

Reasons for Insufficient Success of Light Pollution Prevention Legislation in Slovenia

Aleš Šubic^{*1}

Initiative for Regulation of Outdoor Lighting, Slovenia

Received 25 October 2021, Accepted 27 December 2021

Abstract

In 2007, Slovenia was one of the first countries to adopt light pollution prevention legislation with the Decree on limiting values of light pollution [1]. As such, the Slovenian experience is ideal for studying the effectiveness of the taken measures and of remaining factors, preventing fully resolving the problem. The Slovenian case is taken just as an example, showing a practical insight into the limitations of the present light pollution control approaches, and based on the gathered experience proposals are given for further improvements.

Despite the indisputable progress, the country is still facing a wide spread of light pollution, as the public lighting is intensively spreading to new locations and the illumination of particular road structures is relatively extensive and intense. Besides some relatively well-known improvements, such as correcting the already existing, but too high annual limit of consumption per capita, prescribing the environment-friendly light temperatures and wider application of adaptive lighting, comprehensive eco-spatial policies should be defined, going beyond the sole limiting of the light pollution, which is only a sub-problem of a wider problem of systematic environment and space degradation with outdoor lighting. Above all, the extensive territorial spread of lighting to new locations should be heavily limited. In addition, the technical recommendations, mostly coming from the international level, must be revised and softened in their use.

Keywords: lighting legislation, lighting recommendations, sustainable lighting, light pollution, landscape degradation, EN 13201

1. Introduction

1.1. Background and content

The topic was researched as a contribution of a responsible citizen in the frames, which can be termed citizen science. The effort was focused on finding the origins of problems in lighting recommendations, lighting praxis, and legislation on the one hand, and on finding or defining effective theoretical frames and proposals for problem-solving on the other hand. The conclusions are made based on a large number of observed lighting installations in the local environment, at the national level and in other countries, on studying the available literature, on experience in communication with a large number of experts of different professions in the country and internationally, as well as on deep involvement in concrete efforts to improve the recommendations and legislation. The topic was presented in a presentation form, including case material, at the eALAN 2021 conference [2].

The efforts were more concentrated on road lighting, which is the most problematic light pollution and landscape degradation source in the country, therefore at some places, the document is slightly biased in sense of disproportionally exposing the road lighting.

At the beginning of the document the regulation and recommendations, used in Slovenia, are presented, including the estimation of their influence and drawbacks. Further, it is discussed what exactly is the problem that

¹ * Aleš Šubic, e-mail address: ales.subic@gmail.com

has to be solved, as the problem is often not defined to its whole extent and consequently the policies are not comprehensive enough. As road lighting is the most problematic light pollution source in the country, different levels of road lighting-related problems are discussed in a separate chapter. In praxis, very important questions are, where the content for the policies definition can come from, which institutions and individuals are able to promote and enforce them and how the policies and measures are accepted in the public. At the end of the document some proposals are given on how to improve the theoretical background, policies and recommendations.

1.2. Challenges of light pollution prevention in Slovenia

Different sources of light pollution are covered with the Decree on limiting values of light pollution [1], which was adopted in Slovenia in 2007. The decree is mainly respected, with only minor deviations in particular cases. Recommendations of the lighting profession are followed as well. As far as road lighting is concerned, especially strictly and extensively in lighting state roads. However, while with some minor exceptions most other major sources of light pollution are well managed, road lighting remains a serious problem. It's expanding extensively to new locations, both on state roads and in settlements of all types, with European infrastructure funds playing a significant role in its pace. As far as road lighting is concerned, the only limits are Upward Light Output Ratio (ULOR) = 0 and allowed annual power consumption per capita. It's obvious that additional measures need to be taken to manage the problem.

The necessary additional measures can be roughly divided into the following main sections:

- Limiting locations and amount of lighting equipment
- Limiting lighting intensity and other technical improvements
- Switching off or dimming after curfew
- Environmentally friendly color temperature
- Ensuring aesthetical acceptability (landscape, urban appearance)

While it will be relatively easy to achieve more appropriate color temperature and turning off or dimming after curfew is also in the interest of lighting providers (this indirectly allows them to install more lighting), all other measures pose very difficult challenges:

- Very difficult-to-move approaches of state traffic infrastructure authorities, lighting standards and recommendations
- Civilizational expectations with insufficient consideration of actual needs and cumulative effects
- Inability of state structures and urban planning expert circles to introduce comprehensive spatial planning policies

A further detailed review of individual factors shows that above all the aspect of comprehensive spatial planning is critically absent in the whole issue, both at the macro-level of anticipation and limitation of cumulative effects (not only the light pollution), as well as at the micro-level of ecologically, aesthetically and ethically acceptable placement of individual lighting projects. In these conditions, the technical lighting parameters and the unrestrained and reckless civilizational pressure to illuminate (at least) all populated areas, prevail almost entirely. It would be necessary to limit lighting locations much more decisively, not only by restricting lighting outside settlements but also by theoretically justified avoidance of lighting particular types of settlements or their parts when the needs do not reach a certain threshold.

The influence of international standards (e.g. EN 13201) and, in the event of their inadequacy, their potentially very problematic and extensive negative impacts should be emphasized. As these are expert recommendations, they are very difficult to challenge, therefore both residents and local authorities are usually practically completely powerless even in the cases where it's obvious that unacceptable environmental and spatial impacts are caused.

The situation with the road lighting recommendations also implies that technical recommendations with potentially extensive negative environmental and spatial impacts should not be legally binding.

2. Regulation and recommendations, used in Slovenia

2.1. A decree on limiting values of light pollution

The Slovenian Decree on limiting values of light pollution [1], adopted in 2007 as the first such legislation document at the state level in the world, is the core of the light pollution prevention efforts in the country. It addresses various light pollution sources and aspects, namely roads, public surfaces, airports, ports, railways,

production facilities, office buildings, institutions, facades, cultural monuments, protection of endangered species, advertising facilities, sports fields, construction sites.

In general, the decree is respected and it has brought large advances in light pollution prevention, but unfortunately, it's not effective in limiting the spread of (especially road) lighting to new locations and in limiting the extent of illumination of particular road structures. The most direct reason is that the annual power consumption limit of 44,5 kWh/capita has failed because of the advent of more energy-efficient LED lighting. But also, a deeper problem exists, namely that the road lighting has not been addressed comprehensively. The only limitations that address the road lighting in the decree, are the ULOR = 0 requirement and the mentioned annual power consumption cap. The questions, related to the placement of lighting equipment into the space (which locations, the extent of illumination, spatial distribution, poles height, etc.) are not addressed at all and this leaves a wide space for unnecessary and inappropriate lighting projects.

A very important lesson of experience with the Slovenian decree is that although the ULOR = 0 requirement is stricter than in most other countries and a consumption cap has been prescribed, which is often not a case even in the countries with light pollution prevention legislation, the proliferation of road lighting is still almost completely open. That means that more profound measures should be taken on different levels, the first and most important one being in much more strictly limiting the lighting locations.

Following the requirement to harmonize the lighting with the decree by 2017, today more or less all public lighting meets the ULOR = 0 condition, which is a big advance. However, it can be assumed that the requirement to harmonize the lighting with the decree in ten years from the decree adoption, also had a negative contribution in addition to the positive ones. The pace of the lighting equipment replacement has boosted the road lighting market and this, in turn, has led to a higher pressure for new lighting projects until the present.

Light temperature is not addressed in the present decree. There was a serious problem that most of the LED road lighting, installed in the past decade, was 4000 K. The lighting profession has already accepted that this is a problem and in praxis, the limit is being decreased to 3000 K, although there are no such official requirements yet. The present proposals go in the direction that 2700 K would be recommended for more demanding locations and 2200 K for peripheral ones and the development of recommendations at the global level is monitored as well.

Besides the road lighting, the illumination level limits for allowed intrusive light in residential buildings seem to be another notable open topic. The levels in the decree are copied from the CIE recommendations and are very high. Illumination of sports facilities, where ULOR was subsequently increased to 5 %, is also an open topic because such facilities can have very notable negative impacts on their surroundings. The ULOR = 0 requirement is still often disputed by the lighting experts also for road lighting. Illumination of surroundings and facades of private buildings, which is limited to the areas 240 m from the nearest public lighting, can become a serious topic as well, as the rising availability of such solutions can at least have a serious impact on the night landscape.

2.2. Spatial planning legislation and recommendations

As discussed at several points in this document, the spatial planning aspects should be an important part of the light pollution prevention efforts, probably even the primary starting point. The following main levels should be covered within this aspect, especially the first one being of crucial importance:

- Limits of lighting; where lighting is allowed, forbidden, not recommended
- Influences of lighting installations on (also daytime) space appearance

At present, this topic is not explicitly covered in the spatial planning legislation and, according to available information, not even in any analysis, coming from the spatial planning and landscape architecture expert circles. The absence of this contribution is evident at every step, as the lighting is spreading to many location types, non-regarding the level of needs, and many lighting projects are not in accordance with landscape preservation and general aesthetical goals.

In 2019, the light pollution topic has found its place in the draft of the Slovenian national spatial planning strategy, as one of the topics in its addendum, namely the Environmental report. The review of the content has shown that it's outdated even in the frames of the presently valid light pollution prevention recommendations, let alone in the more effective frames, which should go beyond the present ones. Corresponding remarks were submitted and they were partly considered in the latest versions of the document. In any case, the content is mainly focused on light pollution in a narrow sense and less on the ethical question of lighting limits and on the aesthetical degradation of space with lighting installations.

In general, the spatial planning perspective is underestimated also at the international level.

2.3. Rules on road design

The Rules on road design [3] were the only legislation level document, prescribing road lighting. In 2011 it expired, but partly the document is still valid. At present, this topic is covered with a similar document, namely the Rules on traffic signals and traffic equipment on roads [4].

Both documents include only a short article on lighting, but in the first document, this article has opened a wide door for lighting at different locations. The content is as follows: “Lighting must be installed on roads in settlements, in canalized intersections, at junctions on long roads, at intersections of main and regional roads with main and regional roads outside settlements, at bus stops, in pedestrian corridors in the area of marked crossings or underpasses, on surfaces control stations, service stations, rest areas, and service stations and car parks.” Especially requirements for “roads in settlements”, without any limitations and for “intersections” were very problematic.

The new document is more rational: “Road lighting must be installed on the busiest parts of roads in settlements, on crossings and pedestrian underpasses, in canalized intersections with more than three classification lanes, at junctions on motorways and expressways, at toll stations, service traffic areas along public roads, on roads at border crossings and in medium and long tunnels. Short tunnels must be illuminated if pedestrians or cyclists are allowed to pass through the tunnel.”

It’s symptomatic that the lighting professionals and the representatives of the competent state institutions are relatively often claiming that illumination of particular road structures can’t be avoided because it’s required by legislation. In some cases, this argument is even used to prove absurd intensive technical illumination at locations (e.g. remote road rest-places), where no or minimal lighting should be installed.

The situation on the state-controlled transit roads, influenced also but not only by the mentioned rules, represents the main difference with neighboring Austria and comparable countries [5], where environment and landscape are much less burdened by the lighting installations. What legislation, recommendation, and implementation praxis factors lead to such a favorable situation in these countries, is yet to be investigated.

2.4. Slovenian Lighting Society recommendations

In 2000, the Slovenian Lighting Society has issued recommendations on-road lighting design [6], recommending the lighting design and light intensity for particular types of locations and road facilities. In general, the document is only a translation of international lighting recommendations of the time.

The document is not valid anymore, but in the absence of other documents of this level, it’s partly still used. It’s wrongly stated by society that it’s replaced by the standard EN 13201, which is only partly true. Namely, the standard is only covering the recommendations on the lighting intensity and uniformity but does not say anything about the luminaire distribution, area of illumination, etc. As this is one of the key levels in road lighting design and also at this level the approaches substantially differ from the Austrian and comparable ones [5], an updated and extended document of this level is urgently needed.

2.5. Standard EN 13201

The European standard EN 13201 [7], which provides the frames for lighting design in terms of minimal illumination and minimal uniformity for particular traffic situations, is unfortunately also one of the major sources of excessive lighting projects. The standard is problematic on several levels:

- Although it’s formally valid only as a recommendation, it’s mostly used strictly. On state roads without exceptions, on local roads depending on the level of design expertise, self-confidence, wider well-roundedness, and attitude. In many cases, it’s very harmful that common sense is suppressed by the standard, which is often misleadingly represented as “the legislation”.
- The recommended levels of illumination and uniformity are often disputed in light pollution discussions. The fact is that especially the requirement for uniformity is one of the key drivers for severe environmental and spatial degradation of low lighting need areas, such as the rural ones. Orientational lighting, instead of uniform lighting by standard, would be much more appropriate for most of the rural and other low lighting needs locations. Too strictly following the recommendations for uniformity in some cases leads to absurd illumination also at locations with higher lighting needs.

- The set of parameters used to determine the most appropriate lighting class for a certain location is loose and in some cases misleading or at least unclear, thus often leading the designer to a choice of higher illumination than foreseen by the standard. In addition, environmental and spatial factors are not on the list of parameters, therefore the recommended illumination is biased in favor of anthropocentric and 'lighting centric' perspectives.
- The existing and missing wording of the standard text (in the first part: EN 13201-1) in many cases leads to higher illumination.

It's worrying that instead of promoting the (not more than) recommendation status of the discussed set of documents, the trends worldwide go in the opposite direction, promoting it even as an obligatory part of national light pollution prevention legislation and key international light pollution prevention recommendations at the European Union and United Nations levels. In Slovenia, so far, we are strictly avoiding including this standard as an obligation or even as a reference in the light pollution prevention legislation.

From the perspective of the goal to improve the standard, it seems to be very problematic that also in the most exposed international light pollution circles there are almost no experts, knowing sharply the standard content, the complete pallet of its non-desired impacts, and effective solutions.

The Slovenian efforts go into the direction of defining a national specific variant of the 1st part of the standard (choice of lighting classes), which is in progress.

2.6. Green public procurement decree

The Slovenian Green public procurement decree [8] is a typical example of what happens if inappropriate lighting recommendations are used as a basis for international light pollution prevention recommendations. The Ministry of Public Administration, without having any serious knowledge on lighting and light pollution, has taken the European green public procurement recommendations as a basis for the corresponding Slovenian document. The result is that the regulation, which should take care of environment protection, prescribes the use of the very problematic lighting standard EN 13201, which prescribes minimal lighting levels and, in many cases, causes absurdly intensive lighting projects. The fact that the European document mentions that the standard is disputed and other solution proposals exist, is completely neglected. Besides that, the decree requires the use of an environmentally unacceptable 4000 K light spectrum, presumably because it's slightly more energy efficient.

2.7. Municipal lighting plans

As municipalities are responsible for lighting projects at the local level, and they typically don't have deep knowledge on the matter, it's very important that they follow corresponding recommendations. The Decree on limiting values of light pollution [1] prescribes that each municipality should have a lighting plan. At present, these documents are mainly technically oriented, very rarely going beyond that, to define environmentally and spatially sustainable local policies.

The major problem at this level seems to be that without serious limitations for allowed lighting locations, coming from national and international levels, in the long run, the lighting will inevitably be installed in all parts of all types of settlements and in many cases also between them.

3. What exactly is the problem?

3.1. Today we are mainly focused on mitigating direct negative impacts of ALAN, but is this enough?

If we want to evaluate the effectiveness of the regulation, the problem has to be defined to its whole extent. The use of outdoor artificial light sources has various negative impacts and costs, not only light pollution and its effects on the night sky, live nature, and human health as the most exposed ones. Spending of public funds as the most trivial problem is not discussed in this article. Energy consumption is an important factor, whose control can be sometimes in conflict with control of another negative impact, aesthetical degradation of space. The latter is in general largely underestimated and in most cases left out of discussion even at the top international expert levels. Very important underestimated 'flavors' of this problem are excessive urbanization, changing the character of space, losing contact with the environment and experience of the night, etc. These impacts can hardly be seen as directly harmful and they have to be considered in the frames of environmental ethics and aesthetics of space.

Analysis of particular cases shows that (not) considering these aspects also largely affects the (non)ability to control the light pollution itself.

As can also be seen from the points outlined below, the red thread of solving the problem should be in complex spatial planning, based on deeply corrected ethical boundaries and aesthetical aspects being considered, and the concept of limiting light pollution alone is not sufficient. More than that, when talking about installing the lighting equipment, we are primarily dealing with placing something into the space. That means that the perspective of comprehensive spatial planning should be the primary one, while light pollution prevention should be considered as one of the most important sub-problems, together with the sub-problems of traffic accident prevention and comfort assurance within reasonable frames.

3.1. Ethical starting points

The attitude to the outdoor lighting and its side effects largely depends on the principal ethical starting points, respected by an individual or an institution. These starting points come from a whole range, from the most trivial utilitarian use of outdoor lighting to considering complex and subtle ethical issues. In the case of road/street lighting the prevailing position at present is that it is a must in traffic accident prevention, is in general not problematic in settled places and, if not used properly, it has negative side effects of light pollution and energy consumption. However, this position is not sufficient, for example, because it doesn't leave space for the 'right to darkness' in settlements even in cases of very low lighting needs and it doesn't address the complex problem of the use and appearance of space in its whole extent. In this context, a very important question is, where adaptive lighting is a proper solution and where no lighting is a more appropriate choice because in the case of adaptive lighting the environment and space are still heavily changed at least for a certain period of the night.

In general, the present starting points, even in the light pollution prevention expert circles, too much accept the perspective that road/street lighting can't be avoided in settled places and that there's also no urgent need to achieve that. However, applying this approach to Slovenian countryside, shows that this position is severely insufficient and if it is not changed, the extreme environmental and spatial burden will be caused, severely changing the environment, appearance of the landscape, and life experience. The reckless spread of road/street lighting to all settled places and in many cases even connections between them urgently has to be stopped by defining appropriate policies, where the artificial lighting will only be used in the case of indisputable level of needs.

In discussions of the issue of light pollution, a defensive position is often felt, typically looking for arguments as to why lighting or its mode is not acceptable in certain situations. This defensive position should be changed into actively setting the boundaries of lighting (per level of needs, type of location, etc.) and proof of the need for illumination should be required instead. As e.g. proposed by R. Hartley in [9], the principal starting point must be preserving the natural state of the night, which is changed only in the case of indisputable needs.

A wider ethical framework was discussed by T. Stone in [10,11], who also discussed the limitations of the light pollution concept in [12].

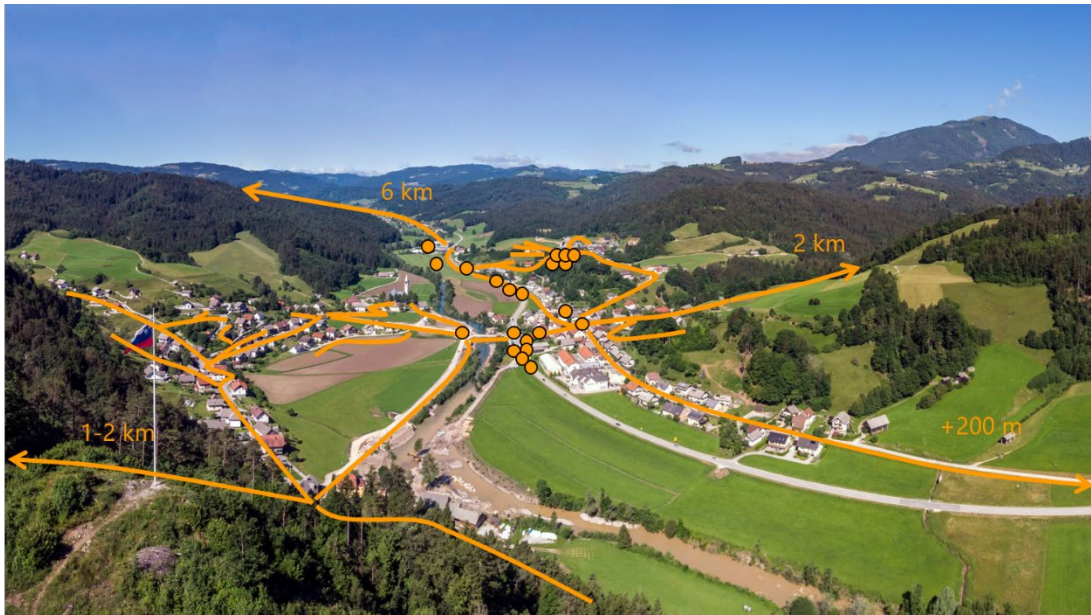


Fig. 1. Final state of a Slovenian rural area, if present starting points are not profoundly changed ($r = 2\text{ km}$, 1.100 residents: 500 luminaires) (photo: M. Prijatelj, A. Šubic)

3.2. What is light pollution?

Even understanding of the light pollution itself, and consequently the depth of actions to control it, can span over a wide spectrum. The definition of what “unwanted, inappropriate, or excessive artificial lighting” means, largely depends on the ethical starting points. Artificial light is not causing pollution only when it severely degrades visibility of the starry sky or affects the live nature, but also when it changes the appearance of the night environment in a place, e.g. a village, with low lighting needs, non-regarding to the applied light intensity and light source density. At present, the later aspect is more or less left out of all the policies and light pollution prevention theories and that represents one of the key reasons for the failure of the present and predictable near-future policies.

3.3. Visual degradation of space

The lighting equipment, especially the road lighting poles and luminaires, largely affect the visual appearance of space, also during the day, when switched off. Installation of unnatural elements in an unnatural layout and proportions in many cases represents a degradation and excessive urbanization of non-urban areas and inappropriate domination of lighting equipment over the appearance of settlements. Although the light pollution prevention discussions often touch this problem, it seems not to be exposed strongly enough. As already indicated above, the problem is that the light pollution and the visual degradation problems are largely intertwined and it's almost impossible to completely solve the first one without addressing the second one.

4. Problem levels from the perspective of road and street lighting

As stated above, in Slovenia the spread and intensity of road and street lighting are the main problems, contributing to the fact that the present light pollution prevention status can't be estimated as satisfactory. The problem encompasses several levels and all these levels need to be addressed in order to comprehensively solve it. Although large improvements were made in Slovenia in the past decades, at present none of these levels is solved sufficiently.

4.1. Civilizational pressure towards systematic lighting for comfort at the local level

Without restrictions on what level of needs should be met for the lighting to be allowed or recommended (location, type and use intensity of settlement/street/road structure, etc.; technically translated, e.g. into the number of pedestrians per unit of time and add to the risk assessment and to division into risk, environmental, landscape, etc. zones), increasing of light pollution and systematic landscape degradation cannot be managed. Lighting is expanding to locations with zero safety needs and negligible needs in terms of comfort (e.g. rural environments). As trends continue, cumulative impacts on the environment and landscape become very extensive, especially with the dispersed settlement, typical for Slovenia.



Fig. 2. Is lighting needed here? Should it be allowed? What is a cumulative result, if we light all such settlements? (photo: M. Prijatelj)

The measures to limit acceptable lighting locations, not only outside settlements but also within them, would be the largest and the only sufficient contribution to solving the problem comprehensively. The low presence of working on this aspect even in the top-level international light pollution expert circles is one of the most problematic drawbacks of the present light pollution prevention efforts and this is one of the first impressions that surprise and frustrate an outside observer. The level of needs and cost/benefit ratio should be estimated even for relatively large settlements and their parts and based on that, decisions should be taken where lighting is (not) recommended. Thus, the non-recommending should also be legitimate for the major part of the rural settlements, except for their centers, other concentration areas, and conflict points. The absence of such an approach is especially problematic because without that there's practically no possibility not to illuminate all roads in all settlements.

The International Commission on Illumination (CIE) in the recommendation CIE 115-2010 [13] defines lighting zones, which partly address the described problem. These zones are used in some national legislation light pollution prevention documents, e.g. the Croatian Ordinance on lighting zones, permitted lighting values, and methods of managing lighting systems [14]. But the problem is that these zones are too generous in terms of lighting acceptability and recommended lighting levels and they create an illusion of action, thus suppressing more effective actions.

4.2. Excessive number of lighting locations on transit roads

In Slovenia, intersections, roundabouts, motorway connections, sidewalks between settlements, bypasses, parking, and other road facilities have been systematically illuminated in the recent decade, within and outside settlements. Even along the lowest level regional roads through dispersed villages, uniform lighting by standard

EN 13201 is applied systematically. This represents a serious environmental and spatial burden and to address this problem, at least lighting outside settlements should be banned and, in many cases, lighting of roads through long dispersed settlements should be ‘softened’ or even avoided. The latter is especially important because the country is populated relatively densely but at the same time with relatively scattered buildings within the settlements.

Solving this level of the problem would largely help to restore the appearance of a preserved landscape, which openly ‘breathes’, such as for example in Austria and Slovakia.

4.3. Large area of illumination for particular types of road structures



Fig. 3. Extensive and intense illumination is present at many locations in Slovenia; all examples shown are outside or near settlements in semi-urban and rural areas (photo: A. Šubic, A. Mohar).

In Slovenia, individual road structures (intersections, roundabouts, bus stops, etc.) are illuminated extensively, in a relatively wide area around the structure, with a large number of luminaires, which are typically high. To address the problem, it would be useful to transfer practices from neighbouring Austria, where the extent of illumination and consequently the number of luminaires is typically much lower [5]. However, in some countries, the extent of illumination is even higher and in general, the theoretical basis for such illumination comes from the international level. For a comprehensive solution to the problem, the requirements of the standard EN 13201 should be critically evaluated as well, although the standard itself is not the main and the only contributor to this level of the problem.

4.4. Optimization of technical parameters and dynamic lighting

The technical parameters, such as illumination intensity, light spectrum, etc. play a central role in the lighting recommendations and praxis. It could even be said that the role of these parameters is too exposed and some other parameters, such as the environmental and spatial ones, are not present enough.

The illumination intensity and uniformity are designed based on the standard EN 13201. Analysis of the lighting cases shows that the standard is very problematic at least for the locations with low lighting needs, where

the standard requirements are often in sharp contrast to the common-sense estimations and to environmental and spatial sustainability and thus the standard is one of the key sources of inappropriate lighting.

A very important aspect of this level of the problem is excessive lighting of roads in smaller settlements and less congested streets. In these cases, it would be necessary to abandon the rigid and strong linear illumination according to the standard EN 13201 and switch to orientational illumination of exposed points.

Light temperature is an important parameter because it has a strong impact on live nature and starry sky light pollution. Discussions go into the direction that 2700 K will be recommended for more demanding locations and 2200 K for peripheral ones.

Dynamic lighting brings advance to locations where the use of lighting is justified and the levels can be decreased after curfew. However, a serious danger exists that the principle of dynamic lighting will be misused to install lighting also at the locations, where no lighting would be an appropriate choice.

4.5. Visual inadequacy of the lighting installations

Not only, but largely due to the fulfillment of the technical requirements of the standard EN 13201, the luminaires are typically high, dense, and linearly placed, therefore they dominate and act as foreign objects in the space and they visually urbanize it. As such, from the landscape preservation point of view, they are particularly unsuitable for rural areas. In such areas, the problem would be largely solved by replacing the standard EN 13201 with orientational lighting and by reducing the number of luminaires per road structure (see also previous subchapters). It should also be tried to reasonably limit the height of poles.

The question of pole and luminaire design is practically completely unaddressed in Slovenia. With few exceptions, ready-made industrial lamps on gray chandeliers are typically installed at all types of locations. It's possible that with a more innovative design that would probably be impossible to control systematically, the situation would be even worse, as is the case in some countries.

5. Dealing with the problem in practice

As we are dealing with a complex topic, where issues of safety, comfort, technology, environment, landscape, health, ethics, aesthetics, business, public finance, marketing, politics, etc. are intertwined, a serious problem exists on which institutions and individuals can be educated, dedicated and motivated enough to prepare adequate policies and recommendations and how these are promoted in the everyday lighting praxis and in public. The questions of cooperation between different stakeholders and their openness are very important as well.

5.1. Who and on what basis?

At the top level, the issue of light pollution is managed by the Ministry of the Environment and Spatial Planning (MESP), with a single person being directly responsible. The ministry is also the owner of the light pollution decree from 2007 [1]. The decree is respected, but no advances were made in the last decade, when it became evident, that despite the progress, the lighting is still spreading very extensively. In 2017, the Court of Audit issued a negative opinion [15], stating that the MESP does not manage the issue, which corresponded to the MESP level of control and knowledge on the matter. It is also very problematic, that open discussion on the matter was suppressed. For a decade there were no organised contacts between responsible person in the ministry and the most exposed light pollution experts, which was probably also partly provoked by the inappropriate approaches of the dark sky society representatives. Rather the lighting experts were taken as a source of information, even on the light pollution prevention topic. At the end of 2019, activities began to amend the Decree on limiting values of light pollution and the project, hampered by the Covid-19 epidemic situation, is still ongoing. Until recently, the Spatial directorate, which should probably be the first owner of the issue, was not involved in the topic, but it's promising that this is changing.

A key contribution to the adoption of the 2007 decree and to the constant attention to the issue in the last two decades, came from the activists and top experts of different professions, gathered in the Dark Sky Slovenia society. A broad theoretical and practical knowledge is gathered in the society, which is constantly present in the public, promoting the light pollution issue, and has important contributions also at the international level. Too fierce activism, a lack of organization, and probably also a lack of innovative comprehensive theories and approaches to support the next step in fixing the problem have led to a situation, where the more or less justified

claims of the society representatives have almost no effect. There is also almost no cooperation with the lighting experts' side, which is a flat rate seen as a lighting lobby.

The lighting profession in general strictly follows international standards and recommendations, without notable innovation at the national level. Its representatives were partly involved in the light pollution decree adoption and later revisions, in general with rational contributions, slightly in favor of lighting, and some of these are problematized and opposed by the other side (e.g. ULOR = 0 exceptions at the illumination of sports facilities). In discussions on the topic, the position of the academic lighting experts varies from a very realistic critical view to a relatively non-critical follow-up to the international recommendations. At both the academic and the lighting designer levels, many of the most exposed experts agree that the present lighting praxis needs to be further improved. Warnings, supported by arguments, based on concrete lighting cases, have recently led to an ongoing national-specific revision of the lighting standard EN 13201 and to the plans to revise higher-level lighting recommendations.

In the last few years, an unusual situation occurred. Coherent innovative theories and proposals of a motivated individual with previous experience in multiple fields (none of which is related to the topic), combined with previously existing efforts of the national dark-sky society, other supporters' contributions, the favorable response of the lighting experts, and some state institutions, have accelerated revisions of legislation and recommendation documents, which are currently in progress or planned at different levels. It's very important that active contributions in these efforts come from both the light pollution and the lighting experts' sides, as well as from some state institutions. However, there was no success so far in actively involving the spatial planning profession, which should contribute to the urgently needed spatial aspect theories. In addition, there's also not possible to find experts, who could contribute to deep discussions on environmental ethics aspects, which are one of the key starting points as well.

Despite the wide knowledge, gathered at the international level, at the achieved state of the matter in the country the contribution of the international level to the problem fixing is relatively limited and does not provide sufficient tools for the needed progress. The most important shortcoming is that efficient tools for limiting lighting locations are not available. The second important problem is that so far there are no concrete, sharp, and effective enough efforts in cutting off the excesses in lighting recommendations, such as the lighting standard EN13201. Except for the relatively new adaptive lighting technology, which is yet to be widely introduced and a necessary shift to acceptable lighting spectra, which is already partly ongoing, the other major available technical improvements are already introduced into the lighting praxis. However, this is not enough. Even potential introduction of light pollution caps (already present in Slovenian legislation by limiting annual energy consumption/capita, but the value needs to be revised due to the higher energy efficiency of LED technology) will not solve the problem, if recommendations for acceptable lighting locations, lighting intensity and uniformity, a number of luminaires and layout of their installation in particular types of road facilities, etc., will not be defined or revised.

The lighting standard EN 13201 and the related CIE recommendations have to be addressed explicitly also in this chapter, as these are the core starting points, present in the everyday lighting praxis. As already discussed above, these documents are problematic and are explicitly and implicitly a direct source of a large part of the problem. In this respect, it's very problematic that these recommendations are finding their place in the light pollution prevention legislation at all levels, without firm assurance that they will be revised profoundly enough. As an example, referencing of the Croatian lighting providers to the new Croatian light pollution prevention ordinance [14] already shows that references to such legislation will be (ab)used to excuse high-intensity lighting projects. It's even more worrying that also the European green procurement recommendations [16] and the emerging UN-sponsored recommendations [17] use the standard and the CIE recommendations as one of the starting points for light pollution prevention. It will not be enough to only stop the penetration of the present lighting recommendations into the light pollution prevention legislation until these documents are undoubtedly revised and confirmed by the light pollution experts. In any case, the lighting recommendations urgently need to be revised as they directly influence the present everyday praxis.

In the described circumstances the definition of more effective and sustainable recommendations is largely a matter of domestic altruistic contribution of individuals from (out of necessity) environment protection circles, accompanied by a favorable response of some key lighting professionals and some public administration institutions. Since at the international level problematic compromises between the light pollution prevention needs and the present lighting recommendations can be expected (see for example proposals in [17]), serious threats exist that the resulting top-level international light pollution prevention recommendations could have negative impacts on the already achieved and achievable advances at the national level.

5.2. Citizens' expectations and reactions

As the lighting is installed for the citizens' wellbeing, it's obvious that the citizens' expectations and reactions to particular situations are one of the key starting points for lighting-related decisions. This strongly influences the lighting praxis, which tends to be anthropocentric or even 'lighting centric'.

There's another important aspect that needs to be exposed in this context. Citizens' expectations are often cited by the municipal authorities as to the reason for installing the public lighting in a particular area. Although a closer look shows that in low need situations (e.g. most of the countryside) only a small minority of residents explicitly requires the lighting, while the majority is indifferent or even strongly against, that's enough to provoke a situation where in reality it's impossible to prevent illumination of all streets in all settled places and even connections between them, without defining the corresponding policies at national and international levels.

It's obvious that open democratic decision making if applied for some reason in very rare cases, will almost always bring compromise results, which in general are not good enough to find efficient solutions. On the one hand, such decision-making partly ignores the expertise regarding efficient lighting, and on the other hand, it's practically impossible to come to a decision for zero lighting even where that would be most appropriate for environmental and spatial reasons. Nevertheless, democratic decision-making, including local residents, can be an important correction mechanism to prevent the most deviant lighting projects.

A case of a planned project in Poljane nad Škofjo Loko, Slovenia, shows that after presenting the 'dark side' of lighting, the residents, in general, understand that the present lighting praxis is problematic, although a part of them will always require the lighting. In the discussed case, it was planned to install 25 luminaires on connection roads in an open field in the middle of an inhabited rural area. The voting at the assembly of locals has confirmed the proposal to radically rationalise the project. For one of the three sections, it was proposed not to install lighting at all, at the second one the number of luminaires was heavily reduced, and for the rarely used path to the church, sensor lighting was proposed. This has led to a reaction of some most determined lighting (in fact road safety) proponents, who for the 600 m long 'no lighting' section gathered a large number of signatures for a proposal to build a separate pedestrian path, where three luminaires should be installed (eight were planned in the project, two agreed at the end as a compromise). The correct solution for this section is probably a separate pedestrian path but without lighting. While at the assembly of locals the voting was slightly biased because the opponents of lighting were more prone to be present, also the number of later signatures for three additional luminaires is not realistic, because it contains a range of motives. However, it's obvious that a large number of residents understand that the lighting praxis should be more rational and on the other hand the majority will seek compromise solutions. In any case, it can be estimated with a high probability that almost none of the locals would agree with the initially proposed project, which has been assigned by the designer as extremely rational. The "extremely rational" statement can only be understood, if seen in the frames of the lighting standard EN 13201 and the present lighting recommendations, but it was immediately rejected by common sense estimations.

The described case shows that raising public awareness of the issue of light pollution and landscape degradation with outdoor lighting is a very important part of problem-solving. In addition, the case shows that with good enough arguments and with environment and space protection theories and policies, promoted by appropriate scientific, public administration, and political authorities, the vast majority of the population will accept the (should be) obvious fact that the lighting is not desired at every single settled place.

This case, together with many other similar cases around the country, also clearly shows that the present lighting praxis too much acts like a kind of a technocentric system, where a few people define the rules and there's almost no possibility for objection without enormous efforts, even in the cases of obvious deviations.

6. Proposed theoretical framework for further improvements

Although notable progress has been made in light pollution control in the past decades, at least in some countries and regions, the theoretical framework for light pollution control and the consequent legislation and recommendation actions still need further improvements. Missing recommendation levels need to be defined and the existing ones need to be improved. In this chapter some general ideas on how to cover the gaps are presented. Some of these ideas need to be further discussed in separate articles.

6.1. Levels of light pollution control

At the top level, the control of the problem can be divided into the following levels:

- Avoid lighting, if the level of needs is not high enough
- ‘Soften’ extent and intensity of illumination where the lighting makes sense
- Improve technical parameters and visual appearance of the lighting equipment where possible

More in detail, light pollution, together with landscape degradation, should be controlled at the whole set of levels, reflected in different levels of legislation and recommendation documents, as well as in technical solutions for the lighting equipment.

- Environmental and spatial planning policies
 - Where lighting is needed/not recommended/not allowed
 - Environmental and spatial aesthetics aspects
 - Based on cost/benefit-based and needs-based decisions
 - Turn the perspective: night is a value, impact it only if proven needs
- Cumulative limits: red-lines, target values, top-down approach
 - Annual consumption in kWh/capita or lumen/capita as the simplest version
 - Dynamic allocation within defined limits in specified geographical areas
- Design rules for different situations
 - Extent of illumination (e.g. 25, 4, or 0 lights per roundabout)
 - Where high uniformity and where only orientational (standard EN 13201)
 - Spatial distribution and height of luminaires
 - Dynamic lighting
- Technical optimisation of individual light sources
 - Light color, optics, shielding, etc.

At present, no country addresses all levels in its legislation and lighting praxis. Comprehensive spatial planning perspective is missing more or less everywhere. Cumulative limits are used only in some countries and even many of those which have light pollution legislation, don't use such limits. It's of crucial importance that the present lighting design rules and lighting recommendations are profoundly revised because they have an extensive impact on inappropriate lighting. It must be assured that these recommendations are used only as recommendations and common-sense estimations are not suppressed by a rigid system.

6.2. Outdoor lighting acceptance for different purposes

At present, outdoor lighting is in general widely acceptable with relatively mild limits, if used for direct use, traffic safety, personal safety, and comfort. In general, also strict limits for decoration purposes are mostly absent, leaving the decisions to the estimations of equipment providers and subjective decisions of users.

The below table shows a proposal of how to define lighting acceptance for certain purposes:

Table 1. Level of lighting acceptance for different purposes.

Purpose	Level of lighting acceptance
Direct use (work, service facilities, events, sports, etc.)	Acceptable, respect limits
Traffic safety	Acceptable, respect limits, rational estimation of needs
Personal safety	Only if high enough needs
Comfort	Only if high enough needs, e.g. in general not in villages, except centers and high concentration areas; orientational lighting in some areas
Decoration (facades, surroundings of buildings, parks, seaside promenades, etc.)	Only in cities, except for buildings/facilities/locations of special importance; switching off after curfew outside cities

The application of outdoor lighting for direct use (work, service facilities, events, sports, etc.) is in general not disputable. Deviations can occur in some cases, also because the easily accessible lighting equipment allows for high illumination levels, e.g. for private outdoor use.

Traffic safety assurance is not disputable as well. However, this argument is often misused to prove illumination in situations, where also the lighting profession states that lighting is not needed for this purpose. Even in more exposed locations, the need for illumination and its extent are often disputable and the influence of lighting on vehicle traffic safety is questionable as such [18]. It's similar in assuring personal safety, where the urgency of solving the issue is lower than in the road traffic case and therefore the need for the proper estimation of needs is even more exposed.

Street illumination for the sole purpose of the comfort of movement and orientation (assuring a sense of safety can be classified into the same category) should be recommended only in public areas with a higher concentration of pedestrians and cyclists. This means that for this reason, illumination should be only used (allowed, recommended) in urban centers, on the central streets of non-urban settlements, and in some special situations. The lighting of peripheral streets of rural settlements is not recommended due to negligible needs and very large cumulative negative effects.

External lighting for aesthetic purposes (e.g. façade illumination) is less problematic in urban areas. Outside the urban areas, it should be in general allowed only for illumination of buildings, facilities, locations, etc. of special importance and it should be switched off after curfew. In rural areas, general acceptance of façade illumination is not desired, because such illumination can reach a large scale over years and, in any case, in rural environments, it has a noticeable impact on night landscape appearance.

6.3. Limits of road lighting

One of the key questions is, where are the acceptability limits for road and street lighting. At present, in Slovenia and also in general worldwide, it's acceptable that all roads and streets in settlements are illuminated and it's even not forbidden to illuminate roads and paths outside settlements. According to the CIE lighting zones [13], which are not used in Slovenia, different levels of illumination are foreseen for different zones, but in general, the lighting is acceptable everywhere, where it doesn't have direct negative impacts. The limit, where lighting is not desired anymore, is only in the naturally sensitive areas. This perspective, which has so far mostly not been seriously disputed, seems to be one of the key mistakes in the lighting recommendations and praxis. Instead of accepting the lighting at all locations, where it doesn't have large direct negative impacts (in praxis we are still far also from here), the lighting should only be accepted at locations above a certain level of needs. In this way, protection of the natural state of the night would be enabled everywhere where possible. The arguments that support such limits are 'practical' (direct negative impacts), aesthetical and aesthetically practical (avoiding excessive urbanisation), and ethical (why would we change the natural state of the night for almost zero needs). Today we are mostly at the first level.

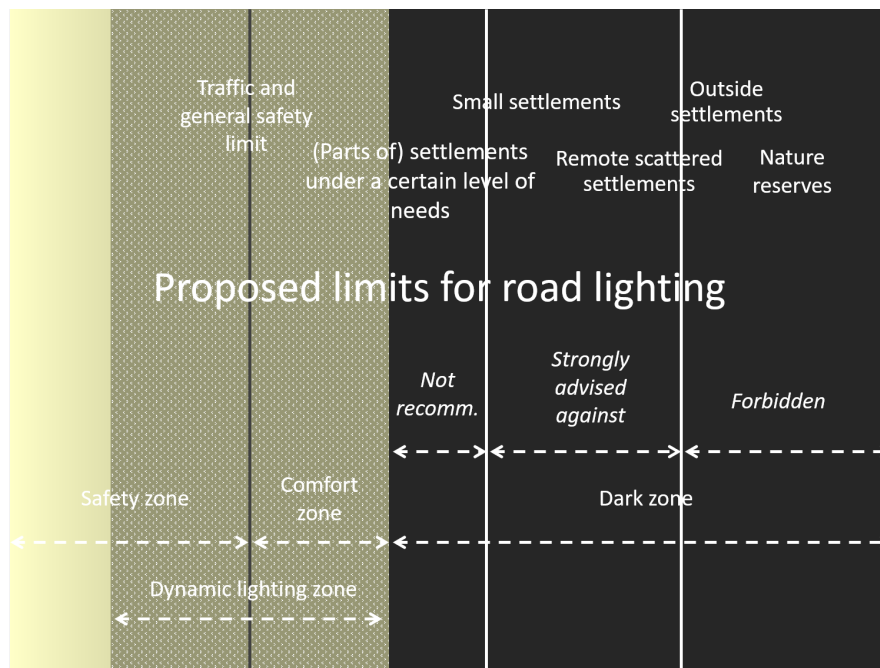


Fig. 4. Proposed limits for road lighting.

According to CIE 115:2010 [13], road lighting contributes to traffic safety only in more congested traffic areas. Below this threshold, lighting is provided “to improve the general amenity, to give passage for pedestrians and to provide a sense of personal security”, hereinafter such locations are referred to as the “comfort zone”.

In general, the traffic safety zone should not be disputable, although different opinions exist even regarding the level of contribution of road lighting to traffic safety. But there should be much more concern regarding the extent of the comfort zone. In different existing recommendations and advanced discussions, the setting of the limit between the comfort zone and the dark zone varies from the borders of nature reserves, borders of settlements, scattered remote settlements, small settlements, up to all parts of non-urban or even urban settlements, where the level of needs is not high enough. For Slovenia, the personal experience shows that the limit could and should be set deep into the non-urban settlements, where only the centers of larger rural settlements, points of concentration, and conflict points should be illuminated. Because at present, expectations of some residents are higher, and also the lighting praxis goes into inevitable illumination of all settled places, this limit should be supported by corresponding theories and recommendations. It can be estimated with a relatively high probability that such limits would be accepted by the vast majority of the population.

A special role in this debate belongs to dynamic lighting, which is a relatively new concept and can bring large advances to the locations, where the use of lighting is proven. While the lighting industry promotes this concept as a solution for a broad range of locations, strict enough limits should be set also if dynamic lighting is used, because it still has impacts when switched on and the lighting equipment still urbanises the space. Dynamic lighting should not be an excuse to install lighting at locations, where no lighting is a more appropriate choice. In this regard it should only be used in the complete comfort zone as defined in the previous paragraph, and in the large part of the traffic safety zone, but not in the to be dark zone.

Probably the best solution regarding the acceptability of road lighting would be to set hard limits (forbidden: outside settlements), medium-hard limits (strongly advised against: small settlements, scattered settlements, scattered parts of settlements), and soft limits (not recommended: settlements and/or parts of settlements under a certain level of needs). The decisions should be made based on the needs and cost/benefit ratio estimations for particular locations and types of locations.

If we look at the problem through the perspective of the road lighting standard EN 13201 and its requirement for illumination uniformity, the following areas might be a solution:

1. ‘Hard’: uniform lighting by a standard; traffic safety zone and high traffic part of the comfort zone
2. ‘Soft’: orientational lighting, uniformity not important, and the present standard not acceptable; all other parts of the comfort zone

3. No lighting; all zones below a certain threshold - dark zone

6.4. Spatial planning perspective

The introduction of a comprehensive spatial planning perspective into the matter is of crucial importance both from the large-scale perspective of policies definition as well as from the perspective of recommendations for particular types of locations. For this reason, the topic is explicitly exposed as a separate point in this chapter, but as it is touched at several points in this document, the content is only briefly summarised here.

The importance of this aspect is the most evident if we go beyond the sole light pollution sub-problem, which we should do if we want to solve the problem comprehensively. At the top level, a national lighting plan should be defined, especially for the road and street lighting, but also for other outdoor light sources, such as e.g. decorative lighting of facades. This plan should consider the practical, aesthetical, and ethical limits of lighting, discussed also in other points of this chapter and in the document in general. In the Slovenian case, these topics are partly included in the Decree on limiting values of light pollution, but as this is an environmental protection document, founded on the Nature Conservation Act, the content, which goes beyond the control of the direct negative impacts, can't be considered.

In some border cases, it's almost impossible to reject profoundly enough the inappropriate lighting projects without the landscape preservation arguments and, from the opposite perspective, these arguments can make a significant contribution to preventing inappropriate projects. For example, kilometers of low-intensity sensor switched road lights through open fields might have no significant negative environmental impacts, but they are not acceptable from the landscape preservation point of view.

6.5. Cumulative limits

Setting cumulative limits is one of the key mechanisms for the control of light pollution. The Slovenian decree on light pollution (contrary to some other countries, e.g. Croatia, where such limits are not accepted) prescribes the maximal annual consumption of 44,5 kWh/capita. This limit had a noticeable effect on the motivation for the lighting infrastructure improvements and the municipalities are trying to follow it. However, the improvements were mostly in a sense of replacement of obsolete classical luminaires with more energy-efficient LED ones and there were practically no cases where road lighting was removed or profoundly adapted to the location requirements.

The advent of more energy-efficient LED lighting has led to a failure of the prescribed consumption limit and much more luminance can be installed per capita than planned with the decree. One of the options to solve the situation is to decrease the limit, where estimations for annual consumption are in a range of 6-8 kWh/capita. To avoid dependence on applied technology, a lumen/capita limit is discussed instead, but concerns exist that control of this parameter is harder to reach than the control of energy consumption.

Recently, more complex approaches for setting red-lines and target values with top-down approach were proposed by Bará et al. [19] and this concept is being accepted as one of the key mechanisms in international discussions.

In any case, the cumulative limits operate only with quantitative aspects and therefore this approach must be combined with qualitative approaches in the frames of comprehensive spatial planning and in the frames of the concrete lighting recommendations.

7. Needed corrections in legislation and recommendations

Despite the achieved level of light pollution control, further improvements are needed at all levels of legislation and recommendations. The following actions are ongoing or are planned in Slovenia in order to cope with the problem:

- Revise Decree on limiting values of light pollution
- Revise Slovenian Lighting Society recommendations
- Write national specific 1st part of standard EN 13201
- Enforce already existing changes in Rules on road design
- Define spatial planning legislation, starting with national spatial strategy, and spatial planning-oriented recommendations

- Revise Green public procurement decree
- Revise and extend municipal lighting plans
- Educate professionals and the general public

The international lighting and light pollution knowledge provides the basic framework for all the mentioned efforts. Not only with positive and not always with effective enough contributions but therefore also at the theoretical level domestic proposals are of high importance. However, the later can have correct and sufficient effects only in very favorable circumstances, therefore improvements of international recommendations (standard EN 13201, limits of lighting, etc.) are urgently needed as well.

8. Conclusion

The Slovenian example shows that significant progress can be made with measures to limit light pollution. However, the achievements can quickly be nullified, if the spread of lighting to new locations is not effectively limited and if the lighting is too extensive and intense.

The reckless spread of lighting can partly be prevented by setting appropriate quantitative cumulative limits of light pollution, but it's evident that for a complete solution to the problem also qualitative spatial planning approaches are needed, where besides the preservation of the environment, also appearance, experience and preservation of space will be considered.

An ethical shift needs to be made in attitude to the lighting. The artificial light should be seen as a pollutant that should only be used in case of indisputable needs. This position should be reflected in the creation of policies, where under a certain threshold, set relatively high, lighting will not be acceptable.

The corresponding measures have to be defined in both the environmental and spatial planning legislation. In addition, the very concrete technical starting points need to be revised in order to substantially lower the extent and intensity of illumination at particular types of locations, especially where the needs for lighting are low. These starting points mainly derive from internationally agreed lighting standards and recommendations, therefore it's very important that these documents are made unquestionably environmentally and spatially acceptable and that at the local level common-sense decisions are not suppressed completely by making such recommendations obligatory.

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Abbreviations

ALAN	Artificial Light at Night
CIE	Comission Internationale de l'Eclairage, International Commission on Illumination
EN 13201 1-5	A set of Standards for Road Lighting
LED	Light Emitting Diode
ULOR	Upward Light Output Ratio