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ARTIGO

ARTIFICIAL LIGHTING APPLIED TO ARCHITECTURE: DESIGN PROCESS

ILUMINAÇÃO ARTIFICIAL APLICADA À ARQUITETURA: PROCESSO DE PROJETO

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ABSTRACT: In the design process, each one of its constituent element influences the quality of the design as a whole. In Brazil, little has been discussed regarding building lighting design process, despite the growth of graduate courses in this sub-area of architectural studies in the last decade. This paper presents some aspects that are currently considered in the artificial lighting design process applied to architecture, according to the understanding of expert lighting designers. The experts were consulted through an electronic survey, and the questions were developed based on a thematic bibliographic review. The questions of the survey were about the design phases, support tools, lighting quality concepts and issues faced in the design routine. Then, to delineate the light designing process, the analysis of the results was based on the compilation of responses that showed the professional activities. Besides identifying how the participants' design process takes place, the survey responses indicated that some design phases and design variables recommended in the literature are not applied in their entirety by all professionals. It was also identified a high incidence of some common problems in the design routine.

KEYWORDS: Artificial Lighting; Lighting Design; Lighting Applied to Architecture; Design Process; e-Survey.

RESUMO: O processo de projeto, com todos os elementos que o caracterizam, é responsável pela qualidade do projeto como um todo. No Brasil, no caso de projetos de iluminação para edificações, pouco se discute sobre o seu processo de projeto, apesar do aumento de cursos de pós-graduação nesta subárea da arquitetura na última década. Este artigo apresenta alguns aspectos que, atualmente, são considerados no processo de projeto de iluminação artificial aplicado à arquitetura, segundo o entendimento de projetistas especialistas que dedicam sua atuação profissional majoritariamente a projetos de iluminação. Os especialistas foram consultados por meio de questionário eletrônico, e as questões foram desenvolvidas a partir de revisão bibliográfica temática. Os elementos consultados foram as fases de projeto, ferramentas de apoio, conceitos de qualidade de iluminação e problemas enfrentados na rotina projetual. Na sequência, a fim de delinear o processo de projeto, a análise dos resultados foi montada com base na compilação das respostas que indicaram as atividades profissionais. Além de identificar como se dá o processo de projeto dos participantes, as respostas dos questionários indicaram que algumas fases de projeto e variáveis de projeto preconizadas na literatura não são aplicadas na sua totalidade por todos os profissionais. Também foi identificada alta incidência de alguns problemas na rotina projetual.

PALAVRAS-CHAVE: Iluminação Artificial; Projeto de Iluminação; Iluminação Aplicada à Arquitetura; Processo de projeto; e-Questionário.

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INTRODUCTION

Light has a significant influence on people's behavior and can either help the cognitive achievement to perform any task or induce inattention, which in turn is liable to severe consequences to physical integrity (WANG; BOUBEKRI, 2011). The benefits of good lighting are undeniable, both on the scale of buildings and cities. Adequate lighting not only contributes to health maintenance but can also help to promote it (JONES; MILLER; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2008). Light can be restful or stimulating, and in both cases it is imperative to balance mood and well-being (BARON; REA; DANIELS, 1992). Thus, depending on the design requirements, all of the aforementioned subjective elements must be considered in the development of solutions with the same significance of quantitative factors.

The Associação Brasileira de Normas Técnicas[1] (ABNT), through ISO/IEC 8995-1/2013[2], highlights, among other concepts, the "requirements for lighting planning" for architecture. These are environmental activity, maintained illuminance, unified glare limit index, and color reproduction index (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2013). Despite the importance and necessity of technical standards, they are created to express general principles with the aim of avoiding inappropriate lighting (BOYCE; SMET, 2014). Therefore, standards cannot assure the quality of design, which include a complex series of qualitative and quantitative parameters. Thus, lighting experts are responsible for interpreting and concatenating these guidelines to obtain appropriate lighting (REA; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2000). Therefore, to achieve good results in the aspects as mentioned above, lighting experts must be able to apply in their designs normative, technical and aesthetic concepts that promote well-being and respect the environment (ABOUT LIGHTING..., [201-?]).

Lighting design applied to architecture tends to be developed by architects, product designers, interior designers, stage illuminators, electrical and civil engineers, as well as luminaire manufacturers (DILAURA; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2011; OLIVEIRA, 2012). According to Toledo (2008), in the undergraduate courses in architecture offered in Brazil, questions about lighting are usually addressed to both daylighting and artificial lighting. Toledo (2008) also notes that lighting designers are often called in advanced stages of the architectural design, which compromises the shared development and consequently underutilizes the daylighting potential of use.

Brandston (2012) notes that while issues such as "global warming" and "sustainability" are recurrent in politics and the media, the same does not occur with enlightenment matters, despite their importance in the two themes cited. Still, it is common the idea that problems related to the rational use of energy will be solved through lighting.

According to the e-MEC register of Institutions and Courses of Higher Education, the first graduate degree in the area was registered in 2009. In this register[3], there is the offer of 21 graduate courses of lighting related to architecture[4], with an average of 420 hours of classes, present in the five regions of the country. These data indicate an increased interest in lighting courses.

Therefore, with the growing enthusiasm for lighting – whether by recognition of its importance in human activities or by its characterization as expertise – the demand for lighting designs applied to architecture increased. As a consequence, there is also interest in understanding the design process to foster design improvements.

In architecture, design methods have been studied systematically since the 1960s, with particular emphasis on methodologies that allow a design process

1 Brazilian Association of Technical Standards – ABNT, initials in Portuguese.

2 "This standard is an identical adoption, in terms of technical content, structure, and wording, to ISO/IEC 8995-1: 2002 and Cor 1: 2005, which was prepared jointly by ICD-TC and ISO/TC 159" (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2013, p. 6).

3 This search was made on the website <http://emec.mec.gov.br/>, in the "advanced search" tool.

4 It was considered graduations that in their titles contained the words or terms "lighting, lighting design or architecture of illumination" (http://emec.mec.gov.br/).

in architecture to be more conscious, and thus less intuitive (KOWALTOWSKI; BIANCHI; PETRECHE, 2011). Such concern is essential since information regarding the application of strategies, tools, and use of parameters to aid the design process is essential. Designing, in architecture, is a complex activity with many variables (KOWALTOWSKI; BIANCHI; PETRECHE, 2011) However, it is difficult to find systematized information regarding lighting design process. In general, the most diffuse information on illumination refers to quantitative and normative aspects, and the commented presentation of lighting design cases carried out in magazines in the area.

Searches conducted by the authors in databases[5] have shown that although there are many lines of research in lighting, little has been discussed so far about the design process[6]. Thus, this paper proposes to raise aspects of the lighting design process systematically. The information of interest was collected through the application of a survey. This questionnaire is based mainly on the recommendations on Lighting Quality listed in the book "A guide to designing lighting for people and buildings" (JONES; MILLER; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2008) and the design phases commonly applied in the development of architectural design.

Lighting quality and design phases

This paper took into account as a primary source the Illuminating Engineering Society (ES) recommendation, according to which quality results from the combination of human needs, economic, energy efficiency and environmental factors associated with architecture (JONES; MILLER; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2008). Although different lighting approaches are possible, the significant challenge for lighting design is to harmonize the three topics above mentioned and represented in Figure 1. However, Figure 1 should not be understood as closed in itself, but subject to adjustments, inclusions or even exclusions of items, depending on the complexity of the lighting design.

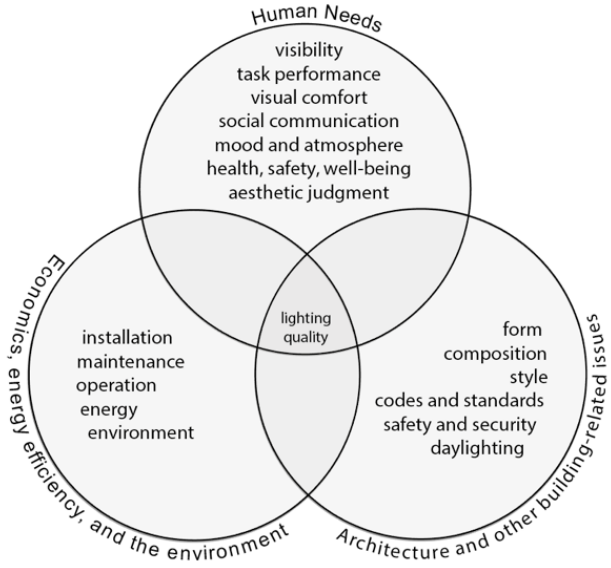


Figure 1: Lighting quality: Intersection of human needs, economic and environmental aspects, architecture and other issues.

Source: Adapted from Jones, Miller & Illuminating Engineering Society of North America, 2008.

[5] Linked to the Portal of Newspapers CAPES/MEC (http://www.periodicos.capes.gov.br).

[6] Searched on January 22, 2017, with the aid of truncation and Boolean operators: Lighting design; lighting design; lighting designer; design process; design methodology; among others, also in Portuguese.

As it occurs with other kinds of design, lighting design is also developed in phases. From a macro view, it is possible to summarize them in pre-design, design, and post-design (ROMANO, 2006). By approaching lighting applied to the architecture, it is also possible to take as reference the architectural design phases defined by NBR 13532 (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 1995). Related to a more specific point of view, the Manual of Scope of Services and Lighting Designs[7] edited by Brazilian Association of Lighting Architects (ASBAI, in Portuguese)[8], suggests six phases for the development of lighting design. Each phase has steps classified as essential, specific or optional depending on the scope of the design (ASSOCIAÇÃO BRASILEIRA DE ARQUITETOS DE ILUMINAÇÃO, 2000). There are no recommendations for design matters. The ASBAI Handbook brings recommendations related to design process documentation and suggestions for the products generated. In this way, the phases recommended by Romano (2006), by NBR 1353 e by ASBAI were grouped in Table 1.

Table 1: Design phases

MACRO PHASES Romano (2006)	PHASES NBR 13532 (1995)	PHASES ASBAI (2000)
Pre-design	a) data collection b) programming c) feasibility study	Phase A: product design Phase B: product definition
Design	d) preliminary study/ preliminary design e) executive design/detailing	Phase C: identification and solution of interfaces Phase D: detailing
Post-design		Phase E: post-design delivery Phase F: post-delivery of the work (fine adjustments of position of luminaires, bulbs, for example, post-occupation evaluation, etc.)

Source: Adapted from Romano (2006), Associação Brasileira de Arquitetos de Iluminação (2000) and Associação Brasileira de Normas Técnicas (1995)

PURPOSE

General purpose

To raise aspects that characterize the design process in artificial lighting applied to the architecture.

Specific purpose

a) Inquire Brazilian experts in lighting design applied to architecture, about their process of design.
b) Identify which lighting design elements as phases, tools, and design variables are, in fact, used in the professional practice of those experts.

METHOD

This paper focuses on artificial lighting design process applied to architecture. So, the better way to understand how such a process occurs is to contact experts in that field directly: the lighting designers. In this way, for exploratory research, a structured survey was applied. This tool is defined

7 Manual de Escopo de Projeto Luminotécnico (Scope Handbook of Lighting Design).
8 In Portuguese, it is Associação Brasileira De Arquitetos De Iluminação (ASBAI).

by Babbie (1999) as a type of methodology that collects data from a sample and whose purpose is to know a particular characteristic of the population studied. The use of an electronic survey[9] was defined, opened to all Brazilian professionals who consider themselves as lighting designers. This online solution avoids embarrassing the participants, broadening the reach and ensuring independent fulfillment among the respondents (GÜNTHER, 2003).

However, among the completed questionnaires, only professionals who dedicate 80% or more of their professional activities to lighting design were selected. Thus, the sample, in addition to being random, is specific, formed by experts[10] and active in the market for lighting design (VOLPATO; BARRETO, 2016). Because it is detailed research, the analysis and discussion of the results are presented to show the central tendency of the data (VOLPATO; BARRETO, 2016), so that the results allow inferring what is or is not part of the design process of the lighting designers participants. Figure 2 shows the summary of method definitions. It should be noted that the questionnaire collects qualitative and quantitative variables of professional activity related to lighting design process. "Survey division" section of this paper details the elaboration of all survey questions.

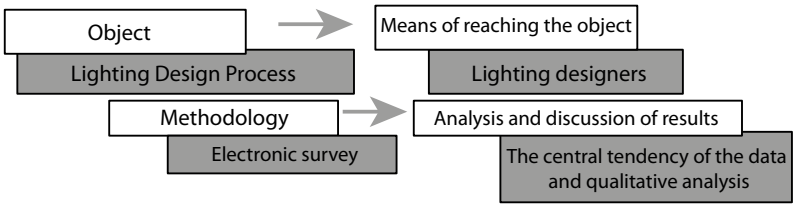


Figure 2: Methodology outline

Another detail to be added to the method is the form of contact with the professionals: a link to the survey was sent, followed by a summary about the researchers, the origin of the questionnaire and its purpose. Participation was not mandatory (GÜNTHER, 2003) but optional based on the justification of the advance in lighting research. Such information was sent to e-mails of lighting associations (and requested to be forwarded to their associates/contacts) and disseminated in thematic groups on architecture and lighting in social networks. Lume Arquitetura[11] magazine also shared it on its Fanpage[12] and sent it to its contacts via e-mail. This work of dissemination and data collection took place in February and March of 2017. In sequence, the survey form, division and questions formulated are presented.

Survey division: methodology in two thematic blocks of questions

The survey was organized in two blocks, from the more general subject to the more specific one of interest (GÜNTHER, 2003). The first one with two questions to characterize the sample. The second block was formed by four questions regarding the design process adopted for lighting design: a) design stages; b) used tools; c) design variables considered; d) difficulties faced. In this way, crucial information from the survey was collected from this second block.

In each question, comment fields were included to receive additional information or even identifying missing options/alternatives in the formulation of the question. As participation was voluntary, it was demanded as a *sine qua non*-condition that all questions must be answered. Participants were assured not even the researchers could identify them, as a guarantee of privacy and

[9] The SurveyMonkey platform was chosen to develop the questionnaire and collect the data because is free for surveys of up to 10 questions,
[10] The population of lighting designers in Brazil is not known.
[11] Lume Arquitetura magazine is a reference in promoting the profession of Lighting Designer.
[12] The page on the social network Facebook.

anonymity. The type of each question – form, matrix, classification – was defined according to the characteristic of the answer sought in the issue.

The division into blocks and the option for questions with alternatives or associations considered the recommendations of Dillmann (1974 apud GÜNTHER, 2003) that the task had to be facilitated to the respondent and reduced the physical and mental effort required to eliminate the possibility of embarrassment. The next two sections describe in detail the formulation of the questions, by thematic blocks, in the same sequence and division that were presented to the respondents.

The Methodology of Block 1 of questions: Characterization of the sample (general information of the professional/respondent office)

This block is composed of two questions. The first question was developed as a form with open answers and aimed to collect the following data: a) percentage of activities dedicated to architectural lighting design – to confirm if the respondents act in this area[13]; b) identify the year of the foundation of the office; c) geographical region; d) professional experience of the responsible designer – in years; e) team composition[14]. The issues addressed in items b), d) and e) were based on the survey developed and used by Deliberador (2010).

For the next question, it was considered appropriate to collect the data with a qualifying question, so that the answers were presented in the ranking format. This part identified the typologies that compose the portfolio of professionals/offices, and which are predominant. The alternatives[15] listed were: a) residential; b) commercial; c) corporate; d) hotel management; e) educational; f) institutional and/or public. Concerning filling and because some professionals/offices can only work with an architectural typology, it was determined that it is mandatory to fill in an item (partial fill). Based on the choice of two typologies, the respondent was obliged to determine their position in the ranking, where one (1) would be more frequent and six (6) less frequent.

The Methodology of Block 2 of questions: Design process in the office routine

This block is composed of 4 questions to address aspects that characterize the design process. The first question of this block was developed in the matrix format to allow the relation of the affirmatives i) YES, ii) NO or iii) PARTIAL, with the following steps: a) Data collection, b) Programming, c) Feasibility study, d) Initial study/preliminary design, e) Executive design/detailing, f) after delivery of the design (post-occupation evaluation, fine adjustments of the position of luminaires and bulbs, etc.). This question had the purpose of identifying which phases are part of the professional routine of the offices, and the options listed were based on Table 1: Design phases.

Subsequently, the fourth question of the survey referred to the tools that support the design process. The respondents were requested to mark: i) YES, ii) NO or iii) PARTIAL, for the following alternatives: a) Guides and manuals; b) Software for 3D representation and/or simulation; c) Codes, standards (e.g., NBRs, ISO), legislation and certifications (Procel Edifica, LEED, e.g.); d) Checklists.

The fifth question in the survey was based on the design variables of lighting quality proposed by the Illuminating Engineering Society (see Figure 1). However, for simplification purposes, the items were presented linearly and continuously, with no defined separation between human needs, economic and environmental aspects, architecture and other issues. And, like the previous question, the following statements were presented i) YES, ii) NO or iii) PARTIAL to be related to the following project variables: a) Aesthetics judgment; b) Form, style, and composition; c) Task performance; d) Visibility and visual comfort;

[13] Thus, for the analysis of the results, reject surveys from designers that do not fit the purposes of the research.

[14] To identify the size of the office.

[15] The architectural typologies listed were based on the market of performance in architecture published by the first Census of Architects and Urbanists of Brazil (CONSELHO DE ARQUITETOS E URBANISTAS, 2012).

e) Daylight; f) Mood, atmosphere, and social communication; g) Health, safety, and well-being; h) Energy consumption; i) Environment and sustainability; j) System installation; k) Maintenance and operation of equipment/system.

The sixth and last question asked the respondent to indicate the occurrence of the following difficulties in the professional practice: a) Unplanned interferences/changes, b) Insufficient resources for the design scope, c) Lighting design is hired in advanced phases of architecture design d) Standard and legislation, e) Difficulty in accessing technical publications, due to language or costs, etc. The question of matrix type allowed to relate each item quoted – from a) to e) – to one of the following occurrences: i) Always, ii) Frequently, iii) Rarely, iv) Never.

Because they were considered fundamental to the understanding of the design process, a mandatory response was requested in all the matrix lines of all the questions in this block 2.

ANALYSIS AND DISCUSSION OF RESULTS

The e-survey was answered by 55 offices. Of these, 46 were considered valid, and nine (9) were nullified – eight (8) of them did not complete all the questions of the questionnaire, and one (1) was answered by an office that does not carry out activities in Brazil. In all surveys, the first item analyzed was: "percentage of office activities dedicated to lighting design." As a result, of the 46 valid respondents, 20 indicated that lighting designs correspond to up to 79% of their activities, an amount considered insufficient for the research purpose and consequently disregarded. Therefore, for this research, it was considered just the offices that dedicate 80% or more of their activities to lighting design, and with effective action in this business. Thus, of the 46 valid surveys, 26 were analyzed, and their answers are considered in this paper. Essentially, all respondents are experts in lighting applied to architecture and active in this market. In this way, it was considered that the sample is representative to raise general aspects of the whole, and thus to initiate a study on the subject.

In sequence, the analysis and discussion of the six questions of the survey are carried out in the same sequence in which the method presented them. In this way, the 26 surveys have their data discussed collectively, but by topic. The analysis and discussion of the results appreciate the central tendency of the data so that the mode among the respondents is always highlighted (VOLPATO; BARRETO, 2016). Regarding the variables, some are qualitative and others quantitative as, for example 'geographical region' and 'quantity of employees', respectively. Thus, general information and the lighting design routine helps to delineate the design process. These analyzes are intended to contribute conceptually to broaden the discussion about lighting design, but also illustrative to present a panorama of the professional performance of lighting in architecture.

Block 1 of questions: analysis and discussion of the results[16] – Characterization of the sample (general information of the professional/office)

After identifying the surveys that could be analyzed, the next phase examined all responses from block 1 to characterize the sample. Tables 2, 3, 4, 5, and 6 help to delineate the sample. As on can be seen in Table 2, it is noticed that architects have significant participation in the team of Brazilian lighting. Designers appear in second, with 17 participants. Thus, it is possible to infer that this expertise, although not exclusive to architects, is a prominent area for these professionals. Regarding the geographic division, one notes that the

[16] There was a reduction of one decimal place from the percentage numbers in tables 3, 5 and 6 (rounding of values).

absolute majority of professionals who dedicate 80% or more of their activities to lighting designs are in the south and southeast of Brazil, 88.4%, according to Table 4. This data resembles the results of the demographic division of architects and town planners in these same regions, 76.41%, identified by the census carried out by the Architecture and Urbanism Council of Brazil (CONSELHO DE ARQUITETURA E URBANISMO DO BRASIL, 2012).

Table 2: Collaborators in specialty categories: architects; engineers and technologists; draftsman; designers; trainees; others.

Occupation and/or position	nº absolute	average per office
architects	45	1,73
engineers and technologists	10	0,38
draftsman	9	0,34
designers	17	0,65
trainees	19	0,73
others	34	1,31

To identify the main typologies for which the participants are contracted, it was asked about the frequency of each one. The highlight in Table 5 presents the main typologies that constitute the portfolio of designs. Six (6) respondents highlighted that corporate solutions are the principal product of their offices. One notes that the function of these spaces has a commercial value associated with their product or service. Another aspect that demonstrates that these environments are more thoughtfully designed is codes, norms, and laws which are more demanding in places of public access, and this applies to the requirements on lighting quality, Figure 1 (JONES; MILLER; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2008).

Most respondents are from small and medium-sized offices – Table 5 – although more than 80% have their boss with high experience or are experts in the subject, with 20 years or more of service in this business (Table 6). These data demonstrate that designs are conducted primarily by offices of up to 10 employees. Although such offices have experienced lighting designers in their staffs.

Table 3: Division of the sample by geographic region

Regions of Brazil	Nº absolute	(%)
Midwest	0	0,0%
Northeast	0	0,0%
North	3	11,5%
South	5	19,2%
Southeast	18	69,2%
Total answers	26	100%

Table 4: Most frequent architectural typology of services offered

Tipologia	quant.
corporate	6
commercial	5
educational	5
Institutional and/or public	4
hospitality	3
residential	3
Total answers	26

Table 5: Office size classification

Nº of employees	Category (size)	nº absolute	(%)
1 a 3	Pequeno	9	34,6%
4 a 10	Médio	13	50,0%
More than 11	Grande	4	15,4%
Total answers		26	100%

Table 6: Classification of the office concerning the boss's experience in years

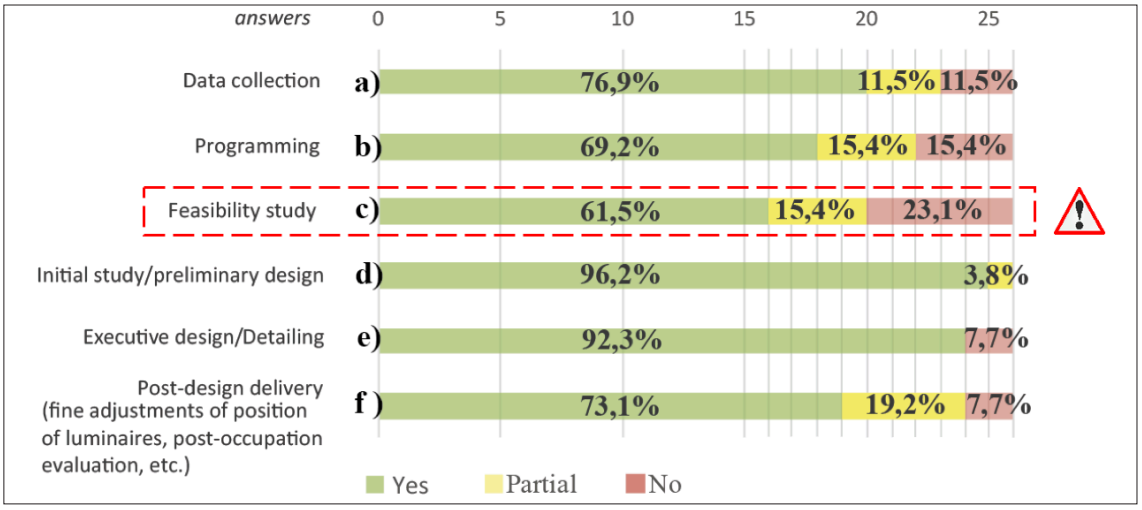
Time's performance of the boss	Category	nº absolute	(%)
2 a 5 anos	Minimum	2	7,7%
6 a 10 anos	Little	2	7,7%
11 a 20 anos	High	9	34,6%
Mais de 20 anos	Expert	13	50,0%
Total answers		26	100%

Block 2 of questions: Design process in the office routine – analysis and discussion of results

Design steps – analysis and discussion of results

This topic analyzes and discusses the results presented in the Graph 1, which represents the design steps developed by respondents. Thus, the most remarkable item in the analysis of results was "d) Initial study and preliminary design," because 96.2% of the designers perform this phase. This option was the only step in which the negative alternative received no marking, which denotes priority in step "d" more than in steps "a," "b" and "c." In his book, Howard Brandston[17] points out that his first design step is to "get the client's program" to make objective and subjective analyzes, then a "preliminary study" is carried out to develop the concept (BRANDSTON, 2010). In this way, like our sample, Brandston (2010) expands its activities in the preliminary study. Both our sample and Brandston follow a different sequence from that described in NBR 13532. In general, lighting designers are contracted for existing building, or when the preliminary study of the architecture is already advanced, it is understandable that contractor information is sufficient to allow that lighting designer can initiate his or her work. In the comments field[18] of the survey, one of the designers highlighted the briefing phase, reinforcing that in the case of the lighting design, data collection can be done in a conversation with the contractor.

Graph 1: Design process developed phases (horizontally stacked bar graph)



[17] Brandston is an award-winning American lighting designer.

[18] Other comments on the question about "Design Steps": Briefing; We control the whole intelligent part of the house: automation, sound, electric, solar panels; Review and follow-up; Technical consultancies; Steps depend on the type of contract, whether or not there is another professional involved, etc. Not all stages are part of all agreements; Measurements of lighting levels/existing lighting assessment with reporting; Research related to physical, chemical and biological processes – Monitoring of equipment competitions (partial).

Although there is a significant amount of information available to the designers, it is necessary to carry out the feasibility analysis and the preparation of pre-budgets for the lighting design. However, step "c) feasibility study" is performed by only 55% of respondents. So, it is pertinent to adapt questions based on the research of Morais, Granja, and Ruschel (2015) to justify not carrying out a feasibility study:

1) it is possible that the designer follows a budget already established by the client, and thus, have to use concepts of target costing;

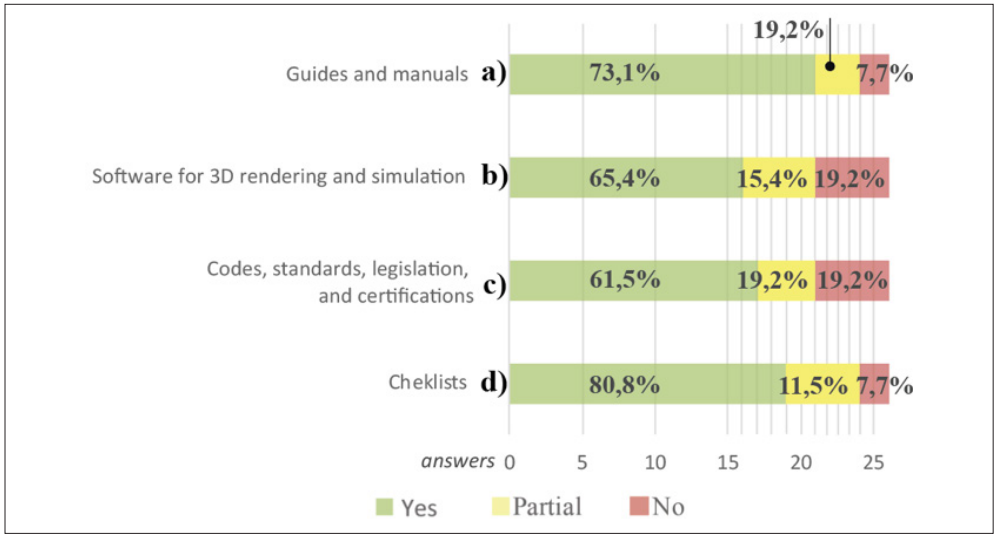
2) in the comments field of the next section (tools used), it is not mentioned the use of any Building Information Modeling (BIM) tool that can assist in the elaboration of quantitative;

Thus, the feasibility analysis of the design could be measured not only with one step before the preliminary study but also through software during the process.

Tools used in the design process – analysis and discussion of results

From the observation of Graph 2, the majority of the participants, almost 80%, use "d) checklists" and "c) codes, standards ...". It has also been identified that each designer/office uses at least one tool to aid the design process. The field "comments" received 07 responses. The most recurring observation was "luminaire calculation software"[19] (DIAlux was cited to simulate lighting, but most cited only the use of specific lighting software). Other comments highlighted alternatives not included in the survey, emphasizing the importance of specific tools: sketching/freehand, graphics techniques in image editor software (e.g., Photoshop), technical catalogs, AutoCAD and Dialux as tools to help the design. Computational resources influence the outcome of the design at different levels and, of course, on its issue (CELANI; GODOI; RODRIGUES, 2007; MORAIS; GRANJA; RUSCHEL, 2015).

Graph 2: Tools used in the design process (horizontally stacked bar graph)



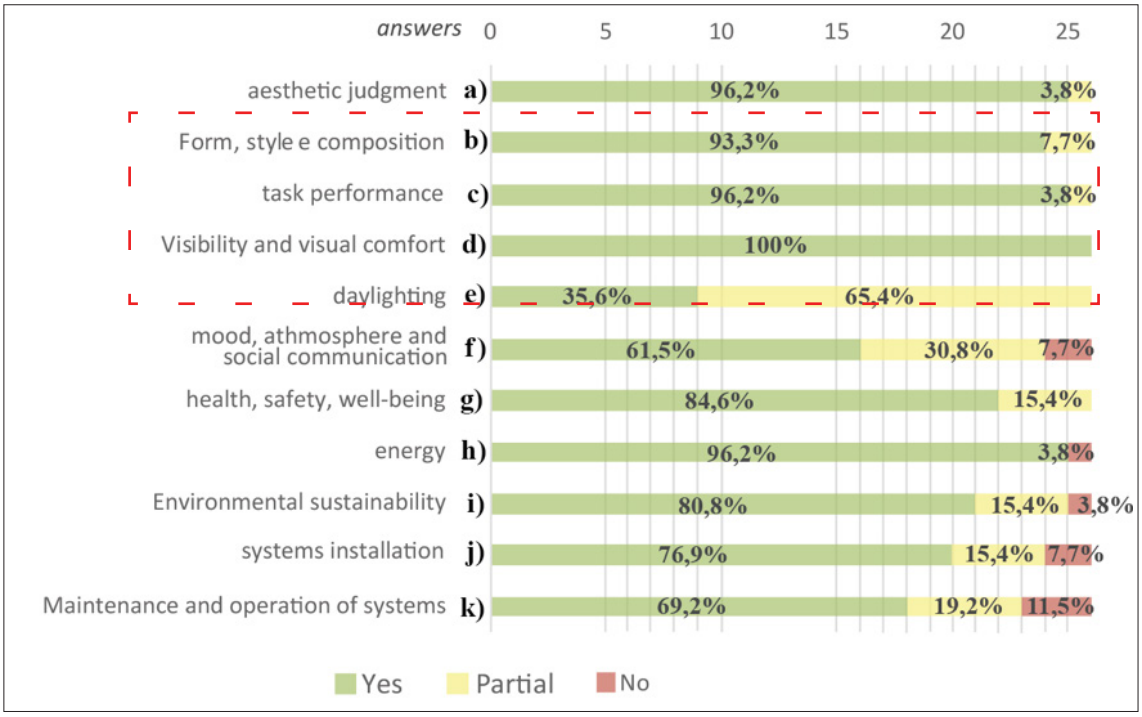
[19] Identical text commented by other three professionals. Therefore, four professionals in total highlighted the use of lighting calculation software.

Variables considered in lighting designs process – analysis and discussion of results

This survey item was based on the literature on lighting quality with the purpose of identifying the design variables used in practice by lighting designers (JONES; MILLER; ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA, 2008). The following are the results referring to the variable considered at the time of design development. Graph 3 presents 11[20] items, 7 of them, a), b), c), g), h) and i), are considered by more than 80% of respondents. Such coincidence is high, especially if we assume that there are designs from different scopes and that some professionals provide services only in some phases. It is detachable item d), where visibility and visual comfort is considered by all the designers consulted, so the topic is essential to a lighting design, according to the interviewees.

The topics "a) Aesthetics judgment", "b) Form, style, and composition," and "c) Performance of tasks" are also highlighted, since they were not considered by more than 90% of the respondents but received no negative responses. In contrast, the least considered item was "k) Maintenance and operation of systems". Which suggests that lighting systems can suffer problems in the maintenance and operation due to lack of planning.

Graph 3: Topics considered in lighting design development (horizontally stacked bar graph)



The feedback field has received information that may be related to some design variables. One of the comments highlighted "Dialogue with the Architectural concept", this may be related to option b) Form, style, and composition; already the comment "Projects are based mainly on the technical norms of security" refers to the topic g) safety, health and well-being; and a third reinforced that "Likelihood of glare is considered in the item visibility and visual comfort" refers to the topic d) Visibility and visual comfort.

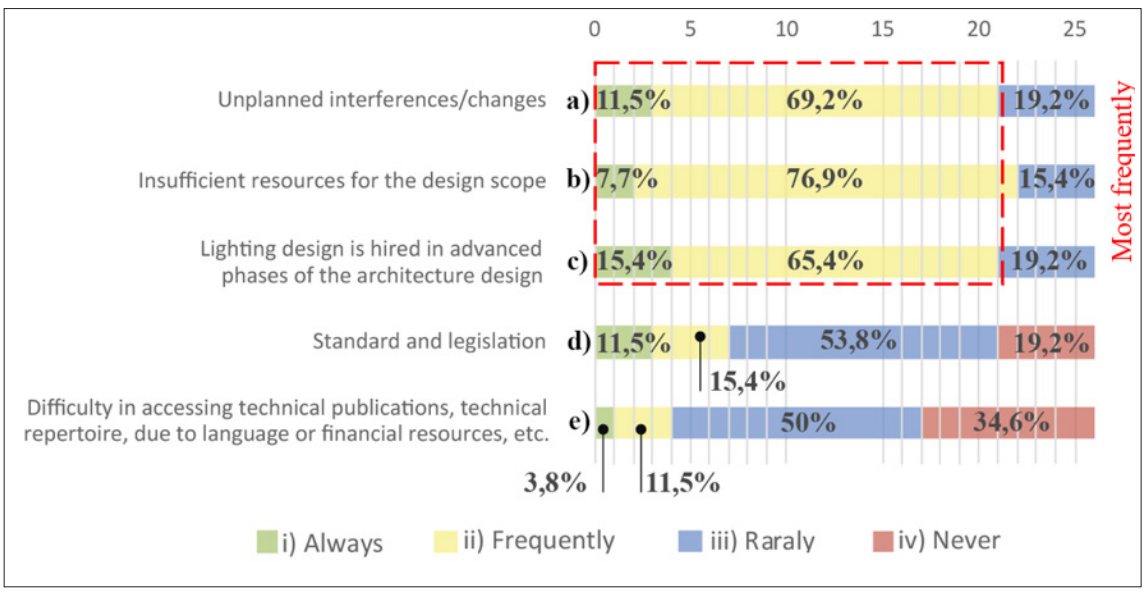
[20] Related subjects, such as form/style/composition, have been put together on a topic because they are in the same circle as the IES diagram, Figure 1.

Difficulties faced by designers – analysis and discussion of results

Identifying difficulties can serve as a means of understanding some problems. As a result, it was asked what challenges are faced in the routine of the designers. According to Graph 4, in general terms, the problem that received most "always" was "c) Lighting design is hired in advanced phases of the architecture design" which added the "often" alternative gives a total of 80.8% incidence. This alternative shows a loss in shared development at the design moment of the architecture, as well as a loss in the use of natural light resources. This tends to limit the lighting designer's job to primarily using artificial lighting.

Other recurring problems were "a) Unplanned interferences/changes" and "b) Insufficient resources for the design scope." The sum of the incidence of alternatives " ii) Always " and "ii) Frequently," also in these two cases is greater 80%. This data demonstrates that there may be a lack of planning by the contractor or the lighting designer who is the service provider. It is possible to relate this lack of planning to the results of step "c) Feasibility study" of the section "Design steps" (Graph 1), since 61.5% of the designers only develops this. 61.5% refers to 16 designers, 6 of them also pointed out that i) Always or ii) Frequently the "b) Resources are insufficient for the design scope" (Graph 4). However, difficulties (a), (b) and (c) are i) Always or ii) Frequently faced by at least 20 of the 26 respondents. This data shows that, possibly, other aspects cause the problems faced by professionals and need to be raised in future research.

Graph 4: Difficulties faced in the routine of the offices (horizontally stacked bar graph)



FINAL CONSIDERATIONS

The study of the design process is fundamental to understanding the relationship between it and the lighting solutions performed. In this paper, the lighting design process was divided into the elements that compose it. Thus, the interpretation of each part helped to understand how the whole is developed, as well identify gaps. This division also allowed to broken down lighting design process into questions. So, using an electronic survey, it was possible to inquire lighting designers, those responsible for choosing the tools and developing lighting solutions applied to the architecture.

The appreciation of the results in general terms, keeping in mind the methodology used, showed that architects have high participation in this

market. Their professional activities are mainly in the most industrialized regions, southeastern and southern of Brazil. Professionals dedicated to the lighting market have high experience (in years), and their offices are composed of up to 10 employees. It is noted that lighting designers have extensive experience in the field and work mainly in small and medium-sized offices. Its portfolios consist primarily of corporate, commercial and educational architecture, which demonstrates that the valuation of this specialist is associated with environments in which the quality of the space adds value to products and services. Thus, it is possible to gauge that lighting offices are focused, their chief designers are experienced, and their clients need designs with quality and safety for public access.

About the design phases and following the order recommended by the literature, the first phases do not happen in all cases. 'Initial study' and 'preliminary design' phases are always performed, so demonstrating a higher complexity to them and the need for mapping to understand their sub-steps and actions. Regarding auxiliary tools, all professionals use at least one.

Literature on the design process in lighting does not delve into this item, which demonstrates a gap to be filled about which tools are used each phase and to assist the activities. Lighting designs are hired at advanced stages of architectural design; this leads to a loss in the choice of solutions that intelligently take advantage of daylighting and also influences a better use of energy efficiency. In general, thus limiting the work of lighting designer to the design of artificial lighting. Related to other difficulties that designers are facing, it is fundamental that future studies identify their causes as well tools and strategies to avoid them.

In a future and broaden research, it is necessary to address specific daylighting issues in the design process, such as the use of solar geometry devices and concepts. It is also essential to investigate more in-depth questions regarding the use of auxiliary tools, especially computational simulation tools, if the professionals are easily accessible, which are the most used, among other aspects. Finally, it is noteworthy that the research, although embryonic on the subject, allowed to characterize the lighting design process through elements previously little discussed in the Brazilian literature on lighting design process. Because it is a new area of architecture – arose around the 1950s (NEUMANN, 2010) –, the design practice of lighting has been little discussed and little recorded. Thus, it is necessary to expand research on this theme and the frontiers of knowledge about lighting quality in architecture.

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