

Light Design Project of Dubrovnik Ancient City Core

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ABSTRACT

Dubrovnik Old city, "the Pearl of the Adriatic", has preserved its beautiful Gothic, Renaissance and Baroque churches, monasteries, palaces and fountains, as well as the city walls that encircle the Old city, giving its characteristic appearance. This precious cultural heritage, inscribed on the UNESCO World Heritage List from 1979., is the subject of the complex light design project. It implements the newest lighting technology in order to achieve the best lighting effects, as well as energy efficient solutions by which the energy consumption is reduced by 40% (comparing to the old one). The 1st phase of the project (lighting of the city walls) was finalized in 2009., followed by 2nd phase: architectural and public lighting inside the Old City.

DUBROVNIK OLD CITY

Dubrovnik Old City, also popular by name "the Pearl of the Adriatic", is situated in south of Croatia on the Adriatic Sea coast, and was an important Mediterranean sea power from the 13th century onwards. The most recognizable feature which gives its characteristic appearance are intact city walls 1940 meters long, encircling the city. This complex structure, one of the most beautiful and strongest fort system in the Mediterranean, consists of a series of forts, bastions, casemates, towers and detached forts.



Figure 1. Dubrovnik Old City by day

Within this magnificent walls stands beautiful Gothic, Renaissance and Baroque churches, monasteries, palaces and fountains, all well preserved. This richness has been inscribed on the UNESCO World Heritage List in 1979.

Unfortunately, old lighting situation made Dubrovnik Old City unrecognizable and invisible during the night.



Figure 2. Dubrovnik Old City by night, old lighting situation



Figure 3. Dubrovnik inside the Old City, old lighting situation

Therefore, the City authorities make a decision to order a Lighting master plan, following by implementation lighting design documentation, that will incorporate latest technology and therefore will consume less energy and require lower costs of maintenance, comparing to old lighting solution.

LIGHT DESIGN PROJECT OF DUBROVNIK OLD TOWN

Lighting master plan of Dubrovnik Old City was done by LiDAC, Philips, defining the main guidelines for the new lighting concept. The main idea was to create a "necklace" of lit city walls and fortresses around Old city of Dubrovnik, with a "pearls" inside the necklace, represented by lit objects within the City walls.



Figure 4. Simulation of future lighting of Dubrovnik Old City

Lighting master plan was followed by complex light design implementation project, made by Croatian company Nova-lux, which incorporate light design and implementation documentation for every part of the walls, as well as all squares, streets and objects within it and around it. All steps were performed in close cooperation with the City authorities, Conservation Department in Dubrovnik, Association of Friends of Dubrovnik Antiquities and other relevant subjects.

Lighting project of Dubrovnik Old City is currently one of the most complex and most technically demanding projects of architectural lighting in Europe. It includes about 600 light fixtures for the lighting of the ancient city walls, 500 new designed luminaires (based on the appearance of old lanterns „feral“) for the lighting of the main squares and streets, 120 luminaires for the public lighting of surrounding streets, parking areas and green areas, 1000 light fixtures for architectural lighting of historical buildings within the Old City core (29 objects), as well as more than 8000 LEDs for lighting of walking path above city walls 2 km long. All lighting fixtures are manageable from the city authority office by computer software.

The 1st phase of the project, lighting of the city walls (without the part of the sea side) as well as squares, streets and parking areas around old city, was realized in 2009. year. Lighting idea was to enhance the continuity of the walls by continuing illumination, in order to emphasize its magnificence, by accenting main fortresses and entrances to

the City. Still, surrounding parks remain in the dark, to enable people to enjoy in its dignity and breathtaking view. It gives new appearance quality of the Old City.



Figure 5. Photo after realization of the 1st phase of lighting project of Dubrovnik Old City

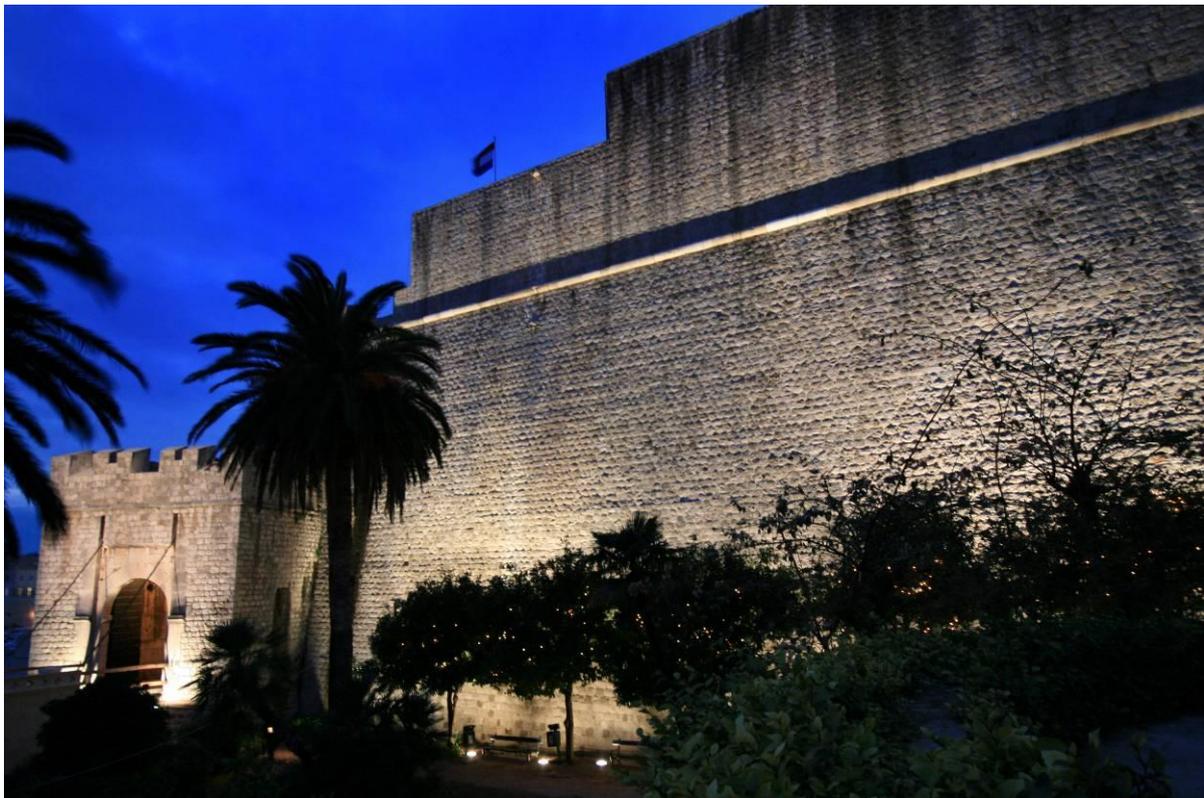


Figure 6. Photo after realization, the main entrance "Ploče" to the Old City

The first phase is continued by realisation of the 2nd phase (lighting the inside of the Old City) and the 3rd phase (lighting of sea-side of the walls and walking path above the city walls), all planned to be finished in 2012.

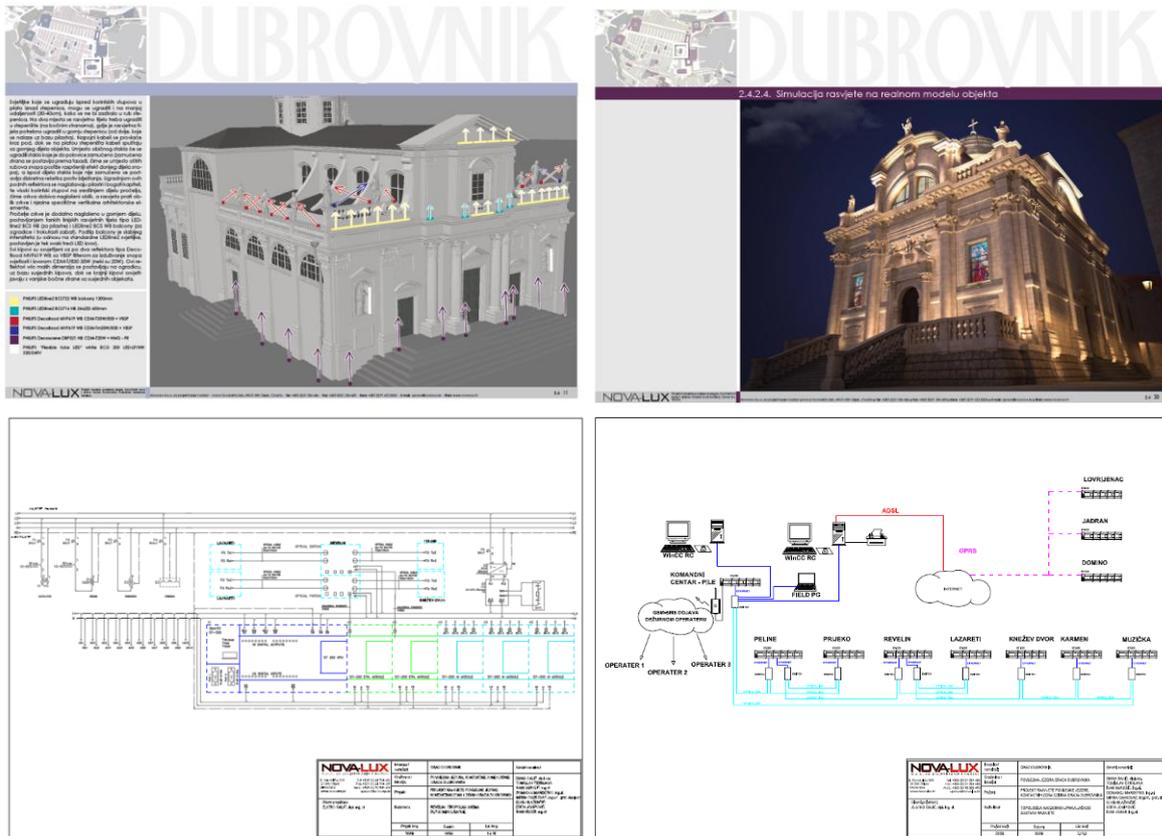


Figure 7. Project layout

ENERGY EFFICIENCY ASPECT OF THE PROJECT

During the project development, energy efficiency was of great concern. Even in the phase of creating a light design concept, methods of saving of energy and reducing of costs of maintenance, was defined.

Only latest lighting technology was used, including very efficient light sources (metal-halide light sources of small power are used, as well as LEDs). For most precise light aiming and reducing maintenance costs, light sources are situated within luminaires with high level of protection from dust and moisture and material quality, resulting in high efficient luminaires with good controlling of light beam. By directing light where it is really needed, energy is saved and the light pollution is minimized. Luminaires are positioned on the least visible locations, to provide comfort without glare, therefore it was necessary to combine different optics, louvers, shields and modalities of fixing.

Control management was another big issue, taking into account that creating different lighting scenes can contribute to energy savings without disturbing lighting quality. Namely, it is prescribed that all architectural and decorative lighting will be turn off at 23h, by scad telemanagement system manageable directly from the municipal office.

By finalizing the project, although the number of lighting fixtures will be increased within new lighting solution, energy consumption will be significantly decreased by using high efficiency light sources and precise aiming of light beams, as well as by light telemanagement.

Energy efficiency in new lighting of the City walls

Old lighting solution of the City walls with forts, bastions, casemates and towers was done by metal-halide sources of old generation of power of 250W (mainly), situated in old lighting fixtures of big dimensions. It required a total installed power of 55 kWh.



Figure 8. Old lighting situation on city walls

New lighting solution is designed and calculated to be maximum efficient: to save more than 30% of an energy comparing to the old lighting solution, but offering better lighting quality and comfort.



Figure 9. Light simulation based on real dimensions and realistic photometry

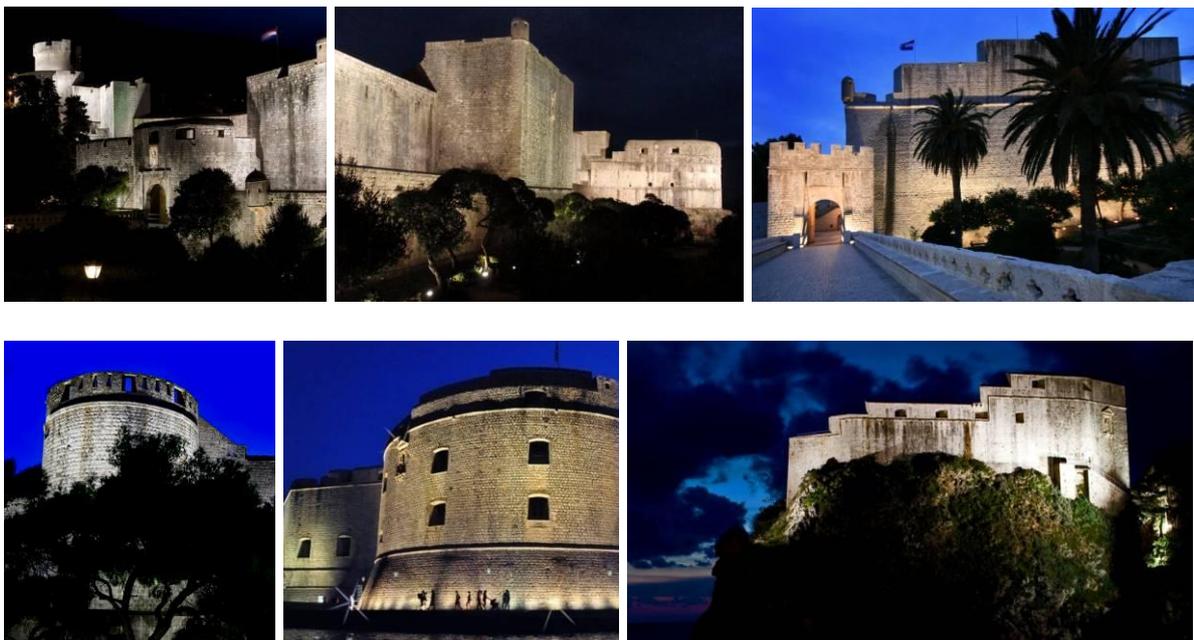


Figure 10. Realization of lighting of Dubrovnik City walls

The lighting management is managed from the municipality office, on descriptive way and quickly, and in addition to the time programming, it allows energy consumption analysis, creating a plan of maintenance etc.

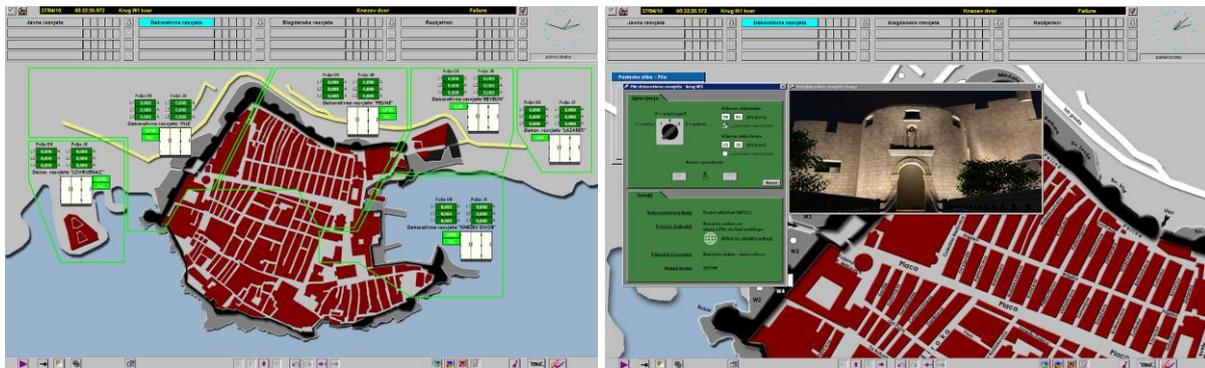


Figure 11. Light management software in municipality office

Table 1. Comparison between old and new lighting solution of City walls, savings

Rasvjeta zidina tvrđava i kula sa regulacijom	Broj rasvjetnih tijela	Ukupna snaga u kW	Cijena (kn/kWh) bez PDV-a	Broj sati rada godišnje	Ukupno godišnje kWh	Ukupna godišnja cijena utrošene el. energije (sa PDV-om)
<i>Staro stanje</i>	217	55	0,71	4.200	231.000	201.732,30
<i>Novoplanirano stanje</i>	603	71	0,71	2.000	142.000	124.008,60
Ukupna ušteda nakon zamjene rasvjetnih tijela:						77.724 kn

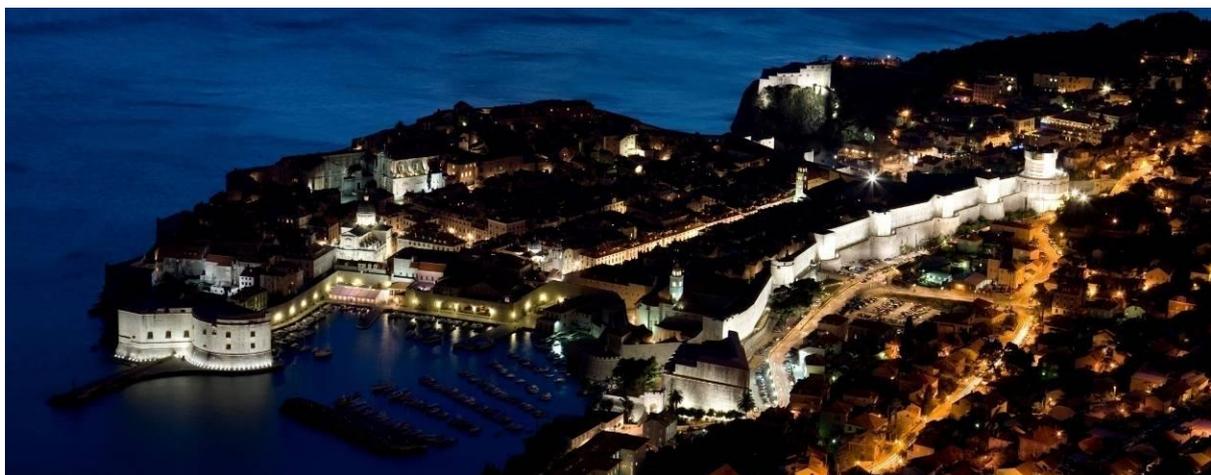


Figure 12. The visual result of completed lighting of Old city walls (except sea side)

Energy efficiency of surrounding area (streets, parks and parking areas)

Old lighting solution of surrounding area was done by inefficient light fixtures that mostly used 250W high pressure Mercury or high pressure Sodium light sources. All light fixtures was equipped with no adequate optics, resulting in glare, light dissipation and

light pollution. At the same time, it obstructed the possibility of enjoying in sightseeing of the Old city.



Figure 13. Old lighting situation in surrounding area (around Old City)

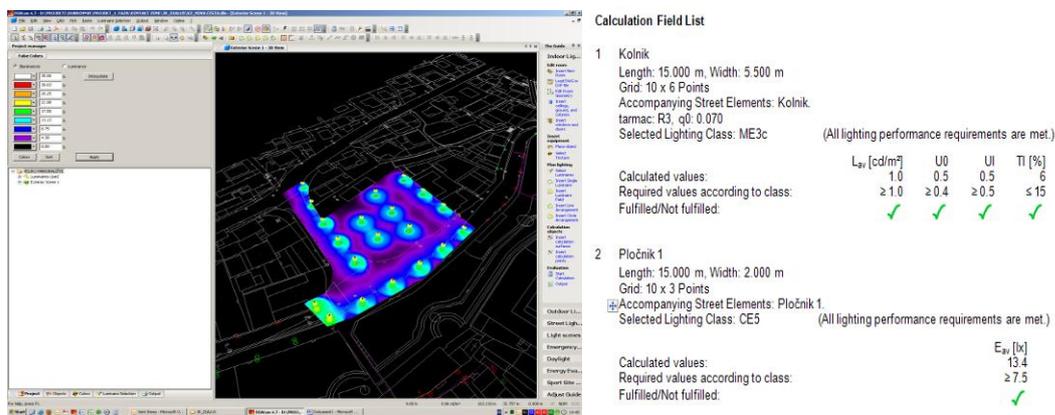


Figure 14. Project layout (light level calculations)



Figure 15. The visual result of implemented lighting around the Old city

Table 2. Comparison between old and new lighting solution around Old City, savings

Javna rasvjeta kontaktne zone	Ukupna snaga u kW	Cijena (kn/kWh) bez PDV-a	Broj sati rada godišnje	Ukupno godišnje kWh	Ukupna godišnja cijena utrošene el. energije (sa PDV-om)
<i>Staro stanje</i>	22,25	0,71	4.200	93.450	81.609,89
<i>Novoplanirano stanje</i>	9,44	0,71	4.200	39.648	34.624,60
Ukupna ušteda nakon zamjene rasvjetnih tijela:					46.985 kn

Energy efficiency in new lighting of the main street Stradun

Old lighting solution of the main street Stradun was resolved by 29 pieces of lanterns with incandescent lamps of 300W, with additional halogen spotlights for decorative facade lighting of 1000W (29 pcs.), which requires a total installed power of 37.7 kWh. By Conservator's request, the shape of old traditional lantern "Feral" luminaires had to be retained, and the number of luminaires and cables had to be reduced.



Figure 16. Old lighting fixture and light effect on the main street Stradun

This requests results in developing new, dual optics, incorporated within new (reconstructed) luminaires to achieve better light effect, as well as to have better appearance during the day. Finally, the number of luminaires is reduced by 50% owing to combining two separate optics in one luminaires, both independently manageable, for both functional and decorative old lighting. Energy consumption is reduced by 600%, maintenance costs is reduced owing to extended lifetime of lamps by 900%, and installed power is 6 times less than before (29 pcs. of 70W metal-halide light sources for functional lighting of walking path, with incorporated additional optics for decorative lighting of facades of power 140W, requires a total installed power of 6.1 kWh).



Figure 17. New lighting fixture and light effect on the main street Stradun

Table 3. Comparison between old and new lighting solution of Stradun

Funkcionalna i dekorativna rasvjeta Straduna (bez regulacije)	Broj rasvjetnih tijela	Ukupna snaga u kW	Cijena (kn/kWh) bez PDV-a	Broj sati rada godišnje	Ukupno godišnje kWh	Ukupna godišnja cijena utrošene el. energije (sa PDV-om)
<i>Staro stanje</i>	58	37,7	0,71	4.200	158.340	112.421,40
<i>Novoplanirano stanje</i>	58	6,1	0,71	4.200	25.620	18.190,20
Ukupna ušteda nakon zamjene rasvjetnih tijela:						94.231,20 kn

Energy efficiency results of a project as a whole

Predicted savings in electricity consumption for the lighting of this project is 464,520 kWh, or 39.7% compared to the old solution (without walking path above the City walls). Converted into domestic currency, the City of Dubrovnik will save 359,956.55 kn (49.000 EUR) each year only on power consumption for the lighting of the Old Town.

Table 4. Comparison between old and new lighting of a project (without walking path)

Javna i dekorativna rasvjeta (sveukupno za projekt)	Broj rasvjetnih tijela	Ukupna potrošnja el. energije u kWh	Cijena (kn/kWh) bez PDV-a	Broj sati rada godišnje	Ukupno godišnje kWh	Ukupna godišnja cijena utrošene el. energije (sa PDV-om)
<i>Staro stanje</i>	873	278,7	0,71	4.200	1.170.540	1.022.232,58
<i>Novoplanirano stanje</i>	2.500	168,1	0,71	4.200	706.020	616.567,27
Ukupna ušteda nakon zamjene rasvjetnih tijela:	<i>(razlika između novoplaniranog i starog rješenja):</i>				464.520 kWh	405.665 kn

After completing the lighting on the walking path, the planned savings will be slightly reduced, but it will contribute to extending of touristic offer and will increase the income from tickets selling (for sightseeing of the city, since this walking path will be open in evening and night hours after implementing the lighting incorporated in new handrail).

Table 5. Comparison between old and new lighting of a whole project (savings)

Javna i dekorativna rasvjeta (uključujući šetnicu na zidinama)	Broj rasvjetnih tijela	Ukupna potrošnja el. energije u kWh	Cijena (kn/kWh) bez PDV-a	Broj sati rada godišnje	Ukupno godišnje kWh	Ukupna godišnja cijena utrošene el. energije (sa PDV-om)
<i>Staro stanje</i>	873	278,7	0,71	4.200	1.170.540	1.022.232,58
<i>Novoplanirano stanje</i>	10.520	184,1	0,71	4.200	773.220	675.253,03
Ukupna ušteda nakon zamjene rasvjetnih tijela:	<i>(razlika između novoplaniranog i starog rješenja):</i>				397.320 kWh	346.980 kn

In addition to this energy saving results, costs for maintenance will be significantly decreased, therefore will additionally contribute to energy efficiency of the whole project.

Dubrovnik is one of the first cities in Croatia that succeed to make good planning in urban lighting, beginning from making a Lighting master plan, and followed by Lighting implementation project. This investment will pay off in just a few years, but the quality and advantages of new and improved lighting system will remain much longer.

REFERENCES

1. Official data from Dubrovnik municipality
2. Lighting master plan, LiDAC
3. Lighting implementation project of Dubrovnik Old city, Nova-lux