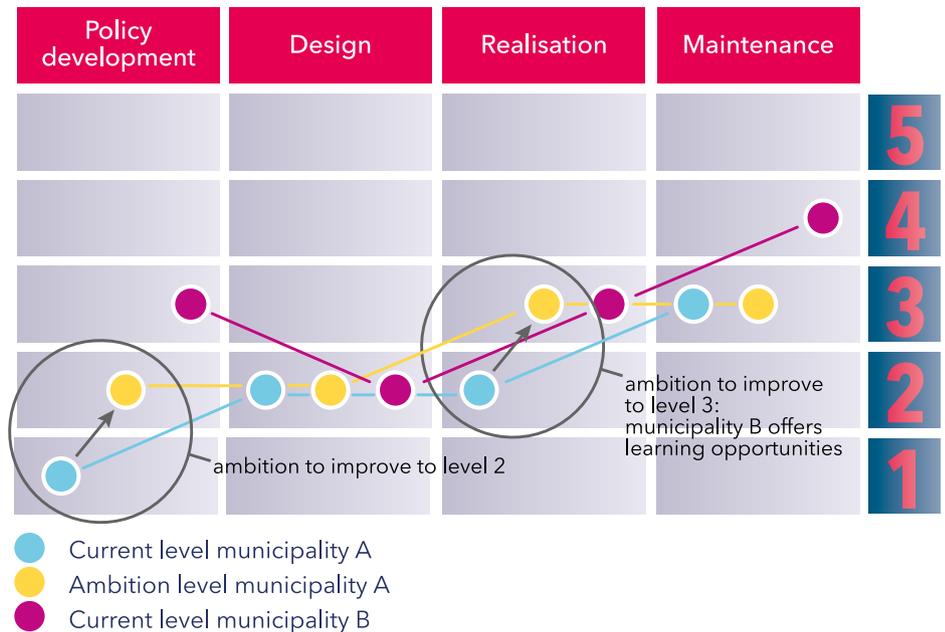
... SMART URBAN LIGHTING

Reference model smart urban lighting

LEVELS

MAIN PROCESSES	Policy development			Design	
	Defining ambition	Sustainability	Lighting innovation	Decision process	Design aspects
5 Visionary - adaptive **Innovating in the quadruple helix** ■ World class level ■ Innovating from a vision ■ Stretching boundaries ■ Platform for innovative services ■ Collaboration government, research, companies and citizens (quadruple helix)	Driving policy development through thought leadership ■ Yearly vision and roadmap ■ Involvement of the quadruple helix in the creation of a shared vision ■ Integrating social, economic and ecological perspectives ■ Recognised as thought leader	Quality of life in public space as a whole ■ Improving quality of life of citizens with human centric lighting ■ Integral approach to public space (including lighting) ■ Objective reviews show 'best in class'	Exploring new opportunities through experimental projects ■ Experimentation in innovation projects (living labs) ■ Sharing results with others (conferences, publications) ■ Smart lighting as stepping stone to smart city	Alignment with policy and roadmap ■ Policy and roadmap drive decisions ■ Autonomous, knowledgeable and experienced teams across quadruple helix ■ Scientific validation of new solutions	Exploration and integrated decision making ■ Integrated decision making ■ Reflection from multiple views ■ Iterative approaches of experimenting and testing of new opportunities ■ Setting new norms
4 Embedded - adoptive **Proactive in total chain** ■ End-user and societal needs driven (outside in) ■ Proactive to achieving goals ■ Sharing data for continuous improvement ■ Operating and collaborating in total chain	Program management to meet future needs of end-users ■ Master plan with ambition ■ Input of the total chain on future needs ■ Program management on a portfolio of projects	Social and ecological sustainability of lighting ■ Sustainability including social factors ■ Urban lighting as a whole (across public/ private boundaries)	Fast adoption of new functionalities ■ Fast adoption of new functionalities of smart lighting ■ Keeping track of new developments in the wider context of public space	Alignment with master plan ■ Master plan drives decisions ■ Incorporating new insights or solutions in the design ■ Involvement of end-users and relevant stakeholders in decisions	Applying proven concepts Monitoring effectiveness ■ New and proven insights are integrated into design decisions ■ Applying new solutions in specifically selected projects
3 Depth - defined **Programs across organisation** ■ Objectives on organisational level (inside out) ■ Monitoring if targets are met ■ Collaboration within the organisation	Program of coherent projects to meet organisational ambitions ■ Ambition defined on organisation level ■ Coherent program of projects to realise objectives ■ Support from all relevant departments	Ecological effectiveness of all lighting in public space ■ Sustainability including ecological effectiveness ■ Relation between projects is taken into account ■ Urban lighting including private systems	Applying proven products for multifunctional objectives ■ Multifunctional lighting: safety, experience, navigation, traffic regulation etc. ■ Application of newly available products in the program of projects (reactive follower)	Alignment with program management ■ Program targets drive decisions ■ Avoiding sub-optimisation ■ Issues are resolved on program level	Meeting integral and extended objectives ■ Objectives are defined beyond common rules and regulations ■ Objectives are considered from an integral perspective (across departments)
2 Aware - explorative **Projects in single departments** ■ Objectives set on project level ■ Recognising improvement opportunities ■ Reuse of practices, methodologies and ways of working ■ Responsibilities in separate departments	Project level targets and activities ■ Targets defined per project ■ One single department is responsible for the results and is aware of past performance ■ Track record of a range of successful projects	Material use and energy consumption in public lighting ■ Sustainability in total product life cycle, including 'zero emission' ■ Limited use of scarce resources and low energy consumption ■ Focus on lamps and luminaires managed by the municipality	Applying standard products for functions and experience ■ Considering experience of citizens and visitors ■ Applying standard products from catalogues, considering impact on experience	Alignment with project objectives ■ Project objectives drive decisions ■ Issues are resolved through escalation to management	Meeting extended objectives ■ Pro-actively following general rules and regulations, as well as upcoming trends ■ Staying with budget targets ■ Applying new solutions to meet extended objectives ■ Staying up to date with new rules and regulations
1 Ad-hoc - unaware **Informal and individual** ■ Individual objectives ('heroes') ■ Implicit knowledge, ad-hoc activities ■ Uncertainty and fear of changes ■ Informal networks	Ad-hoc and informal activities ■ Individual ambitions (on managerial or operational level) ■ Informal networks ■ No structured process and/or skill levels defined ■ No consequences when targets are not met	Regulation driven ■ Adherence to regulations and laws ■ Scope of sustainability is dependent on individual perspective ■ Under influence of elections, politics and governmental terms	Applying standard products Purchasing standard products for functional lighting ■ Focus on functional aspects of lighting (safety) ■ Products are purchased from catalogues, with focus on functional specifications and costs	Ad-hoc ■ Ad-hoc decisions by people involved ■ Issues may lead to not achieving objectives	Solving problems ■ Choices are driven by complaints of citizens ■ Reactive approach to new rules and regulations

	Realisation			Maintenance		
Stakeholder involvement	**Contract management**	**Project management**	**Stakeholder management**	**Configuration management**	**Quality management**	**Progress monitoring**
Learning process ■ Learning process across organisations in the quadruple helix ■ Respecting each other's contribution as thought leader ■ Shared responsibility for societal impact of innovative solutions	**Joint roadmaps in a stakeholder network** ■ Defining roadmaps involving the quadruple helix ■ Distinguishing between repetitive (scaling up) and innovative projects ■ Platform for continuous service innovation	**Quadruple helix based management of targets and risks** ■ Project management on shared targets across the quadrupel helix ■ Monitoring targets and adjustments based on evolving insights ■ Risk identification with full quadruple helix	**Shared objectives and strong involvement** ■ Involvement of stakeholders in planning of realisation projects ■ Planning based on best timing to minimise burden ■ Combining works and activities whenever possible	**Configuration management on integrated system level** ■ Integrated configuration management system maintained by relevant stakeholders ■ Continuous monitoring and evaluation of changes ■ Platform management for (open) system, data and services	**Continuous improvement based on pattern recognition** ■ Intelligent systems are part of a continuous innovation process ■ Recognising patterns in the system generated data ■ Integrated management of maintenance and upgrades of the system, anticipating on roadmaps	**Continuous improvement in the quadruple helix** ■ Improvements based on continuous feedback from the quadruple helix ■ Proactive attitude of all parties to bring shared vision to next level ■ Joint improvement plans
Monitoring effectiveness ■ Monitoring effectiveness of participation of various stakeholders ■ Stakeholders suggest when involvement is desired or required	**Specifying opportunities** ■ Suppliers involved exploration of innovation opportunities ■ Tendering of innovative solutions ■ Supplier performance evaluation on innovation capacity and collaboration in the total chain	**Management of targets and risks on network level** ■ Project management on shared targets across the total chain ■ Risk identification in separate organisations and impact in total chain	**Proactive sharing of information and alignment stakeholders** ■ Planning to minimise disturbances for relevant stakeholders ■ Prior notice of information on works to stakeholders	**Configuration management in total chain** ■ Configuration management system for design and system changes, maintained in collaboration across suppliers and departments ■ Impact assessment of changes on total system	**Improvements based on monitoring of systems** ■ Continuous monitoring of individual systems ■ Structural improvements on insights obtained from data analysis ■ Preventive and reactive maintenance based on real-time information from the system	**Structural improvements in the total chain** ■ Structural monitoring process for the objectives in the master plan ■ Adjustments of plans and activities whenever needed to realise the objectives
Process management ■ Inviting specific stakeholders for specific decisions ■ Stakeholders are aware of their role and prepared	**Specifying generic objectives** ■ Tendering of proven concepts and technologies ■ Supplier performance evaluation on project targets (generic level) ■ Supplier management process in place	**Management of targets and risks on organisational level** ■ Project- and program management on organisational level ■ Deploying of organisational goals to project level ■ Risk identification in separate projects and their impact on total program	**Planning based on external information** ■ Planning of works based on important external factors ■ Important stakeholders get relevant information ■ Additional information available through standard channels (e.g. website)	**Configuration management on organisational level** ■ Documentation of all systems and their interlinkages (lighting, traffic management etc.) ■ Tracking and controlling of documentation on changes ■ Configuration baselines available for checks and audits	**Preventive actions on organisational level** ■ Complaints handling and comparison across all systems in the city ■ Sharing of solutions across projects and installations ■ Preventive and reactive maintenance based on fixed schedules	**Structural improvement on organisational level** ■ Structural collection of data on performance of individual projects ans systems across the whole organisation ■ Monitoring of the realisation of objectives on organisational level
Active involvement ■ Some important stakeholders are always involved in design projects	**Specifying standard products / systems** ■ Procurement of commercially available products, based on requirements specification ■ Supplier performance evaluation on product specifications ■ Supplier agreements Specifying standard products / systems	**Management of targets and risks on project level** ■ Project management on technical / functional objectives ■ Reactive risk identification based on incidents and concrete threats for the project	**Planning based on internal information** ■ Planning based on internal planning and resources ■ Basic information on the execution of the works available through standard channels - no detailed or specific information provided	**Configuration management on project level** ■ Documentation on project / system level	**Reactive structural improvements** ■ Systematic complaint handling in projects ■ Reactive maintenance with fast response based on pareto analysis of failures and stock of spare parts ■ Curative maintenance through periodic replacement of parts	**Systematic data collection** ■ Data on performance in projects in relation to targets is systematically collected
None ■ Ad-hoc stakeholder involvement	**Purchasing standard products** ■ Standard products for standard applications ■ Supplier performance evaluation based on individual deliveries ■ Ad-hoc selection of suppliers	**No structured project and risk management** ■ No performance indicators are defined for the realisation project ■ No risk management procedure in place	**No stakeholder management** ■ Execution of works based on internal planning and resources ■ No information provided	**No configuration management** ■ No configuration management procedure in place	**Complaints handling** ■ Individual complaints are analysed and solved ■ Reactive maintenance based on incidents ■ No stock of spare parts	**None** ■ No systematic collection of feedback on projects ■ No systematic monitoring of processes on achieving objectives

LIGHT HOUSE
/ expertise in smart lighting & smart cities

TU/e
EINDHOVEN UNIVERSITY OF TECHNOLOGY

© 2018-1205 TU/E LIGHT**HOUSE**

Evaluation of the current situation

The reference model as shown on the previous pages indicates for each of the five levels what should be in pace in the (sub)processes. To evaluate the current situation in a municipality, one starts at level 1 and checks which processes are well in place. If all requirements are fulfilled, the next level is checked.

Once not all requirements of a cell in the matrix are met, this defines the final score for that sub-process. Sometimes the requirements are only partially met: in such a case it can be decided to give a partial score. For each of the (sub) processes this procedure is repeated to define the current situation of the organisation.

As shown in the example below a municipality may score differently in the various sub-processes. This reflects the specific strengths of the organisation.

On each level best-practices can be identified. These best-practices are ways of working that can be an inspiration for other municipalities and could be used in exchange of knowlegde and experience. By comparing their own situation with others, people gain insight in ways of working that fit in their own context.

Example of the municipality of Eindhoven in a self-assessment (2012) and ambition levels after 5 and 10 years.

LEVELS	MAIN PROCESSES	Policy development			Design			Realisation			Maintenance		
		Defining ambition	Sustainability	Lighting innovation	Decision process	Design aspects	Stakeholder involvement	Contract management	Project management	Stakeholder management	Configuration management	Quality management	Progress monitoring
5	Visionary - adaptive / Innovating in the quadruple helix												
4	Embedded - adoptive / Proactive in total chain												
3	Depth - defined / Programs across organisation												
2	Aware - explorative / Projects in single departments												
1	Ad-hoc - unaware / Informal and individual												

Legend: ▇ current situation   ▇ desired situation 5 years from now   ▇ desired situation 10 years from now

Choosing an ambition level

When choosing an ambition level it is important to take into account the desired scope (e.g. if there are smart city ambitions or not) and what the competences and financial possibilities of the municipality are. There is no particular value related to a certain level: the aspiration level should be mostly related to the specific context. Some – often smaller – municipalities enjoy a low complexity of the organisation with limited number of staff and departments. In such cases 3 is a good ambition level. In more complex organisations, and with more complex installed systems it is desirable to score a minimum of 4 or 5, for at least a number of sub-processes.

In the image is indicated that it will only be interesting for a few municipalities to set an ambition level on 5, because this means more innovation projects that require a larger budget and more specialised knowledge. For many others it will be much more interesting to follow visionary municipalities and adopt innovations that have proven their value. For successful adoption of innovations a municipality should aspire level 3 or 4, to ensure that conscious decisions are made for solutions to adopt. When defining ambitions a differentiation can be made for (sub)processes, as well as in levels for the shorter and longer term.

Realising goals

A comparison of the ambition levels with the current situation shows which improvement steps need to be made and the model shows practical ways to achieve this ambition. When the ambition level is significantly higher than the current situation (more than 1 level), it is recommended to realise the desired situation step-by-step. First the ways of working of the lower level are implemented and subsequently of the higher levels.

When more municipalities have applied the reference model, it can be used to exchange knowledge and experience on the identified best-practices. For this purpose a municipality with a higher score on a specific process is approached to learn from their ways of working, methodologies and processes. Knowledge exchange based on carefully selected best-practices will enhance the learning process.

5 Visionary - adaptive
Innovating in the quadruple helix

*suggested average target level for **a few** (1-5%) municipalities*

4 Embedded - adoptive
Proactive in total chain

*suggested average target level for **some** (~15%) municipalities*

3 Depth - defined
Programs across organisation

*suggested average target level for **most** (>80%) municipalities*

2 Aware - explorative
Projects in single departments

1 Ad-hoc - unaware
Informal and individual

Note: It is nog necessary to score on equal level for all processes: organisations may choose their own areas for excellence

LIGHT HOUSE

Experience in ...

... **Smart Lighting** and **Smart Cities**

NAVIGATING TO THE **KNOWLEDGE** ...

Lighthouse was founded to make the knowledge of Eindhoven University of Technology (TU/e) about intelligent lighting and smart cities accessible to society at large.

LightHouse maintains close links to the research programmes into urban lighting and smart cities. LightHouse works closely together with the TU/e strategic areas of Mobility and Energy, and the research programmes of the Intelligent Lighting Institute (ILI), the Data Science Centre Eindhoven (DSC/e) and the Smart City Program Eindhoven (SCP/e). LightHouse operates knowledge-intensive projects based on people's wishes or requests from the community and organisations. This work forms part of the valorisation activities of the TU/e Innovation Lab.

We make use of the knowledge, methods and designs of the various departments of the university in practical applications. In this way we create liveable, sustainable solutions in the areas of public lighting and smart city solutions.

We co-create solutions together with cities, multinationals, SMEs and start-ups. We add value to TU/e by inspiring its new research and teaching programmes with best practices and societal trends.

Projects

- Self-assessment as part of the Vision and Roadmap Urban Lighting Eindhoven 2030.
- Identification of best-practices in sustainable urban lighting with Bassano del Grappa (Italy), Birmingham (UK), Burgos (Spain), Iasi (Romania), Leipzig (Germany), Lyon (France), Nice Cote d'Azur Metropole (France), Patras (Greece), Sofia (Bulgari), Tallinn (Estonia) as part of the Interreg IVC project PLUS (Public Lighting Strategies for Sustainable Urban Spaces).
- Knowledge network Smart Lighting of OVLNL.NL.

For more information, please visit:
www.tue-lighthouse.nl

DR. IR. ELKE DEN OUDEN
Founder & strategic director
e-mail: e.d.ouden@tue.nl

DR. IR. RIANNE VALKENBURG
Founder & value producer
e-mail: a.c.valkenburg@tue.nl

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY