

Contemporary lighting solutions in the historic urban landscape: Project-oriented approach

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Abstract—Integration of sustainable project management into small business practices is seldom examined in architectural lighting design. One of the major elements of the sustainability of urban ambience entities and preservation of social, architectural and urban values is lighting phenomenon. Its significance is reflected in the aesthetic, as well as the functional qualities of safety and amenity for users. Usually, keeping the traditional types of luminaries (i.e. lanterns) in order to preserve ambience values lies in contradiction with the contemporary requirements, mostly because of the obsolete structural support which normally yields the application of the obsolete lighting technology. On the other hand, the introduction of contemporary luminaries in the urban areas of cultural and historical significance is often undesirable. Thus, the issue of sustainability of the historical urban ambience entities in the context of the application of the contemporary lighting technical solutions is presented in this paper from the point of view of a project-oriented small organization, which holds in core business the philosophy of the confirmation of the existing lighting fittings to the users' space. This paper proposes and confirms business model which assures preservation of architectural ambient, with added value of the energy efficiency, functionality, life cycle savings, safety and amenity for the users, through the case study of Park vojvode Bojovica in Belgrade, Serbia by experimental collecting of model inputs, whereas the obtained results are verified by means of numeric simulation. Results of this case study make contributions to the domain of management of sustainable projects in area of architectural lighting design while exploring broader social context.

Keywords— *lighting design, urban environment, open public space, architectural values, ambience, safety, economic evaluation, project management.*

I. INTRODUCTION

Relationship between sustainable development and project management has not been yet thoroughly researched [1]. However, recently, the sustainability concept is more connected to project management [2]. In that sense, contemporary challenges lay in small and medium organizations. These projects are critical

to the survival of these organisations, such as the development of new products to adapt to the market or new legislation, management system implementations, etc. [3].

Management of sustainable projects as a business-driven concept of sustainability with a focus on increasing both social and business value, also known as the Shared Value [4,5], has attracted wide interest in recent years [6,7,8]. The literature on this topic is however scarce, especially in the developing countries [9] while the largest part of the published works are more prescriptive than descriptive [10] in nature, as most of the contributions have remained at conceptual level [11].

The social sustainability of urban renewal projects through social entrepreneurship has gained certain popularity in the latest period [12,13,14], but not enough attention has been paid to the social aspects of sustainability, which can be best noted in the preservation of the identity of the open public spaces and the energy efficiency, as well as the users' safety. Certainly, there is a need to establish the business model which would achieve a new added value through the innovative SME. This would be accomplished by performing the business venture with the project-oriented approach, in purpose of design and production of the luminaire for the space that retains specific characteristics which need to be taken into account in a socially sustainable way.

In this study, the primary aim is to contribute to the management of sustainable projects and opportunity identification theory, by offering a set of guidelines to lighting design in the open public spaces of a city with the particular identity that should be preserved enduringly through establishing a desirable ambience and accentuation of the architectural spatial values. The main research issue in this study is aimed to provide an answer to the question of how innovative SMEs should apply specific business models in highly demanding projects.

In that manner, this case study would result in recommendations for all the companies in similar

business and social context on the way to operate to fulfil sustainability criteria along with the business goals.

This study is conducted in Serbia, which is a developing country because in this particular context the sustainability concerns are evident but still without much hard public and institutional pressure to behave in a sustainable manner. Accordingly, the sustainability issues are addressed by the entrepreneurs to the extent mainly dependent on their discretion and goodwill. Therefore, in this study the focus will be on the management of sustainable projects issues in social domain.

The social aspect of sustainability, which is in the core of this research, is applied to the preservation of the identity of the public open space. By means of the energy efficiency improvements, as well as the promotion of the ambience values in space, and the safety and amenity of the users, a business model will be proposed. The resulting business model enables an enterprise to achieve a new added value by performing its business venture with the project-oriented approach in the field of the open public spaces lighting in the complex urban context framework.

The progress of the presentation in the paper is conceived in several steps. The first task would be to formulate the research problem. Secondly, there will be some considerations in the previous researches. Thirdly, the research context will be proposed. Fourthly, the research methodology will be explained, and the empirical tests presented and discussed. In the end, the conclusions will be reached, and the prospective future research areas pointed out.

A. Previous research

As already noticed, the environmental and social dimensions of management of sustainable projects in previous studies [9,10,11,12], have not been researched enough, especially when it comes to the field of public lighting [15], although it is known that the aim of lighting in an open public space is to enable an agreeable ambience and the desired visual experience; to offer safeness, security, but also to emphasize the aesthetic values of the space.

The quality of visual information is of great significance for the users' experience of space. Open public spaces for pedestrians are characterized by an intimate relationship between users and their environment, which allows for a more articulated process of interpretation and memory of the space. Keeping in mind the speed of movement, the user has the opportunity to note the specific characteristics of the space from a close distance. Regarding the fact that the cities represent the symbols of complex social relationships, according to Lynch, an image of a place contains three components: identity, structure, and meaning [16]. Each user forms his own image of the city in relation to his or her experiences and perceptions. However, each city is specific so that it has an impact on the formation of images in the memory of users, and in order to preserve the spirit of

the city, emphasis should be put on the quality of understanding of the visual information. Lighting can enable the desired presentation of the characteristics of the space and the creation of an adequate image of the place.

Technological innovations, as well as cultural changes, have shaped the development of cities, which is reflected as a change to the physical structure, as well as on the public life that takes place in the context of public open space. Permanent social changes affect users by shaping their wishes and needs, which also reflects on the ambience values of space. Preservation of architectural and ambience values of space in the night time is conditioned by the quality of lighting and the possibilities of its improvement in accordance with the changes. Often, modern design lights do not fit the traditional values of the existing environment. Thus the solution to the problem can be found in the design of a new solution that is in line with the advancement of technology, or to apply modern lighting technical solution (retrofit) in the context of the existent luminaire. In accordance, and taking into account the required lighting technical features, energy efficiency, maintenance cost, as well as the criteria of architectural and environmental value of the area, the aim of this paper will be to set up an organisational model from the perspective of technology-driven companies that through an innovative way, approach solving the problem of lighting space with strong spatial identity.

It is also important to point out that the current practice of lighting design is based on the recommendations and standards that place focus of the design process on achieving visibility with the intention of creating a safe space in which users feel secure, while the architectural values of space, as well as the achievement of the desired environment and atmosphere, are completely ignored. Consequently, it is necessary to establish an organisational model that will include the possibilities of improving the process of illumination of open public spaces from the aspect of emphasizing the ambience and architectural values while preserving the safety of the users and from the perspective of the entrepreneurial sustainability-focused small technology-driven company. Such small companies with scarce resources could play a key role in the innovation field and at the same time perform a high level of growth rates [17,18,19].

II. MATERIALS

The setting of the organisational model, which would support the innovative approach in design and planning of the luminaires for the areas with accentuated architectural and ambience values which need to be preserved by means of lighting, is carried out through the case study of the Park vojvode Bojovica, in Vracar – the old town's district of Belgrade.

Given task should be executed by small Serbian technology-driven company focused on outdoor lighting infrastructure that achieves good business

performance and employs well-educated and trained workforce (3 of 15 employees possess a PhD degree [20] and as authors of this paper have been engaged as consultants on this issue). Unpleasant contemporary market conditions and public support force smaller firms to reinvent their business through new technologies and innovations that are easily linkable with their organic management advantages compared to larger firms [21]. Companies of this type are usually focused on entrepreneurship and grow financially through balancing business growth, innovation and risk [22]. It is expected that small Serbian technology-driven company as entrepreneurial one is focused on sustainability and also is looking to and achieves other goals alongside financial ones, as proposed by Rodgers [20].

The cultural and historical space entity of Vracar is known for its significance for the identity of Belgrade. This exceptional city ambience consists of a cluster of interrelated material, and spiritual values represent the cultural heritage of the city of Belgrade.

Park vojvode Bojovica is a noticeable zone with the great importance for the Vracar district's image and hence creates a landmark within the urban structure. The Park position in urban fabric contributes to the creation of a very active open public space – zone which forms the access plateau of Kalenic Market. In addition to its main role, as a place for relaxation and gathering, Park represents a place that hosts small holiday festivals, as well as fairs of handmade products. The monument of Duke Bojovic is located within the space as the most dominant object, which additionally emphasizes memorial values.

In regard to its importance, this space is inadequately lighted. The problem of the existing lighting of this area can be noticed by the obsolete methods of lighting design, as well as the tendency to use the existing systems and the particular form and shape of the luminaire which is adopted for this space. The shaping features of the existing lanterns are in accordance with the traditional spatial values and hence attribute to the identity conservation. However, in terms of the technical characteristics these luminaires are not in with correspondence with technology advancements and the possibilities to achieve better efficiency.

Open public pedestrian spaces are places in which the public life of a city is performed. This form of traffic implies the following: slower motion, retention, gathering and stopping, communication and interaction of the users with the surrounding and among themselves. With all this in mind, lighting should satisfy the users' needs relating to the: feeling of safeness and security; ability to recognize faces and objects; ability to perform planned activities within the space; accomplishment of the pleasant feeling and agreeable atmosphere; ability to orientate in space; possibility to experience the aesthetic and ambience values of the space. With the objective to clearly define parameters relevant for the lighting in the open public space framework, it is necessary to take in

consideration the current standards and recommendations for the lighting design in the complex urban realm of the city. This research is performed following the recommendations for the lighting design in the open public spaces according to the IESNA (Illuminating Engineering Society of North America) [23], CIE (International Commission of Illumination) [24] and CEN (European Committee for Standardization) [25].

Standards and recommendations for the lighting design in the open public spaces, in which the principal users are pedestrians, proclaim requirements which put fulfilment of the functional lighting features in top priority – to achieve the adequate visibility according to the users' needs, as well as meeting all the safeness and security requirements in the open public space. These requirements are achieved by reaching the adequate level of illumination according to the space function and the pedestrian traffic frequency in the night time. Three categories in this respect are notable: very active (commercial zone), moderately active (intermediate zone) and little active space (residential zone) [23]. The surroundings influence, i.e. lighting from the neighbouring areas to the public space under consideration, is reduced to three categories describing the luminosity of the surroundings – high, moderate and low [24]; or depending on the urban character – rural, urban and city central category [25].

III. METHODS

The need to define the basic criteria which would articulate the process derives from the outset of the creation of the organizational model for design and production of the luminaires which are aimed to support and help preserve the identity of the space. These criteria originate from the analysis of the spatial characteristics which set requirements for the lighting design process. The visual information quality is of great importance for the users' perception of space, and lighting can enable a desirable presentation of spatial characteristics, as well as an adequate locus image. One should bear in mind that inadequate lighting can bring about the so-called fake night locus vision; given that lighting has capability to create efficient virtual objects that don't exist during daylight.

The criteria to set variables at the creation of the organizational model are:

CRITERION 1 - The importance of the space for the town's identity preservation

This criterion is related to the formulation of the space value, which would help establish the image of the city. Also, it would provide an answer to the primary question that classifies a space to the category of the cultural and historical heritage, or the category of the second-grade spaces. For this purpose, it is necessary to preserve the representation of the spatial architectural elements in the night period.

CRITERION 2 - Ambiance values of the space

The transformation of the lifestyle through history is characterised by the new emerging users' needs which generate new activities and new functions that can take place in the existing setup, provided that the ambience values are sustained. Along with the identification of the new emerging needs it is vital to answer the question whether the considered space bears the specific ambience values of enduring quality, or whether there is a need to emphasise the change.

CRITERION 3 - The existing lighting characteristics

In the process of lighting improvement in the space, it is necessary to ascertain if the existing lighting system provides sufficient quality in terms of luminaires positioning and appropriate light distribution which don't affect planned activities in the space. Furthermore, the features of the luminaires must be noted, as well as the possibilities to improve technical solutions for the existing fittings.

The next step in the creation of the organizational model would be to identify the phases which determine the development stream of the process of design and production of the luminaires for the spaces with highly stressed identity (Figure 1).

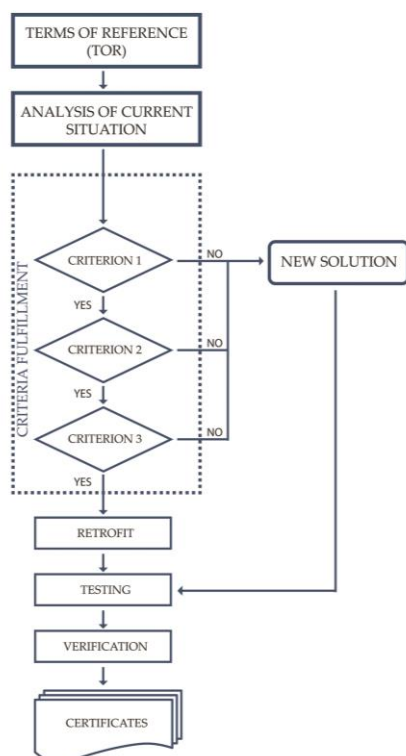


Fig. 1. Business model algorithm

A. Creation of the design brief

The design brief is created in accordance with the existing location characteristics. It sets parameters for establishing the lighting solution. The parameters which affect the decision on the lighting solution are: spatial specifics - physical and functional structure, ambience values, major positions which need to be

accentuated; luminaires disposition; the features of the selected luminaires; applicable standards and recommendations for the lighting design in public open spaces; users' requirements for performing certain activities, as well as the safety in space.

B. Establishment of the lighting technical solution

After the design brief is created, it is needed to come to a lighting technical solution. The analysis of the applied luminaires in space provides an insight into the possible courses of the solution development. There are two basic options in relation to the design brief – (a) to conceive a new luminaire solution for the specific space, or (b) to retrofit, namely to create a new lighting technical solution within the existing luminaire fitting, which is the more demanding and complex path to develop the model.

(a) If the decision is to design the new luminaire which in shape relates to the ambience space values, the product is developed in accordance to the formal and technical requirements which are set by the emerging needs, but also by following relevant standards for the lighting design in public open spaces.

(b) When retrofit option is selected, it is necessary to determine the limitations of the existing luminaire in terms of shape, but also in terms of other features, to find the solution according to the following properties: characteristics of the space; mechanical requirements (IP); maintaining conditions; optical system solution which is suitable for the existing structure – to provide appropriate cooling, distribution of light and the users' amenity level by installation of an adequate protector.

C. Product testing

The product testing is carried out in specialized laboratories for goniophotometer and mechanical examination.

D. Solution control against the spatial requirements

The functionality of the proposed and tested lighting technical solution should be put to trial by means of the simulation of the lighting of the location. The results are used in the photometric calculation, according to the current recommendations and guidelines for the lighting design.

E. Product certification

To apply the lighting technical solution in a public open space, it is necessary to acquire the certificate of the accredited institutions. The certification is conducted under the standards IEC/EN 60598-1 (IEC/EN 60529), IEC/EN 60598-2-3, EC/EN 62262 [26,27,28].

The examination of the proposed organizational model is carried out through the experimental research in laboratory conditions, as well as by simulation. All technical features were analysed on the selected segment of the open public place which has distinctive ambience value for the identity of the city of Belgrade.

After the analysis of the existing lighting on the location, as well as the particular architectural and ambience values, a proposition for the new technical solution is reached, which would provide improvements corresponding the technology advancements. The adopted lighting technical solution is then put on test in the laboratory conditions. The results obtained by the laboratory examination of the luminaire, along with the results obtained in real-life conditions examination, are applied to create the photometric calculation, following the provisions of the current recommendations and standards.

IV. RESULTS

The results of the experimental research (a case study of Park vojvode Bojovica) are presented by key phases of the proposed organizational model.

A. *Creation of the Design Brief*

In order to acquire appropriate effects in space by lighting, it is of great importance to note and record the existing conditions as well as the parameters which will influence the lighting design. These parameters are existing luminaires disposition, existing luminaires analyses, applied light source analyses, lighting pollution analyses, users' safety, as well as the ambience and architectural spatial values. It is essential to provide a reference to the current standards and recommendations for lighting design, taking in consideration that the regulations are based on the criteria which aim for the uninterrupted flow of activities and the achievement of safe surroundings for users.

1) *Luminaires Disposition on Location*

Users' paths are emphasized by the positions of the luminaires. The longitudinal axis of the park is defined by a double-sided system of the luminaires, with the interval distance between them at 15 m in one row.

2) *Installed luminaire*

The luminaire is placed on the column 3.8 m high, with the focal point at 4.0 heights. The column consists of the aluminium alloy casting basis and steel tube set. The console is made of steel profiles. The luminaire case is made extruded aluminium, while the protector is made of milky white tempered glass which also serves as diffuser. By its shape, the luminaire is half-shaded. The luminaire and the column by its shape conform to the ambience and attribute to the accentuation of the architectural spatial qualities.

3) *Light Source*

The light source is metal-halide, with the nominal power of 100 W, and the warm white temperature of approximately 3000 K. The additional effects of the coloured light can appear depending on the lighting within the contents of the space boundary.

4) *Current Recommendations and Standards for Lighting Design*

According to the chosen guidelines for the pedestrian areas design, Park vojvode Bojovica is classified as the intermediate zone, by the *IESNA*

handbook [23]. Public space area under consideration is characterised by the very low motion speed, high traffic density for pedestrian-only, absence of the parked vehicles, with the moderate surrounding luminosity due to the service functions in the vicinity, which qualifies it for the lighting technical class P5 under *CIE 115-2010* standards [24]. As proclaimed by the recommendation of the *EN 13201* standard [25], this zone falls into the lighting technical class E1, and into class S4 according to the parameters related to the pedestrian frequency, risk of criminal activity, and the distinctive surroundings luminosity for a town centre zone. According to the above standards, the recommended values of the horizontal illuminance for the Park are: minimal 0.6 lx [24] and 1 lx [25]; average 6 lx [23]; 3 lx [24] and 5 lx [25].

5) *Lighting Pollution - Direct and Reflected Glare*

Having in mind that the luminaire is half-shaded, with the protector serving also as diffuser, direct glare is reduced to a minimum. The street pavement has very low level of reflection (0.20) which prevents reflected glare.

6) *Users' Safety*

In the analysed open public space and on its bordering zones it is made possible to recognize faces and elements in space, due to the adequate luminance level, as well as the luminance uniformity which enables the users' eyes to adapt. This makes the space perceived as safe for users.

7) *Ambiance and Architectural Values on Location*

The selection of light source and colour stimulates the impression of an atmosphere in which the priority is lean on the aesthetics of the traditional ambience values. The monument of Duke Bojovic is located within the space as the most dominant object. The monument is additionally accented by focused light, which emphasizes the importance of this element.

After the analysis of the spatial characteristics and the existing lighting is carried out, and the requirements regarding the particularities are formulated, a design brief to determine the further process of lighting solution development can be adopted. The key project goals were therefore set:

- preservation of the locus identity, with full respect for the ambience and architectural values on location;
- fulfilment of the conditions set by the users' needs - safety, amenity, uninterrupted flow of activities;
- improvement of the lighting in accordance with the sustainability criteria - energy efficiency, easy installation, life cycle savings, undemanding maintenance.

B. *Establishment of The Lighting Technical Solution*

Regarding the need to increase the lighting efficiency, from the aspect of improvements in the ambience, as well as from the aspect of energy

efficiency and easier lighting system maintenance, decision was made to apply a solution based on the chip on board (COB) LED technology. A chip on board solution is adopted as compact, convenient to retrofit into the existing fitting, and economically viable [29]. The light source features are solid-state lighting; luminous flux (luminaire/lamps) 3388 lm / 4100 lm; luminaire wattage 38.0 W; average colour temperature 3036 K.

Structural changes on the luminaire which were made to enable the retrofit COB LED module installation, as well as the selection of the heat sink solution, mechanical adjustments to keep the existing shape design and yet achieve the required degrees of mechanical protection of IP and IK, are beyond the scope of this work.

C. Product Testing

The product testing consists of the lighting technical and mechanical examinations.

The lighting technical solution testing was carried out in the laboratory for goniophotometer examinations.

The lighting technical features measuring for the newly designed solution was carried out in the far-field, in the appropriate laboratory installation.

The laboratory facility is a specially constructed dark chamber, 12 m in length, separated in three sub-chambers, with round-shaped openings between them. These openings, which also have anti-reflexive wall surface, enable clear optical way for the light from the goniometer to the photometer-chromameter. The goniometer *Type C* [30] works fully automatically, paired with the stationary photometer-chromameter, which enables the operator to determine the distribution of the luminance intensity and the chromatic aberration. The system is set on the 10 m length of the optical path, thus facilitating the measuring of the lighting technical features of the luminaires with the clear diameter of up to 1000 mm. The largest diameter of the luminaire that could be tested in this facility is 1500 mm, and the maximum mass is 30 kg. The facility is equipped with the photometer-chromameter *Konica Minolta CL-200 A*, and the data processing is performed by a specialised software package.

D. 3.4. Solution Review Against the Guidelines and Recommendations for Lighting Design of Open Public Spaces

Reviewing process of the newly designed technical solution is conducted through the lighting simulation in the open public space. In order to fulfil the functional requirements which are set by the current recommendations and standards, the new solution is applied to the positions of the existing lighting systems. Through simulation it is first established whether the existing solution satisfies the proclaimed standards, primarily in terms of safety and security for

users. If this is not the case, a new lighting technical solution has to be developed.

During the lighting design process, a photometric calculation was performed based on the key spatial features and the selected luminaires and sources, following the recommendations and guidelines for the lighting design. This simulation was conducted in the software package DIALUX 4.11 (4.11.0.3).

The calculation was performed for a characteristic segment of space - the calculation field. The parameters to be considered during the photometric calculation for an open public space for pedestrian use are as follows:

- spatial features – geometry and dimensions of the open public space: the analysed segment of the Park is linear, considering the dominant traffic routes.
- luminaires positioning along the selected segment of space in Park is the double-sided removed system; with the interval distance between luminaires at 15 m in one row.
- installation height of the luminaire: 3.8 meters;
- light source: LED 38 W.

It is proved by the simulation that the proposed lighting technical solution meets all the requirements of the current recommendations and standards in terms of the minimal level of horizontal luminance [23, 24, 25]. Minimal horizontal Illuminance 1 lx; average horizontal Illuminance 11 lx; maximal horizontal Illuminance 79 lx.

E. 3.5. Product certification

Since the experimental research have shown that the proposed solution fulfils all the present spatial requirements, as well as the provisions of the recommendations and standards for the lighting design of the open public spaces in relation to the minimal level of horizontal luminance for this type of spaces [26, 27, 28], the product has qualified for the process of certification by an accredited independent laboratory.

V. DISCUSSION AND CONCLUSION

The aim of this paper is to present multidisciplinary research in which certain empirically validated variables are established. These variables were imposed by the specific characteristics of the context (surroundings) in which the task is to design and produce the luminaires for open public spaces in the complex urban realm. By setting up a model that interlinks the theoretical social background and managerial methods in practice, a contribution is achieved in terms of optimisation and improvements in the process of the lighting design for the open public spaces, especially in the context of the historic urban landscape.

Therefore, in this case, study it has been pointed out on the importance to value the extended social

context in the process of the lighting design in the open public spaces of historical significance. The emphasis is on the social impact which the presented business model creates and hence contributes to the preservation of the ambience values by the complex phenomenon of lighting. Even though the inauguration of this organisational model has purpose in the competitiveness enhancement of a small technology-driven company on the market, the economic measurements were not taken into account, but the advantage was given to the effects that consider the users of these spaces. Similarly, the effects of the energy efficiency and savings, carbon dioxide emission and maintenance cost were not considered in detail, since the ecological, technical and economic aspects of LED technology in lighting are already extensively researched and published.

Furthermore, some of the phases in the application of the proposed business model are presented in mere outline, without a detailed explanation of the process, with the aim to rather illustrate the entire cycle including the testing and the obligatory certification which is the prerequisite for the application of this lighting technical solution. Hence, the presented phases may serve as the outposts for further researches.

The newly established methodology embraces the innovative approach in which the foundation is not in conventional designing, but the involvement of the particularities of the space that form the locus identified in the design process.

The results of this paper make contributions in the domain of management of sustainable projects and are useful both for lightning designers and producers in SMEs, as well as the users and to the purpose of the cultural heritage preservation.

ACKNOWLEDGEMENT

A special thanks to the company METEOR, which made possible the experimental research performed in the METEOR lab facility.

FUNDING

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia: "Climate Change and its effects on the Environment - Monitoring, Adapting and Mitigating" [grant number III 43007] and "Research and systematization of housing development in Serbia in the context of globalization and European integrations for the purpose of improving housing quality and standards" [grant number TR36034].

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