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MASTERARBEIT

Usability of Building Performance Standards in View of Design Support - Lighting Standards

Ausgeführt zum Zwecke der Erlangung des akademischen Grades eines Diplom-Ingenieurs/Diplom-Ingenieurin unter der Leitung von

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ABSTRACT

Like in all fields related to the design and construction of buildings, the lighting design process implies the use of standards, as it is typically required to demonstrate the compliance with nationally and/or internationally established standards for different types of functions and situations. In this context, the codes and standards can be seen as tools, and examined in view of their effectiveness in supporting the lighting design process.

This paper will focus on two dimensions of the usability of lighting standards – the basic level of usability, tested through experiments on students having to tackle basic tasks while handling the standards for the first time, and a more advanced level, revealing problems of usability of the standards content itself inside the practice, by talking with lighting professionals and investigating the problems they found in their years long experience of working with standards.

The contribution of this paper is firstly a framework of possible methods of investigating the usability of regulating documents such as standards and other guidelines, and then the results of the analysis, pointing to the identified problems and suggestions for the improvement of the usability of lighting standards. Most suggestions will however apply to all other kinds of building design standards.

KURZFASSUNG

Wie in allen Bereichen mit Bezug auf das Entwerfen und Bauen von Gebäuden, benötigt der Lichtplanungsprozess den Einsatz von Normen. Die Erfüllung der nationalen oder internationalen Standards, muss in verschiedenen Bereichen und Situationen bewiesen warden, wie vom Gesetzgeber gefordert.

Diese Arbeit wird sich auf zwei verschiedenen Wegen mit der Benutzerfreundlichkeit von Normen in Bezug zur Beleuchtung auseinander setzen. Im ersten Schritt werden diese Normen Studenten vorgelegt, welche mit diesen zum ersten Mal zu arbeiten haben. Dabei wird überprüft, wie einfach es Ihnen fällt mit diesen Normen elementare Arbeiten zu lösen. Im nächsten Schritt wird der Einsatz der Normen durch Interviews mit erfahrenen Lichtplanern und Experten in der Praxis geprüft.

Das Ergebnis dieser Masterarbeit soll ein Rahmenwerk für mögliche Methoden zur Erforschung der Benutzerfreundlichkeit von Normen und Richtlinien sein. Des Weiteren sollen die Ergebnisse der durchgeführten Analyse die identifizierten Probleme zeigen, sowie Vorschläge zur Verbesserung der Benutzerfreundlichkeit liefern. Diese Vorschläge sollten nach Möglichkeit auch bei allen anderen Baunormen einsetzbar sein.

1. INTRODUCTION

1.1. Objectives

The usability of lighting standards will be analyzed in this paper from two perspectives – on one level from the point of view of lighting practitioners with many years of experience and a close insight into the workings of the standards and the challenges in real life practice, and on another level, from the point of view of users (in this case building science students) having to tackle basic tasks while handling the standards for the first time.

The intention of this study is to assess the usability of the codes and standards which are most used in Europe, using as main subject of study the standard EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places", which is also representative among all other standards in use in terms of form and content.

1.2. Motivation

In the field of software and web development, usability investigates the clarity and elegance with which the human-computer interaction is achieved through careful design of the interface. The reasons behind this type of evaluation are mostly commercial, since a user is more likely to utilize a certain piece of software or website if the process is effective, quick and pleasant.

Although standards can be seen as tools, they are not in themselves products that compete on an open market of alternatives from which professionals can pick and choose. However, as a community, lighting professionals, including official bodies, have all the reasons to establish a common language and clear guidelines that facilitate the lighting design

process in a unitary manner by all practitioners, while avoiding much conflict that may arise from the debate about good lighting practice between specialists working on a project.

At the same time, it is of paramount importance to make sure that the requirements established by the standards are determined by professionals in the field, with no other interests outside of good lighting practice and energy efficiency issues.

1.3. Background

When studying the usability of lighting standards there are two main parameters to consider – on the one hand, a short overview of relevant lighting standards in use today and the way they are developed, and on the other hand a definition of usability and a review of the methods in which it is usually tested, especially in the case of other similar standards or guidelines. Additionally, establishing the target groups of users of lighting standards in particular will help in choosing the best methods of evaluating their usability in a relevant way.

1.3.1. Lighting standards

The main international organization in charge with the development of standards and codes, as well as technical reports in the field of lighting is the Comission Internationale de l'Eclairage (CIE). The CIE has contributed to the joint ISO-CIE standard CIE S 008/E: 2001/ISO 8995-1:2002(E): "Lighting of Work Places – Part 1: Indoor".

The recommendations given by the CIE have been adopted and interpreted in different countries within national standards, with some differences. After a preliminary analysis of the available lighting standards and the usual practice in the field, it is apparent that out of lighting standards relating to buildings, there are a few which are more often used in the day to day practice.

Throughout the EU countries, the standard that is most used is the CEN certified EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places", which has been translated and integrated within the national standards.

1.3.2. Users

Lighting standards are highly specialized documents addressing professionals capable of understanding and applying them. However, lighting design on its own is a relatively new field, and the specific tasks relating to lighting are not always entirely divided among professionals.

Ideally, lighting standards should be used by a specially appointed professional – the lighting designer, a professional who usually comes from various backgrounds himself. However, it is often the case that lighting, and implicitly the standards regulating it, are to be engaged by building physicists, electricians, and sometimes even by architects.

With this in mind, it is important to assess the usability of lighting standards extensively, from multiple points of view. For example, while an engineer may be less interested in format and graphics and more interested in the way the information is structured, an architect may need a more visual approach in both font formatting and graphical support.

1.3.3. Usability evaluation

As defined in ISO 9241-11 "Guidance on Usability", usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use", and gives guidelines in evaluating usability in terms of measures of user performance and satisfaction. The three stated concepts of effectiveness, efficiency and satisfaction are then individually defined.

Usability is also a topic in the standard ISO/IEC 9126-1 "Software Product Quality Model", where it is encompassed in the larger concept of "quality in

use" and defined as "a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users", with the main features of understandability, learnability, operability and attractiveness.

Based on established concepts and standard definitions, usability of websites and software tools is typically measured by taking into account a series of methods, out of which it is this study's intent to pick out the ones which can be successfully applied to evaluate the usability of lighting standards.

Past research shows that the extrapolation of usability principles from the IT area, in order to apply it to different fields, has had good results.

Basic usability evaluation includes usability testing, a technique of evaluation through direct testing of a product on users, which is usually the most reliable method of investigation, as it involves the observation of direct interaction of users with the product. Usability inspection, as complementary to usability testing, is a set of methods done by the developers, and include cognitive walkthrough, heuristic evaluation and pluralistic walkthrough.

A cognitive walkthrough analyses the specific tasks that need to be accomplished using a certain product, specifying a sequence of actions required and identifying potential issues that need to be addressed in the next step.

Heuristic evaluations are the most informal methods and rely on a set of heuristics developed by the examiner. They are often not mutually exclusive and cover many of the same criteria of usability that apply to the product or system. Jakob Nielsen's set of 10 usability heuristics is probably the most-used in the field of web and software development (Nielsen, 1994).

A pluralistic walkthrough, also known as a Participatory Design Review, centers on using a group of developers and usability professionals working

together through typical task scenarios and discussing usability issues they encounter, identifying problems and making suggestions.

1.3.4. Usability of standards

Testing the usability of standards has been previously undertaken and described in several scientific papers, mostly in the area of usability standards themselves, concluding that “the ability of designers to use and understand a standard can have more impact on interface quality then the rules specified in the standard” (Thovtrup & Nielsen, p.2).

In their study, Mosier and Smith [1986] found that only 58% of the users of a large collection of interface guidelines were able to find the information they needed, while 36% "sometimes found it". De Souza and Bevan [1990] had three professionals re-design an interface using a draft of the ISO standard for menu interfaces, according to a set of guidelines, and reported that 11% of the rules were ignored and 30% of the rules were difficult to interpret and to implement accurately. Nielsen interviewed 15 developers using both a structured and a free-form set of questions.

Some of the most recurrent conclusions about what a set of guidelines should include:

- Clear statement of design goals and benefits (de Souza, p.8)
- The conditions under which the guideline should be applied (de Souza, p.8)
- Any procedure which must be followed to apply the guideline (de Souza, p.8)
- Checklist of specified design elements (Nielsen, p.10)

2. METHODOLOGY

2.1. Overview

The methodology for investigating the usability of lighting standards was developed as to address two categories of users, in the hope of obtaining a more comprehensive view. The first category was that of professionals in the field of lighting – mostly lighting designers from Austria and the UK, while the second category was that of future professionals (students) in the field of building physics and technology. Each category of users was approached through different usability testing methods.

2.2. Methods to investigate the usability of lighting standards

Out of the methods usually employed to assess usability, the most appropriate ones were chosen in this study, considering the differences between a computer interface design and a document design, and adapting the methods to working with lighting professionals, on the one hand, and with a group of students on the other.

2.2.1. Interviews with lighting design professionals

A series of 5 interviews with professionals in the field of lighting design was made in December 2014 – January 2015, addressing extensively issues of usability of lighting standards in general. The interviews were audio recorded and then transcribed. (See Appendix A)

Out of the 5 participants, 3 are independent certified lighting designers, one is a certified lighting designer associated with a lighting equipment production company, and one is an electrician with a wide practice in lighting design for many years. The full user profiles are detailed in Appendix A.

The interview protocol was initially based on a series of 5 more general questions, to which the respondent would answer in an extensive way while discussing the topic with the interviewer.

Table 1. Questions for interview – Version 1

1	In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them?
2	Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process?
3	Are the standards interpretable or clear?
4	What would, in your opinion, make a standard more usable? (More useful, efficient, user-friendly)? Why?
5	When you think about the level of usability of the standards, find a single word which would define it.

This version of the interview was conducted only once and proved to be less efficient than expected, as the interviewee tended to divert from the subject and not give the desired input.

A more detailed version of the interview protocol was then developed, specifically targeting the usability traits that were to be investigated, by reformulating vague questions and adding sub-questions to the main 5 topics of interest.

Table 2. Questions for interview – Version 2

1	In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them?

Table 2. Questions for interview – Version 2

2	Do you prefer to use standards in their digital form or printed? Which is easier to use and why? What would you say the advantages of each are?
3	What information do you look for in the standard you use? Explanations about lighting design criteria / Calculation methods / Lighting requirements values?
4	Do you read a new issue of a standard when it comes out, to familiarize yourself with it, or is the information so straightforward, that you only need to use it when it is needed in a project?
5	Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process?
6	Does the standard give you the input you need? Do you always get the necessary information?
7	Are the standards in line with the latest technology?
8	Have you found mistakes in any of the standards you have read?
9	Are the explanations and definitions clear and easily understandable?
10	Have you ever found some information which is vague? (modified question)
11	Do you think the quality of lighting design would be lower if no standards were to be used?
12	If lighting design was to be practiced without standards, could this lead to safety issues?
13	If there were no lighting standards to be followed, how do you think this would affect the energy consumption of lighting in buildings?
14	The standard you use most often. Is it a satisfying experience overall? Or is it rather a tedious, unpleasant part?

Table 2. Questions for interview – Version 2

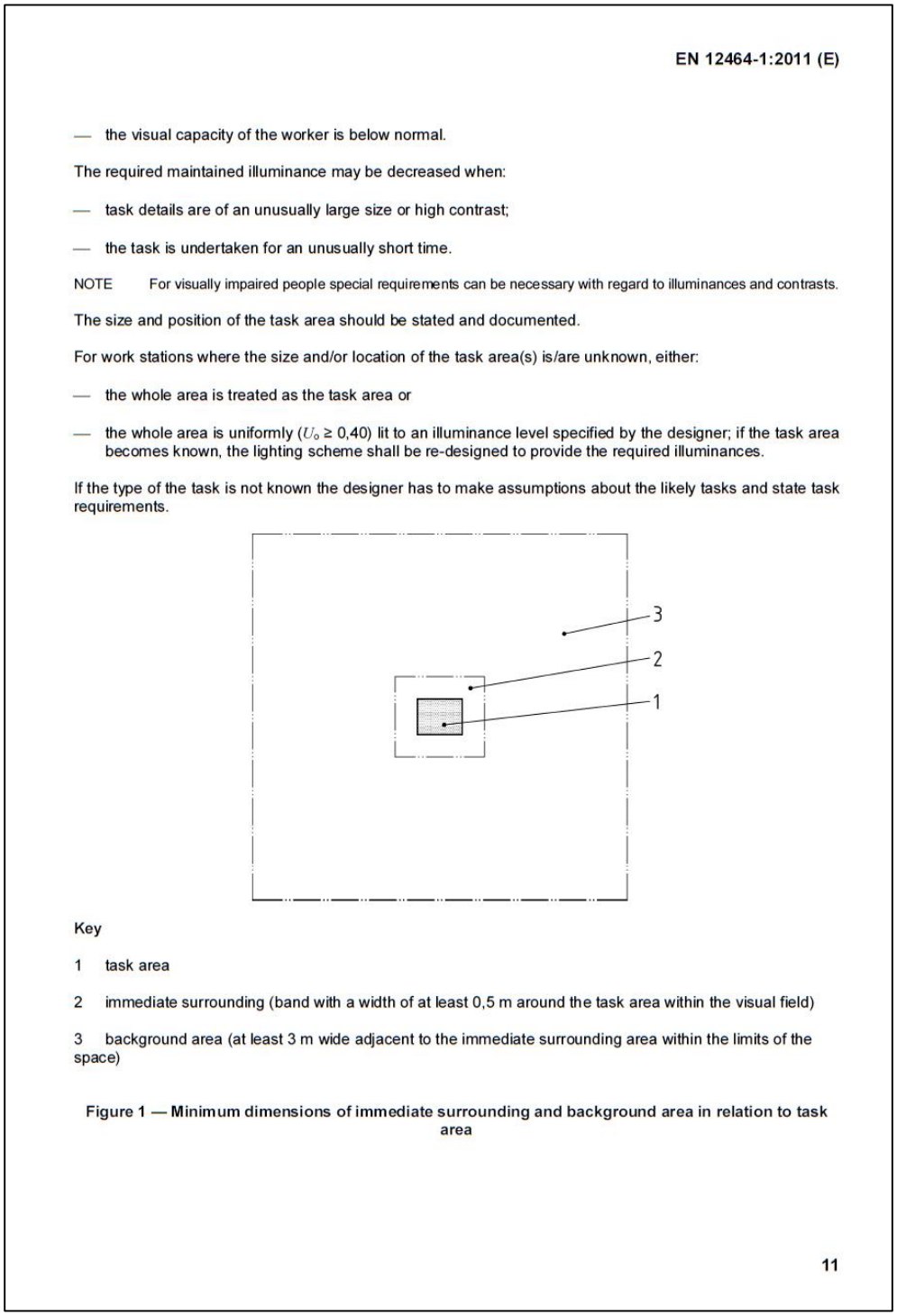
15	Is it easy to find what you need? Inside a standard, and even between standards, you know from their title what information to find and where?
16	Does the graphic design of the standard make a difference in your experience of working with them?
17	Difference in perception of satisfaction of using one standard or another – Experiment showing the same table/graphic from two different standards.
18	What would, in your opinion, make a standard more usable? (More useful, efficient, user-friendly)? Why?
19	When you think about the level of usability of the standards, find a single word which would define it.

Additionally, during the interviews, other deriving questions emerged in the flow of the conversation, specific to each discussion, revealing important issues related to the standards. (See Appendix A)

In the second version of the interview samples from two different standards were used in order to assess in a tangible way the impact of the graphic design on the impression they make on users. The chosen pages were on the same topic each time – a table with requirements for the lighting values of specific areas and a graphic representation of the task area, immediate surrounding area and background area. The participants were asked to comment on their preference for either one of the samples in each case.

The two standards chosen were on the one hand, the EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places", and on the other, the CIBSE SLL "Code of Lighting". The choice was made based on the different appearance of the two documents – while the EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places" looks more like a legal document, with minimal graphic consideration and very few

figures, the SLL Code of Lighting has clearly been designed graphically, with attention to figures and other graphic means of conveying the content. It is the author's conjecture that graphic design in a document is very important in raising the level of usability, in terms of both searchability and understandability of the content. The four comparative sample pages from the two standards are shown in the figures below.



— the visual capacity of the worker is below normal.

The required maintained illuminance may be decreased when:

— task details are of an unusually large size or high contrast;

— the task is undertaken for an unusually short time.

NOTE For visually impaired people special requirements can be necessary with regard to illuminances and contrasts.

The size and position of the task area should be stated and documented.

For work stations where the size and/or location of the task area(s) is/are unknown, either:

— the whole area is treated as the task area or

— the whole area is uniformly ($U_o \geq 0{,}40$) lit to an illuminance level specified by the designer; if the task area becomes known, the lighting scheme shall be re-designed to provide the required illuminances.

If the type of the task is not known the designer has to make assumptions about the likely tasks and state task requirements.

Key

1 task area

2 immediate surrounding (band with a width of at least 0,5 m around the task area within the visual field)

3 background area (at least 3 m wide adjacent to the immediate surrounding area within the limits of the space)

Figure 1 — Minimum dimensions of immediate surrounding and background area in relation to task area

Figure 1. Sample 1 – Page 11 from EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places"

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The illuminance of the immediate surrounding area may be lower than the illuminance on the task area but shall be not less than the values given in Table 2.1.

In addition to the illuminance on the task area the lighting shall provide adequate adaptation luminance in accordance with section 2.1.2.

The size and position of the immediate surrounding area should be stated and documented.

Table 2.1 Relationship of illuminances on immediate surroundings to the illuminance on the task area

Illuminance on the task area E_{task} / lx	Illuminance on immediate surrounding areas / lx
≥ 750	500
500	300
300	200
200	150
150	E_{task}
100	E_{task}
< 50	E_{task}

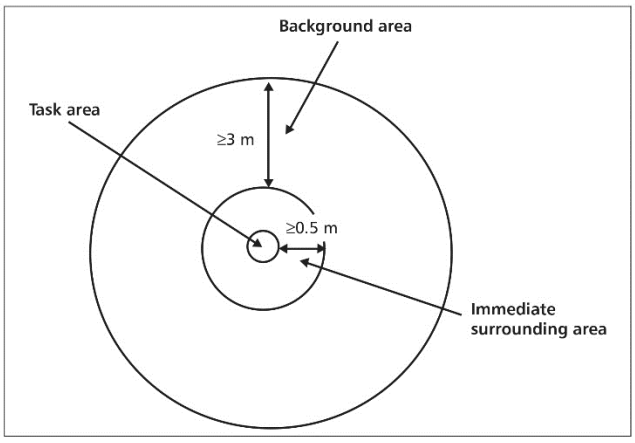
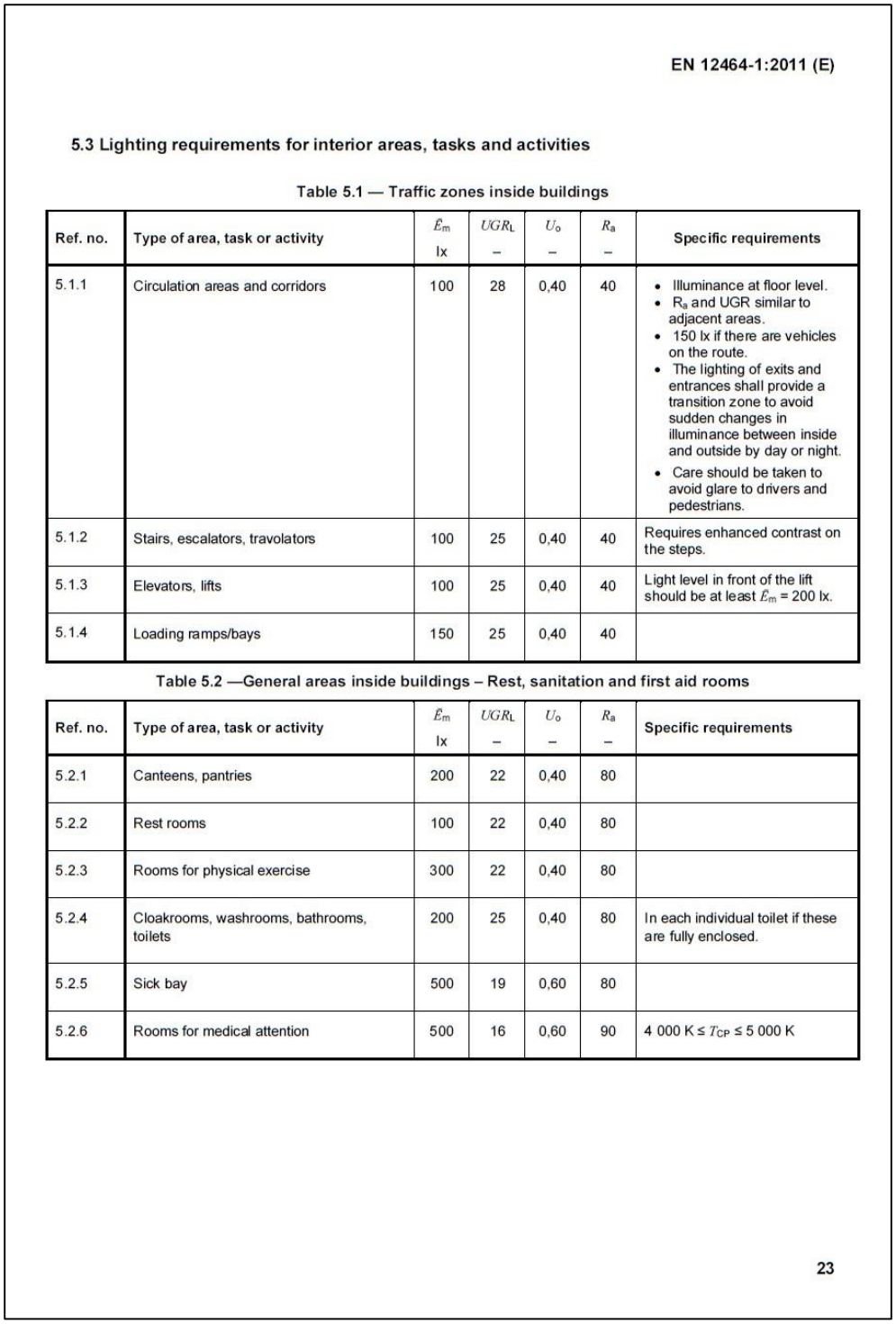


Figure 2.1 Task, immediate surrounding and background areas

Figure 2. Sample 2 – Page 34 from CIBSE SLL "Code of Lighting"



5.3 Lighting requirements for interior areas, tasks and activities

Table 5.1 — Traffic zones inside buildings

Ref. no.	Type of area, task or activity	$\bar{E}_m$ lx	UGR_L –	U_o –	R_a –	Specific requirements
5.1.1	Circulation areas and corridors	100	28	0,40	40	• Illuminance at floor level. • R_a and UGR similar to adjacent areas. • 150 lx if there are vehicles on the route. • The lighting of exits and entrances shall provide a transition zone to avoid sudden changes in illuminance between inside and outside by day or night. • Care should be taken to avoid glare to drivers and pedestrians.
5.1.2	Stairs, escalators, travolators	100	25	0,40	40	Requires enhanced contrast on the steps.
5.1.3	Elevators, lifts	100	25	0,40	40	Light level in front of the lift should be at least $\bar{E}_m$ = 200 lx.
5.1.4	Loading ramps/bays	150	25	0,40	40	

Table 5.2 —General areas inside buildings – Rest, sanitation and first aid rooms

Ref. no.	Type of area, task or activity	$\bar{E}_m$ lx	UGR_L –	U_o –	R_a –	Specific requirements
5.2.1	Canteens, pantries	200	22	0,40	80	
5.2.2	Rest rooms	100	22	0,40	80	
5.2.3	Rooms for physical exercise	300	22	0,40	80	
5.2.4	Cloakrooms, washrooms, bathrooms, toilets	200	25	0,40	80	In each individual toilet if these are fully enclosed.
5.2.5	Sick bay	500	19	0,60	80	
5.2.6	Rooms for medical attention	500	16	0,60	90	4 000 K ≤ T_{CP} ≤ 5 000 K

Figure 3. Sample 3 – Page 23 from EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places"

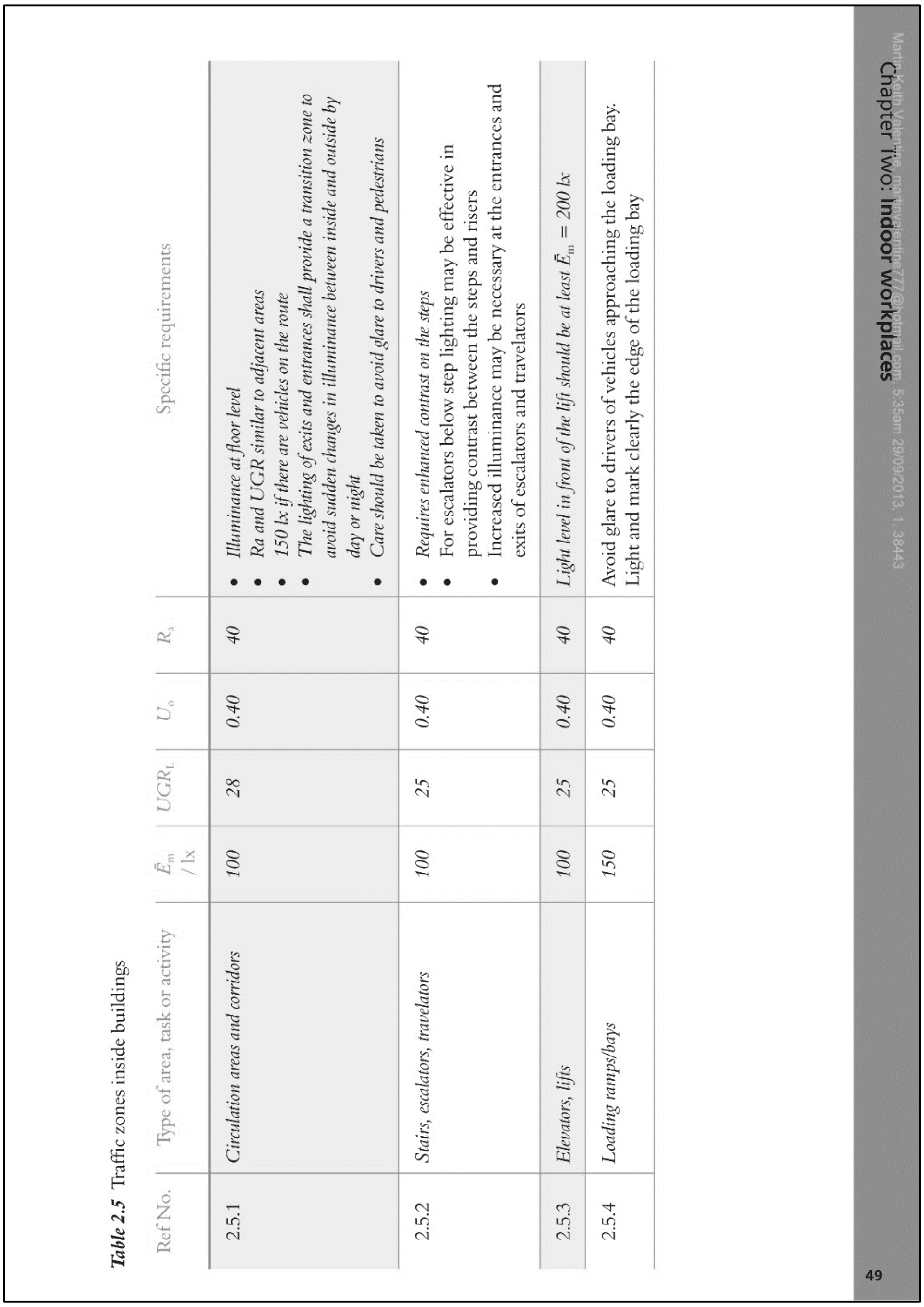


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Table 2.5 Traffic zones inside buildings

Ref No.	Type of area, task or activity	$\bar{E}_m$ / lx	UGR_L	U_o	R_a	Specific requirements
2.5.1	*Circulation areas and corridors*	*100*	*28*	*0.40*	*40*	• *Illuminance at floor level* • *Ra and UGR similar to adjacent areas* • *150 lx if there are vehicles on the route* • *The lighting of exits and entrances shall provide a transition zone to avoid sudden changes in illuminance between inside and outside by day or night* • *Care should be taken to avoid glare to drivers and pedestrians*
2.5.2	*Stairs, escalators, travelators*	*100*	*25*	*0.40*	*40*	• *Requires enhanced contrast on the steps* • For escalators below step lighting may be effective in providing contrast between the steps and risers • Increased illuminance may be necessary at the entrances and exits of escalators and travelators
2.5.3	*Elevators, lifts*	*100*	*25*	*0.40*	*40*	*Light level in front of the lift should be at least $\bar{E}_m$ = 200 lx*
2.5.4	*Loading ramps/bays*	*150*	*25*	*0.40*	*40*	Avoid glare to drivers of vehicles approaching the loading bay. Light and mark clearly the edge of the loading bay

Figure 4. Sample 4 – Page 49 from CIBSE SLL "Code of Lighting"

The main points extracted from each individual interview were summarized, in order to get an overview of the most important ideas relating to lighting standards from the point of view of professionals who work with them on a daily basis. This summary is presented in the form of a table divided in topics of discussion, in order to easily compare the different opinions on the same topic from the 4 interviewees who were asked the second set of questions.

Extracted from these individual and comparative summaries is a list of problems relating to standards and their usability, as well as a list of suggestions about how they could be improved, according to the interviewees.

The interviews have provided a view from within the field, from people who work with them regularly and are very familiar with their format and content. The information they provided is referring more to core issues regarding the usability of standards, which can only be known after numerous experiences with actual projects and encountering specific problems. This gives an important insight that could not be identified by experimenting with individuals who have had little or no contact with the standards before. Further discussion about the usability of the standards as concluded from the interviews is available in the Discussion Section.

2.2.2. Questionnaire for lighting professionals

Development and deployment of a subsequent questionnaire, which was derived from the main conclusions of the interviews, allowed for a wider sample of lighting professionals to provide a general opinion on usability issues of the lighting standard they use most often.

The questions from the interview were analyzed from the point of view of their resulting input from the respondents. The most important ones were then selected and reformulated in a simpler way and multiple choice answers were assigned to each. Furthermore, new topics derived from the

discussions with the interviewees were added to the questionnaire (See Appendix B).

During the interviews it became clear that the most used standard in the lighting practice in Europe is the EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places". For keeping the questionnaire clearer, the questions referred either to this standard in particular, or to the standard declared by the respondent as the most used standard in their practice. Since most respondents did indeed refer to the EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places", the 2 answers that were not about this standard were left out.

While based on the preliminary analysis of the interviews, the questionnaire was developed to address the 3 main traits of usability – effectiveness, efficiency and satisfaction, as shown in the table below.

Table 3. Questions addressing the 3 main traits of usability

Usability Criteria	**Evaluation Questions**
Effectiveness Accuracy and completeness with which users achieve specified goals	How would you evaluate the Standard? (General effectiveness)
	Does the Standard state the design requirements in a clean and unambiguous manner?
	Do the minimum requirements of light levels in the current Standard limit the flexibility in designing energy efficient solutions?
	Does the current version of the Standard sufficiently consider new technologies (e.g. LED)?
	Do requirements in the Standard address real-life issues that can affect lighting? (E.g. surfaces, colours, dust, smoke, etc.)
	Do you think that recent research results about lighting and human vision/health are sufficiently included in the current Standard?

Table 3. Questions addressing the 3 main traits of usability

Efficiency Resources (mainly time) expended in relation to the accuracy with which users achieve goals	How easy is it to find information in the Standard?
	How accessible is the language in the Standard?
	Is it easy to verify that all requirements in the Standard have been met after the project is completed?
Satisfaction Freedom from discomfort, and positive attitude towards the use of the product	Do you think that the Standard limits the designer in proposing creative solutions?
	Do you think that besides scientific findings about good lighting practices, there are other interests behind the Standards?
	How would you evaluate the overall experience in working with the Standard?

The results from the questionnaire were summarized through graphs for each individual question as well as correlation graphs, in order to find possible links between user profile characteristics and their responses. In the "Discussion" section of this paper these findings are further expanded.

2.2.3. Usability experiment with students

An experiment with students of building science allowed for a close inspection of the interaction with the lighting standard EN 12 464 "Lighting of Work Places – Part 1: Indoor" by users with a background knowledge of the issues of lighting, but who had not previously come in contact with the studied standard.

The initial form of the experiment implied a "think-aloud" type of experiment, in which the individual participants were to be closely observed in their interaction with the standard while performing certain tasks, and having them talk about what they are doing at each moment, what problems they encounter and how the document could be more helpful for them (See Appendix D). This version of the experiment was carried out once, with an

architect, and proved very efficient. However, the time needed for this type of experiment would not have allowed for an adequate number of answers to validate the results in an extensive enough manner.

The experiment was therefore adapted to be carried out with a larger group (in this case, students). Questions regarding the tasks as well as self-evaluation questions were part of the experiment, providing results in respect to the performance of completing the tasks, as well as self-evaluation of the participants and direct feed-back about their interaction with the standard (See Appendix E and F).

The table below shows the main traits of usability and the way they are evaluated for each task, either through the direct answers of the participants to the experiment, or through their performance in completing the tasks.

Table 4. Experiment tasks and questions addressing main traits of usability

Task 1 – Familiarization with the standard (15 minutes total)		
Usability criteria		Task / Question
Satisfaction (Freedom from discomfort, and positive attitude towards the use of the product)		Do you now have a clear idea about what kind of information you can find in this Standard?
		Were you able to identify the main chapters and what they contain?
		Would it be easy for you to find specific information in the Standard?
Task 2a – Finding and understanding information (15 minutes)		
Usability criteria	Sub/criteria	Task / Question
Effectiveness	Accuracy and completeness of answer	Define “Task area”, “Immediate surrounding area” and “Background area” and provide lighting requirements for each from the standard

Table 4. Experiment tasks and questions addressing main traits of usability

	Searchability	Were you able to find the information in the Standard?
Efficiency	Intuitive structure of the standard	Did you find the information where you expected to find it?
		Number of steps to finding the information
Satisfaction	Clearness	Is the information clear to you now?
Task 2b – Finding and understanding information (10 minutes)		
Usability criteria	Sub/criteria	Task / Question
Effectiveness	Accuracy and completeness of answer	Define “Mean cylindrical illuminance” and provide lighting requirements from the standard
	Searchability	Were you able to find the information in the Standard?
Efficiency	Intuitive structure of the standard	Did you find the information where you expected to find it?
		Number of steps to finding the information
Satisfaction	Clearness	Is the information clear to you now?
Task 3 – Practical “real-life” example (20 minutes total)		
Usability criteria	Sub/criteria	Task / Question
Effectiveness	Accuracy and completeness of answer	Write down all relevant requirements for an office space as stated in the standard.
	Searchability	Were you able to find the information in the Standard?
Efficiency		Did you find the information where you expected to find it?

Table 4. Experiment tasks and questions addressing main traits of usability

	Intuitive structure of the standard	Number of steps to finding the information

3. RESULTS

3.1. Interviews with lighting design professionals

The results of the interviews can be seen as the transcripts of the audio recordings in Appendix A. The main points extracted from each individual interview were summarized, in order to get an overview of the most important ideas relating to lighting standards from the view of professionals who work with them on a daily basis.

The answers from the interviews could be further summarized based on the main topics of discussion and organized in the table below. This way, a comparison can be made between the 4 interviewees on which the same interview protocol was used.

Table 5. Interviews summarized answers

Topic	Interview 2	Interview 3	Interview 4	Interview 5
When do standards come up in the Lighting Design Process?	As framework at the beginning and to re-check at the end	From the very beginning and throughout the lighting design process	From concept phase to detail and until the end, designing within the standards	All phases (concept, detail, verification)
Digital or Printed?	Digital Easy to access and search (a more intelligent search function would be good)	Printed It feels more "real" to read it on paper	Printed Easy and more comfortable to mark/find important pages	Printed and Digital If the pdf is not searchable, then printed is preferred
What chapters* are most frequently used	Lighting requirements	Lighting requirements values, glare	Lighting requirements values	Lists and values

while working on projects?	values, glare and contrast As framework and as decisive argument in discussion with the architect/interior designer	Not so much: Calculation methods (calculations done by software)	The rest is generally already known	Most other chapters are already known
Mediums of keeping up-to-date with new versions of standards	Discussions in LTG meetings, discussions with colleagues, reading it as soon as possible	Checking the new version when it is needed in a project	Market, newsletters, looking for differences from the old version as soon as the new one is available	Events for designers by companies that work in the regulations institute (Light Days, LTG, Zumtobel), newsletters, presentations
Constraints in the lighting design process	The best solutions come from restrictions – standards requirements are among them – acting as a framework	Some requirements are too restrictive Ex: A range would be better than a minimum/maximum value	Some requirements are sensible, while others are not, resulting in a narrow spectrum of solutions	We need regulations The state of the art of technological development is not enough
Do you get the needed input from the standards?	Yes	Most of the time Some areas are not easy to understand	It depends on the standard In the case of 12 464 – yes; others are not very clearly written (e.g. Tunnel lighting standards)	No Standards tend to get crowded up after several revisions (mostly electrical standards)
Are the Standards in line with the latest technology?	To keep up with the pace at which technology evolves, standards should be revised every 2 years (instead of 5 or 10)	New requirements should be integrated in the standards to regulate new technologies (LED light colour affects	Yes – they only give values, while choosing the technology is up to the designer	They are not, they should be quicker updated to new technologies. For LED we need very urgent regulations.

Table 5. Interviews summarized answers

		the quality of lighting)		
Mistakes in the standards?	No Standards are a snapshot in time, constantly evolving, getting better	Lighting requirements are too high and in some cases not necessary – they are industry driven (See Annex for examples)	Human vision and health are not sufficiently considered; Some areas could be explained better/clearer	There are sometimes conflicts with other regulations (See example in Annex)
Are the definitions and explanations clear and understandable ?	More or less – some must be read 2-3 times to understand	European Standards are usually better than American ones. Operator standards can be quite complicated.	Mostly ok Might be hard to understand for people who don't use them so frequently	Not always – some are too long and complicated and one must read them 2 or 3 times to understand
Vague content in the standards?	It happens, yes, but they are always improving them	There are requirements that cannot be easily checked at the end of the project. Ambient factors (surfaces characteristics , dust, etc.) are not sufficiently considered.	Yes, but with good lighting designers, interpretable content gives room for flexibility, so it can be a good thing	No
What would happen if no standards were to be used?	More fighting, more suing, safety issues	In some cases it would be better, depending on who is doing the design. In other cases, it could lead to safety issues.	The quality of lighting design would be lower. Still, standards could be better in this regard.	Lower lighting design quality, safety issues.
How do the standards influence energy efficiency?	Lighting standards are not about energy efficiency, they are about	Energy consumption would be higher. It is already too high	It depends on the designer and the interests.	Power consumption would rise without standards.

Table 5. Interviews summarized answers

	lighting levels, health and safety	because of the standards.		
Overall satisfaction in working with standards	It is ok. One word description of their usability: Useful. Necessary.	It's fine. One word description of their usability: Practicable.	It is ok. One word description of their usability: Helpful.	We need it. One word description of their usability: Awful.
Are the standards searchable?	Sometimes it is faster to search for something on Internet than in the standards	Most of the time, yes	Usually, yes (familiar format)	It's good when the standards are searchable, but with internet it is even easier
Are design format and layout of the standards important? (see also comparison test)	Yes. Familiarity with the layout is very important. Colours are not that important.	Definitely – format and graphics are very important	It would help to understand better	Standards should be more like travel guides, without so many footnotes and references from one page to another
Last suggestions about making standards more usable	A better search function, a clickable glossary at the end, clear structure of the chapters, an overview at the beginning	Energy consumption, budget and overall quality of lighting would all be better if the standards were written through independent sources	Consulting with lighting professionals for making the standards would make them more usable	Each line should have a number, to be easy to reference.

Since the first interview was made using the first set of questions (See Table 1), the main ideas could not be included in the summary table above. Below is a summarized list of the main topics that emerged and the interviewee's opinion about them:

- Standards are considered a minimum requirement, which must be fulfilled, but only after that does the lighting design really begin.

- Standards are to lighting designers what laws are to lawyers – they must be interpreted.
- The better one is at interpreting the standard, the better quality of lighting design.
- Standards make life easier.
- Lighting standards are behind technological progress in the field of LED, making the job of the lighting designer very hard.
- Design of the standard was not an issue in talking about usability
- One problem with standards is that the comities making them include for the most part people from the lighting industry, who bend the requirements in their own commercial interest.

3.2. Questionnaire for lighting professionals

The questionnaire was addressed to professionals in Austria and the UK and had a response rate of approximately 20%. There were responses from lighting designers of different ages (24 to 57), different backgrounds and years of experience in the field (from 1 to over 25 years) fairly evenly distributed. A full list of the user profiles is available in Appendix C.

The figures below correspond to each question as a graph, giving an overview of the questionnaire responses. On the horizontal axis are the 4 answer options of each question, while the vertical axis counts the number of answers corresponding to each category.

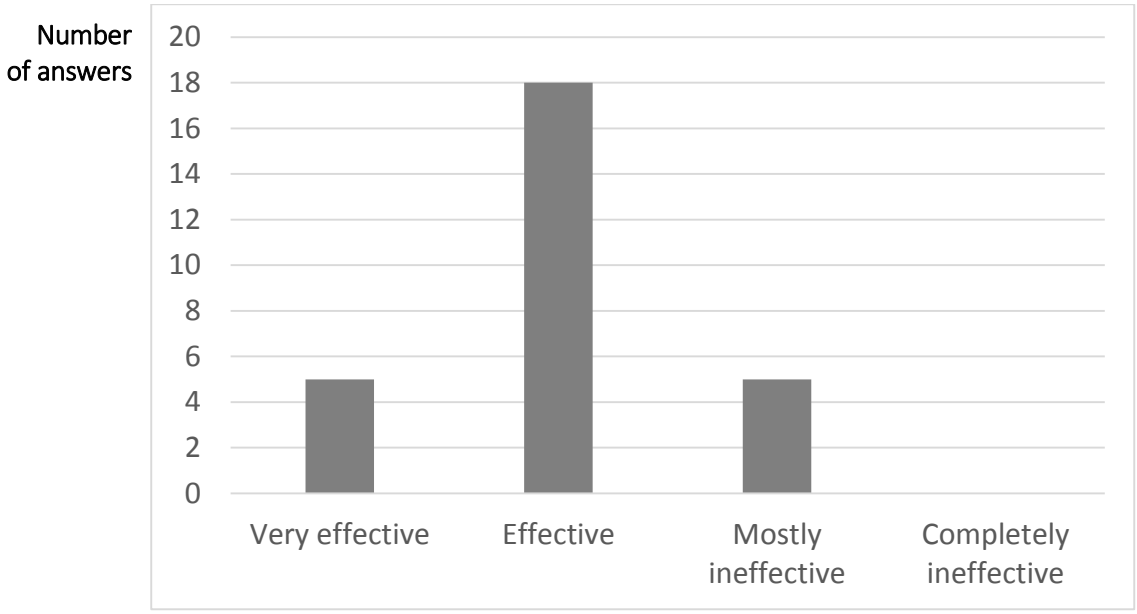

Figure 5. How would you evaluate the standard?

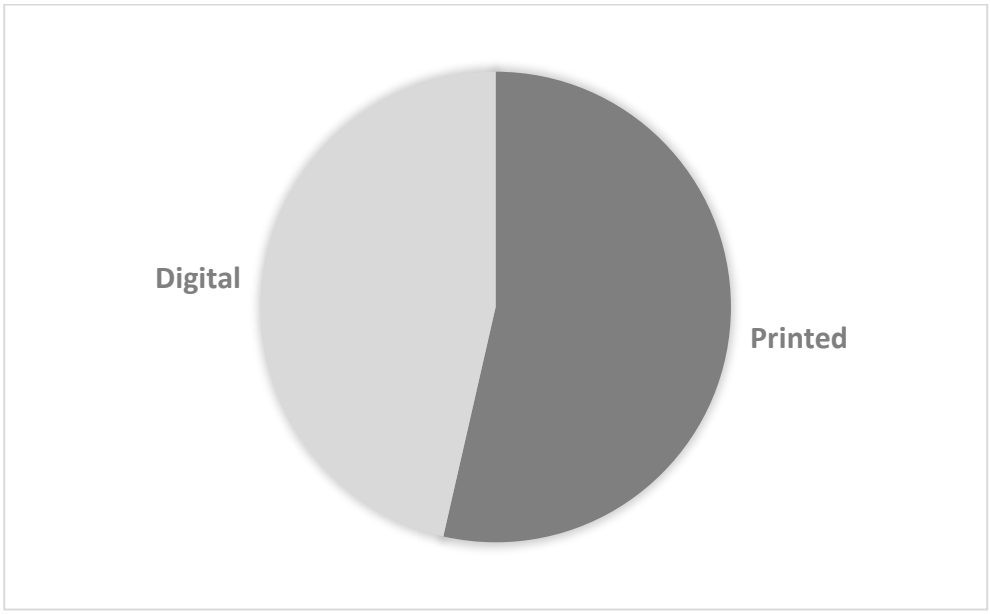

Figure 6. Do you prefer the printed version or the digital version of the standard?

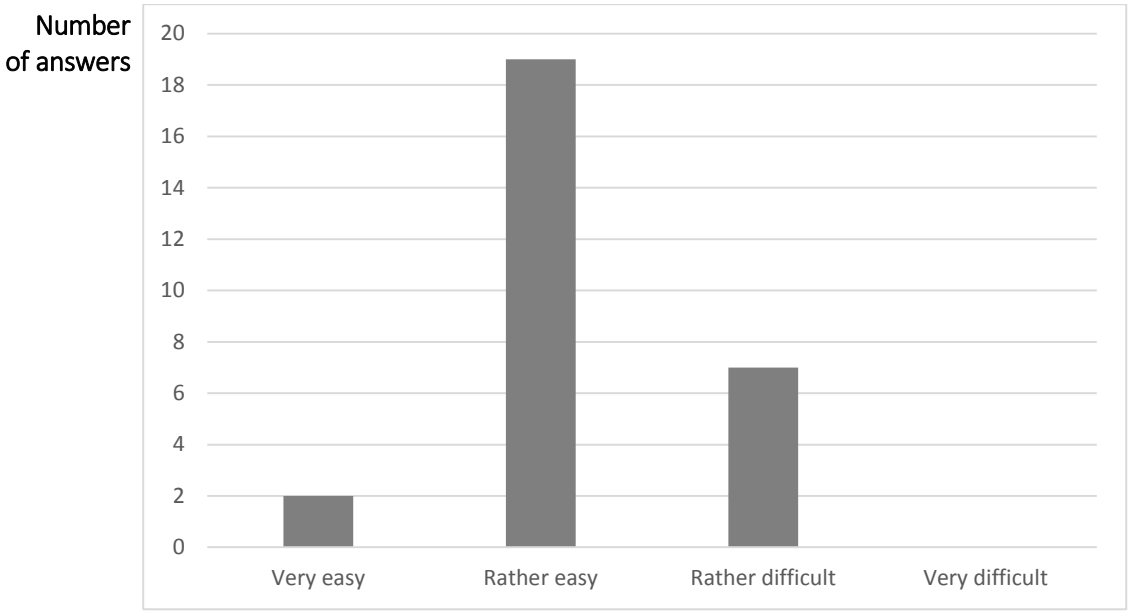

Figure 7. How easy is it to find necessary information in the Standard, without using other resources (Google, etc.)?

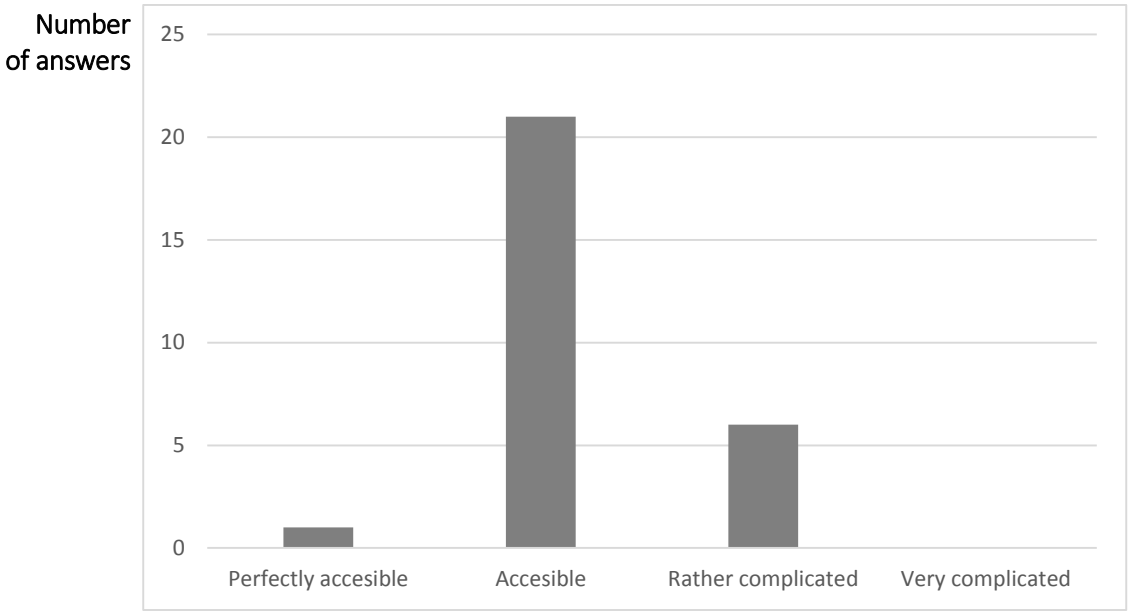

Figure 8. How accessible is the language used in the Standard?

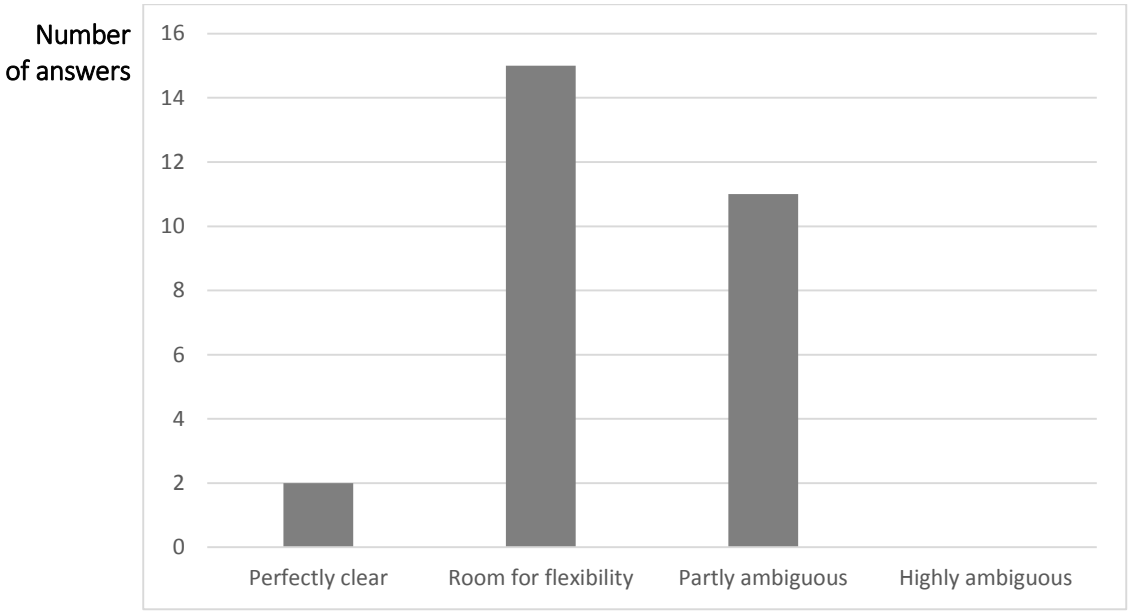

Figure 9. Does the Standard state the design requirements in a clean and unambiguous manner?

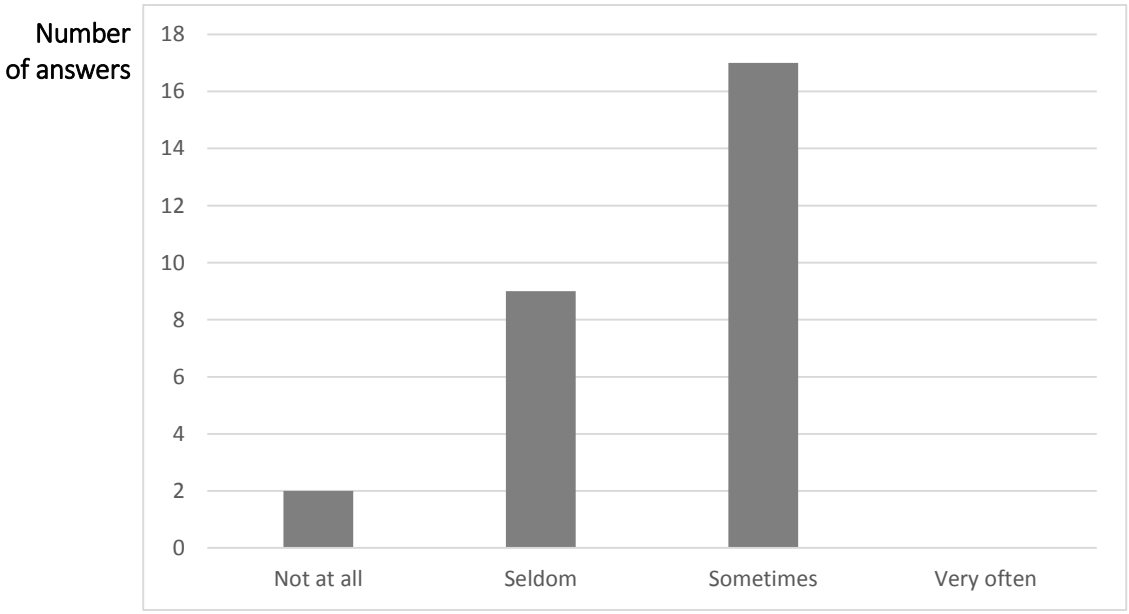

Figure 10. Do the minimum requirements of light levels in the current Standard limit the flexibility in designing energy efficient solutions?

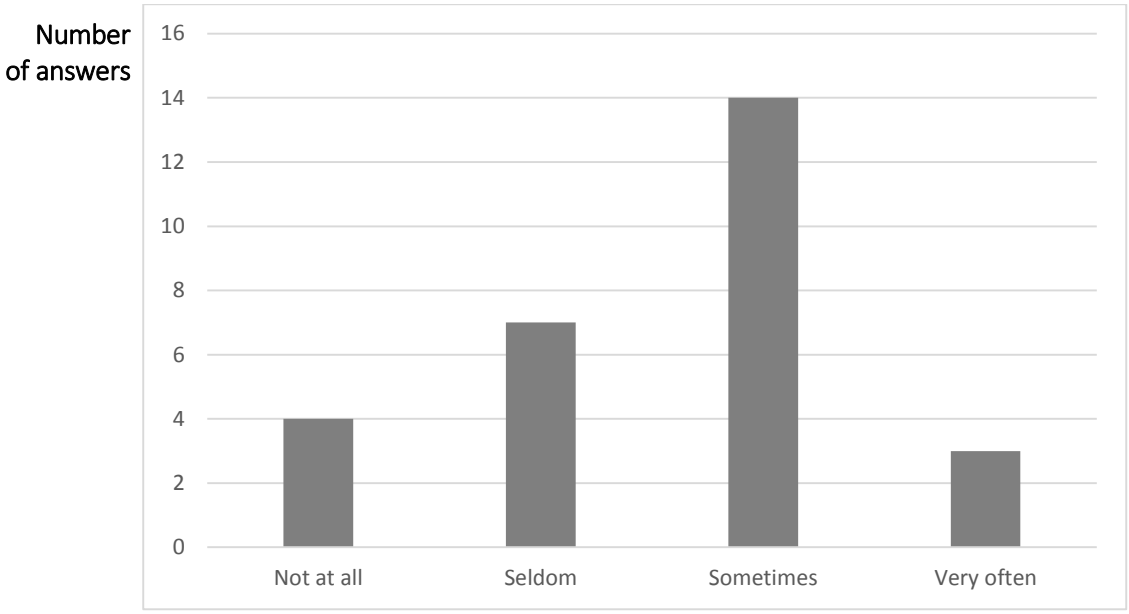

Figure 11. Do you think that the Standard limits the designer in proposing creative solutions?

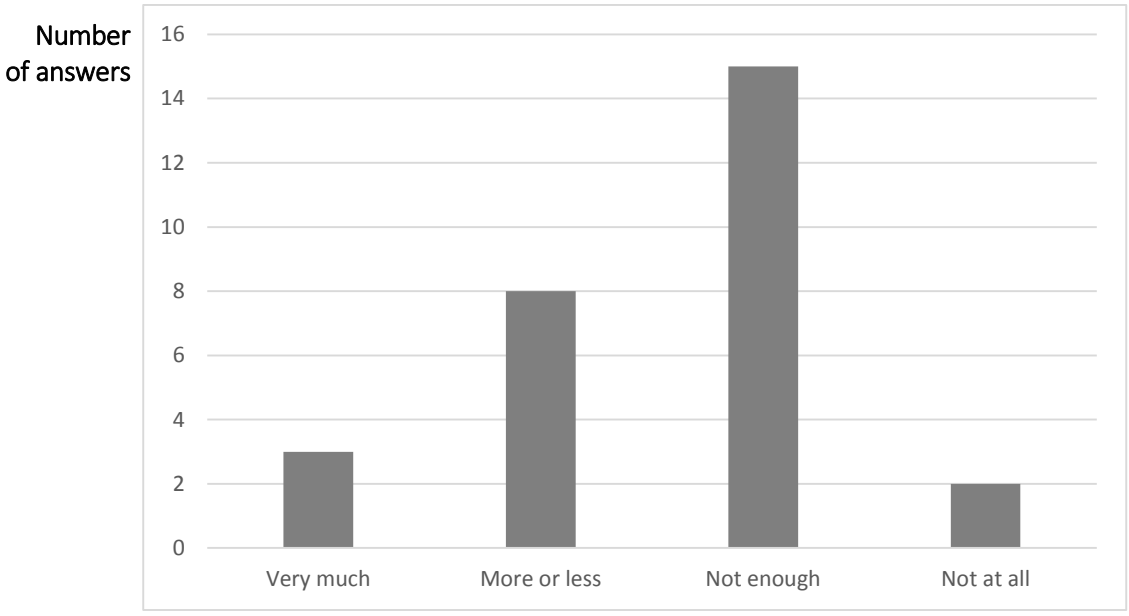

Figure 12. Does the current version of the Standard sufficiently consider new technologies (e.g. LED)?

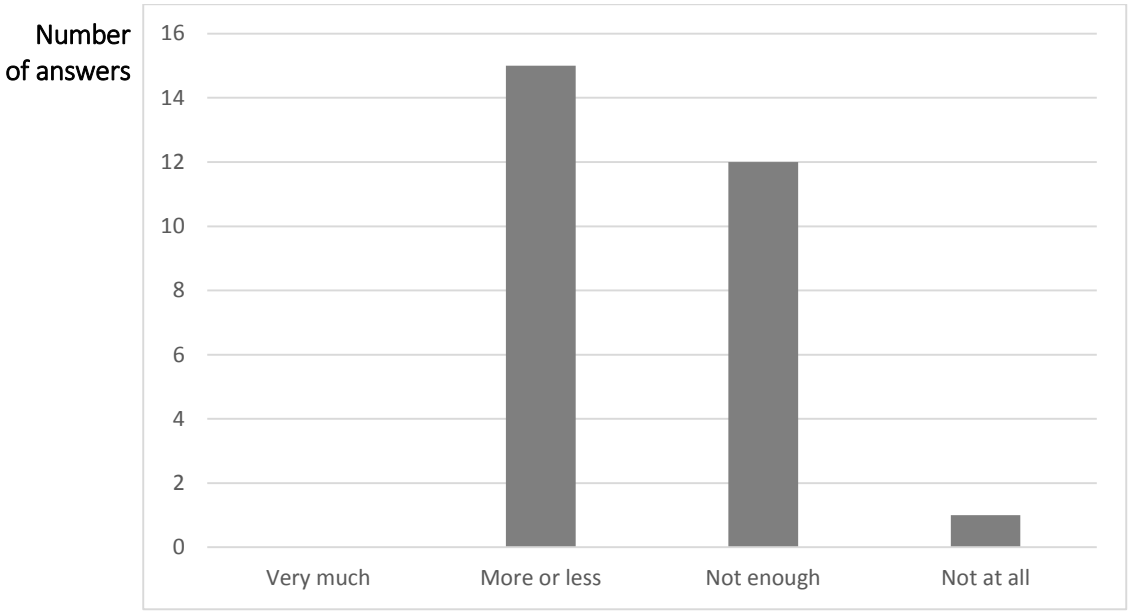

Figure 13. Do requirements in the Standard address real-life issues that can affect lighting? (Colours, dust, smoke, etc.)

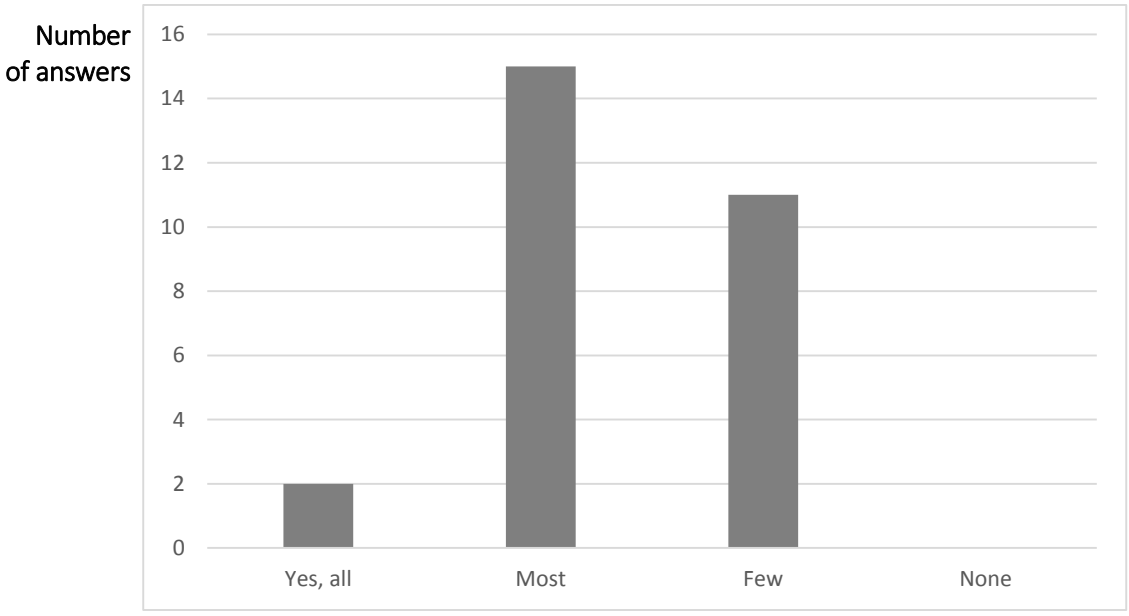

Figure 14. Is it easy to verify that all requirements in the Standard have been met after the project is completed?

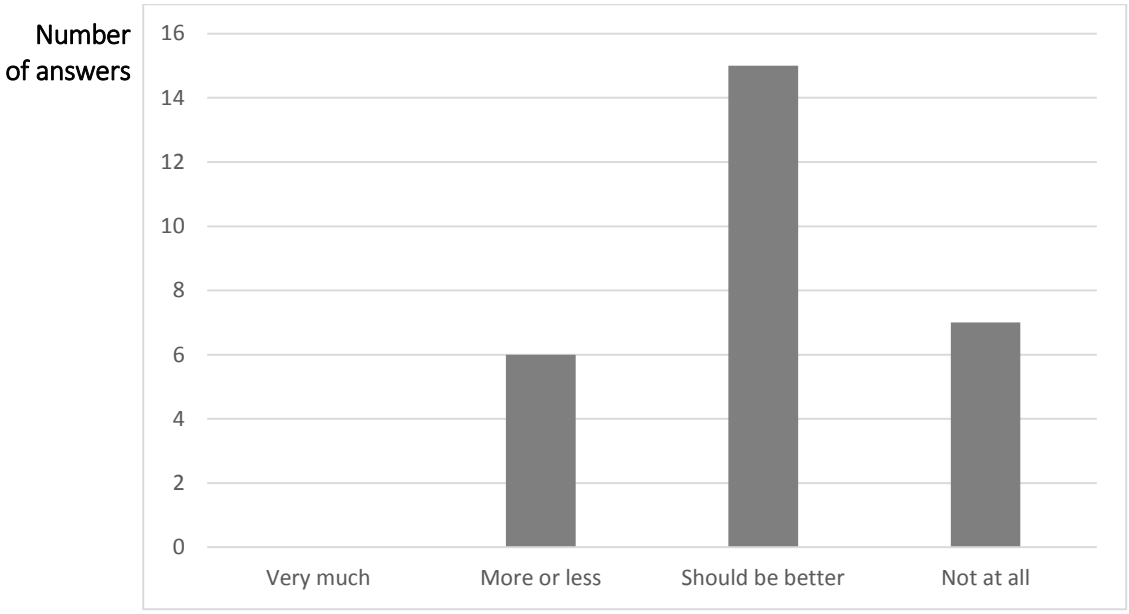

Figure 15. Do you think that recent research results about lighting and human vision/health are sufficiently included in the current Standard?

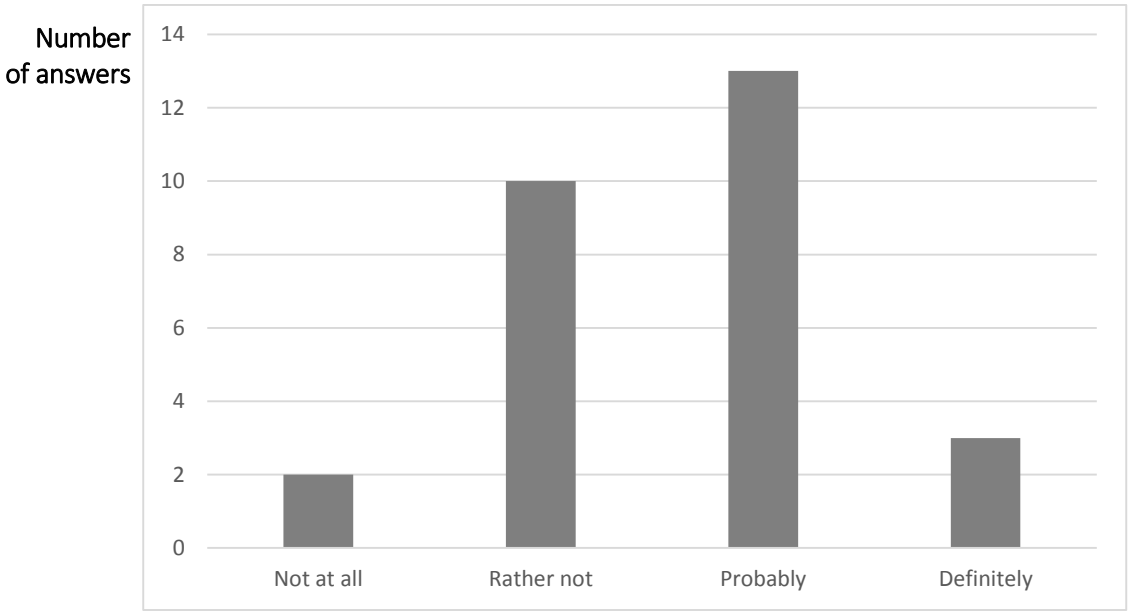

Figure 16. Do you think that besides scientific findings about good lighting practices, there are other interests behind the Standards?

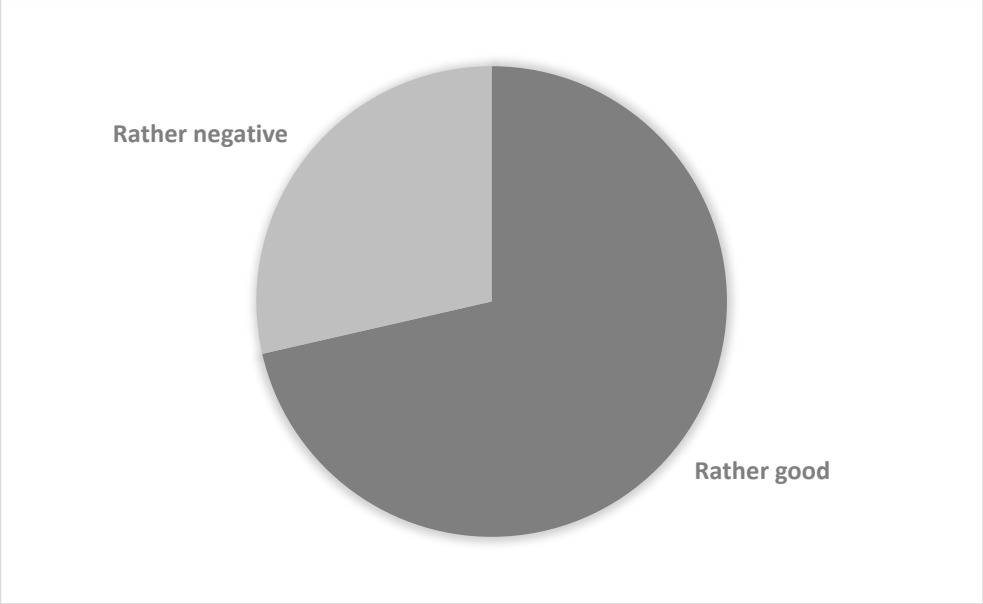

Figure 17. How would you evaluate the overall experience in working with the Standard?

The following figures show the correlation between different factors taken from the user profiles such as age and years of experience and their answers regarding lighting standards.

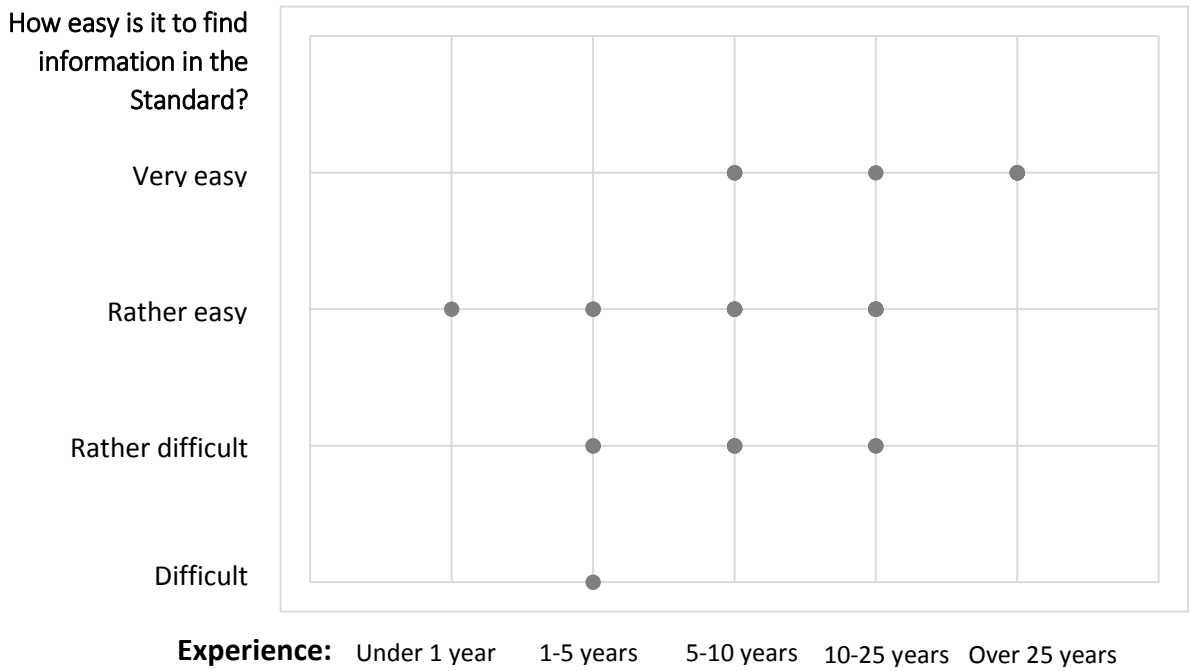

Figure 18. Correlation – Experience duration vs. perception on the searchability of Standards

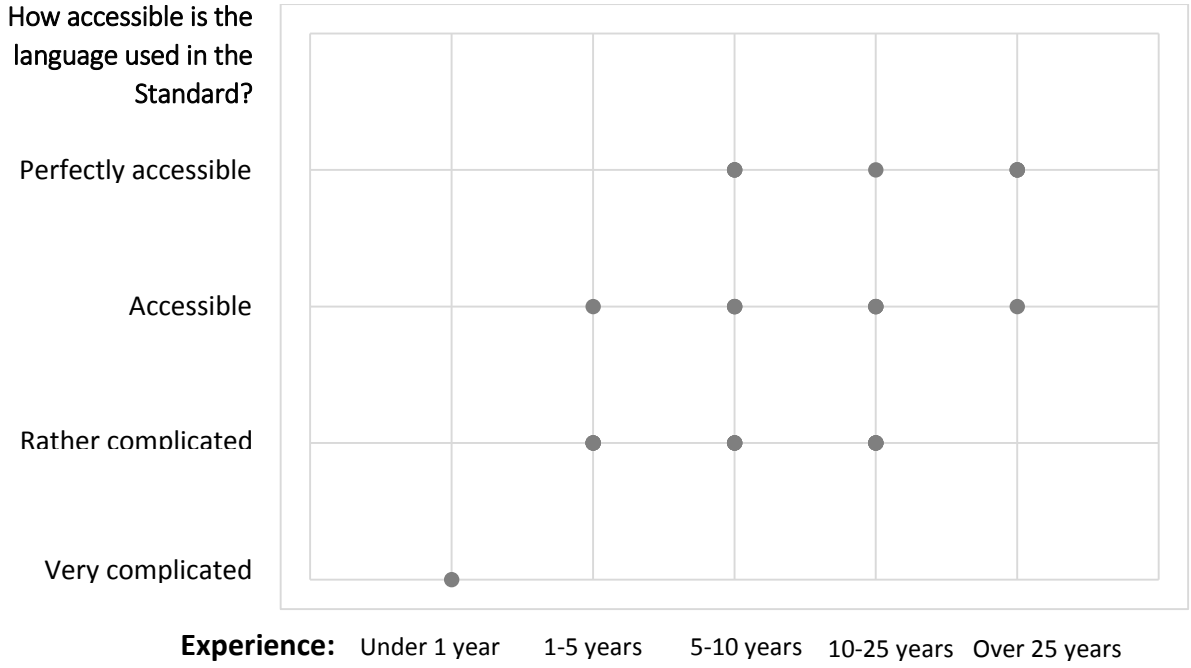

Figure 19. Correlation - Experience vs. Language accessibility

3.3. Experiment with students

The experiment was conducted with the kind participation of 37 students of the "Visual aspects of building performance" course by the Department of Building Physics of the University of Technology in Vienna. The age range of the participants was 21-32 years old, with most of them having had no prior contact with standards of any kind before.

The experiment slides and form filled by the participants are available in Appendix E and F.

The following figures summarize in a concise way the results of the experiment, task by task. In the Discussion section of this paper, the answers are analyzed and expanded.

Stage 1: Familiarization with the standard

Task 1. Create a mental picture of the Standard, for future use. What does the Standard contain? Which are the most important/useful chapters? Write down your first impressions. Use sticky notes to mark important places.

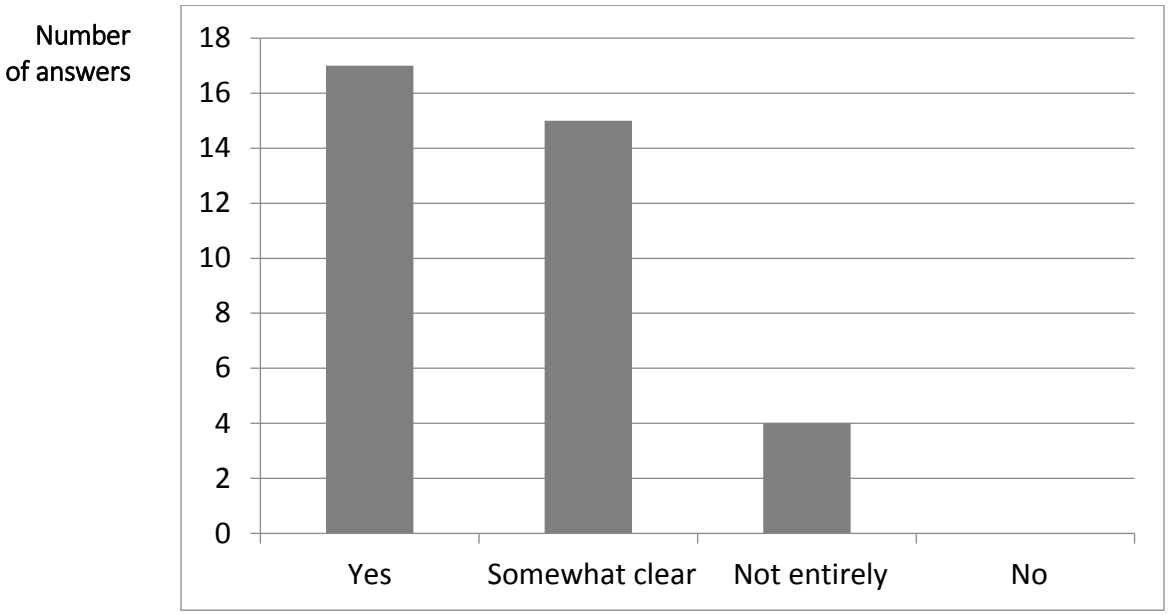

Figure 20. Do you now have a clear idea about what kind of information you can find in this Standard?

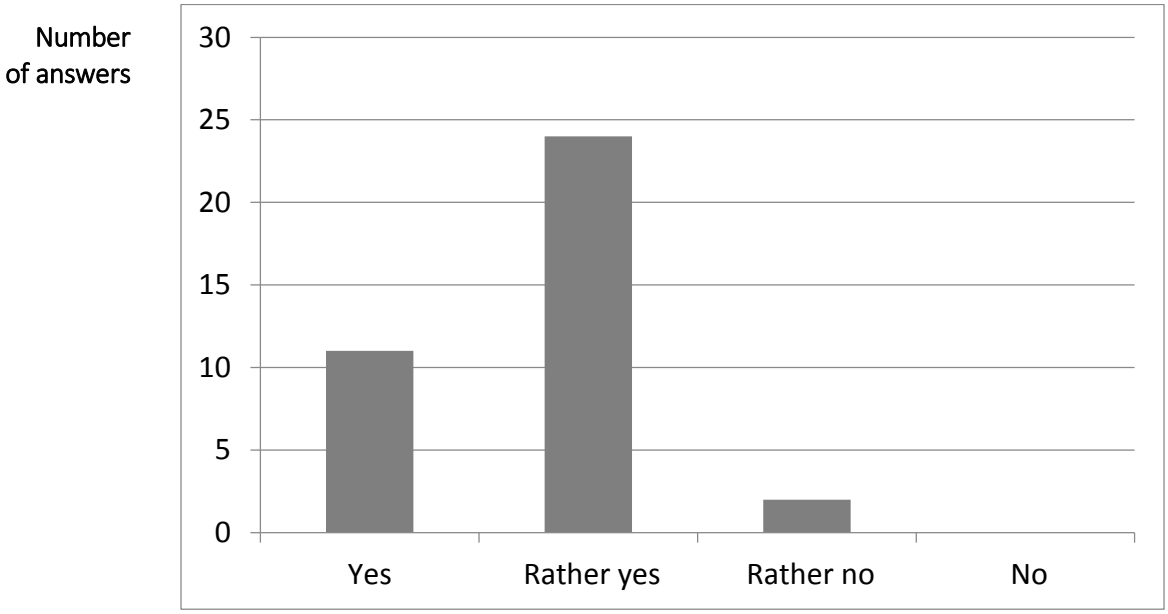

Figure 21. Were you able to identify the main chapters and what they contain?

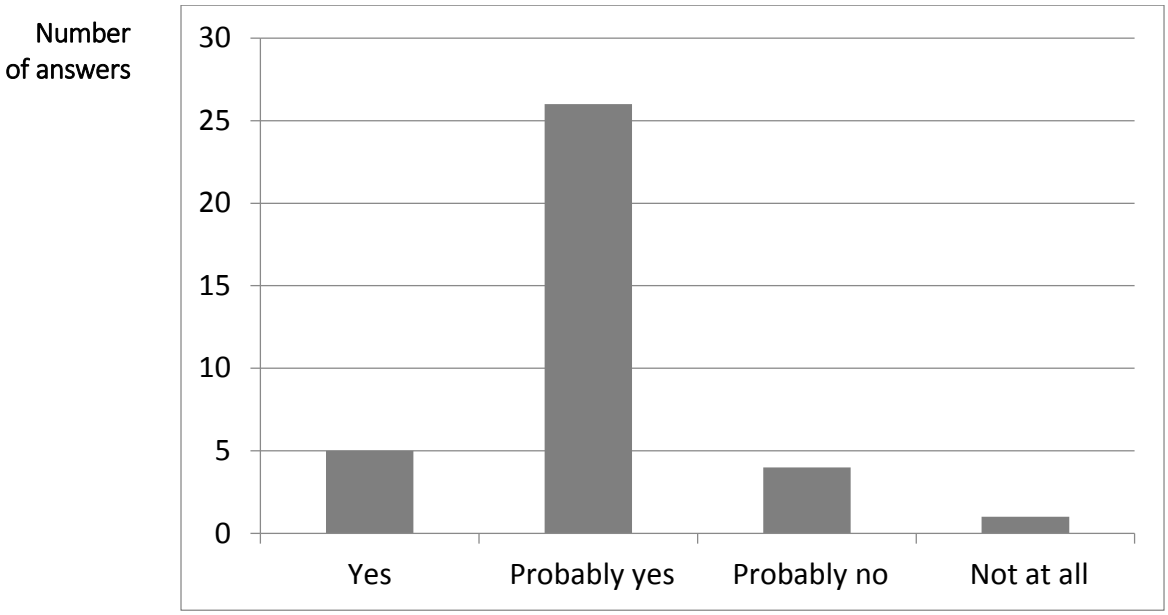

Figure 22. Would it be easy for you to find specific information in the Standard?

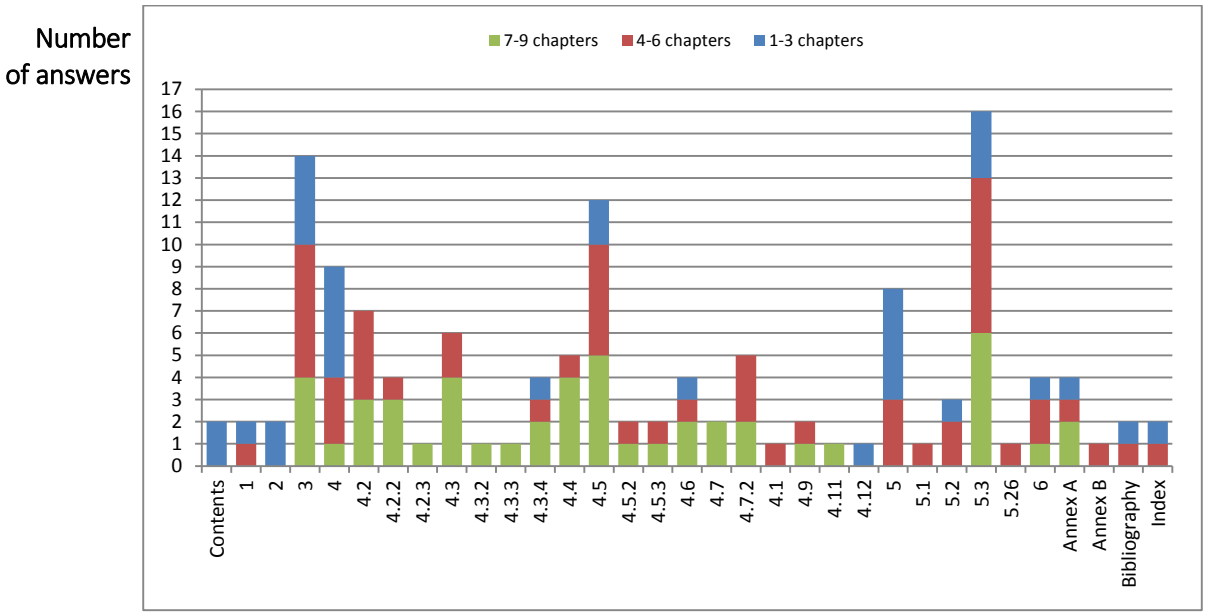

Figure 23. Chapters most marked by users (divided in groups by the total number of marked chapters)

Stage 2: Finding and understanding specific information

Task 2a. According to the Standard, how are the following concepts defined? 1. “TASK AREA” 2. “IMMEDIATE SURROUNDING AREA” 3. “BACKGROUND AREA”. What are their dimensions? What are their required lighting values?

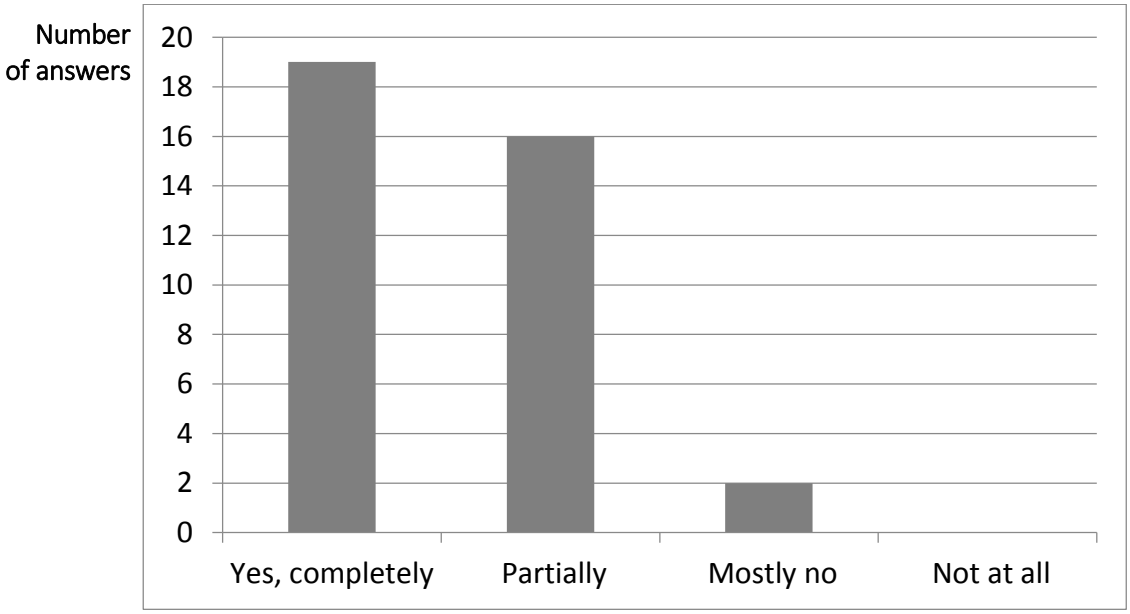

Figure 24. Were you able to find the information in the Standard?

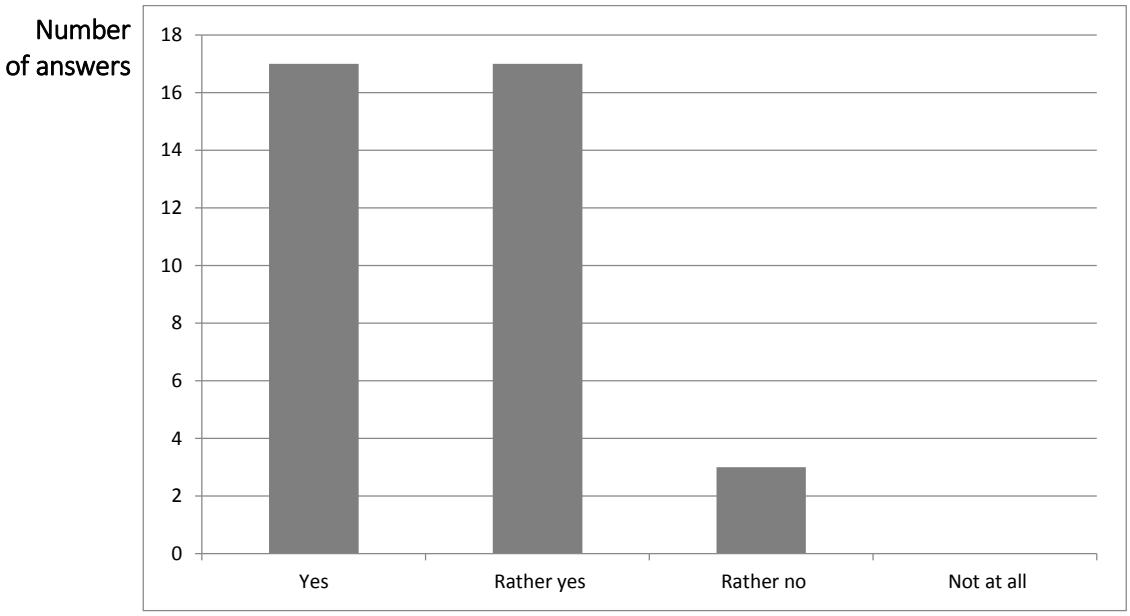

Figure 25. Did you find the information where you expected to find it?

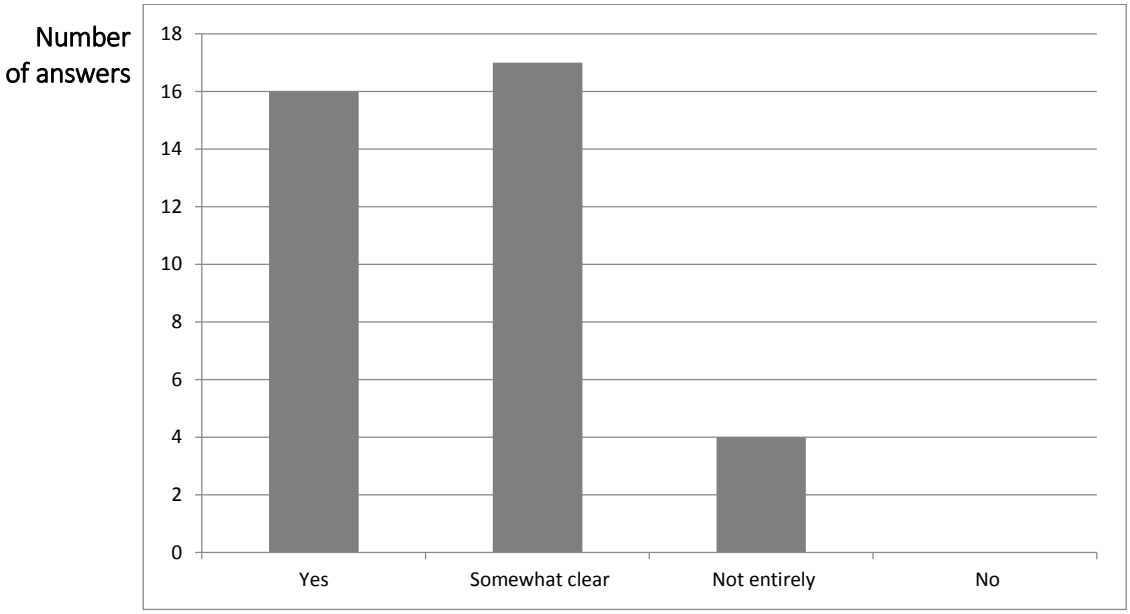

Figure 26. Is the information clear to you now?

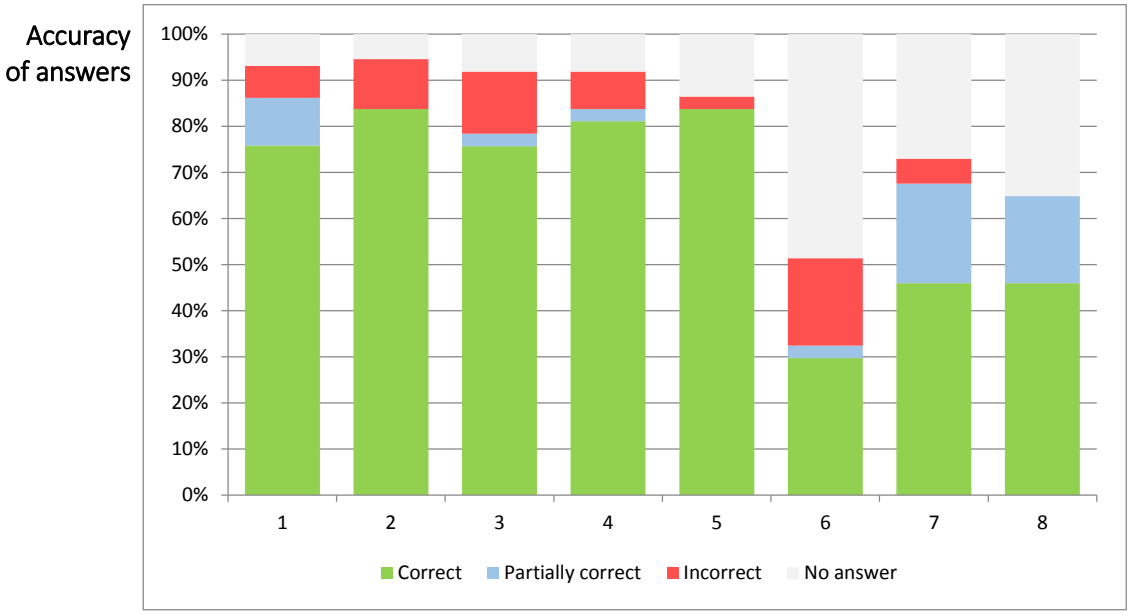

Figure 27. Evaluation of the answers

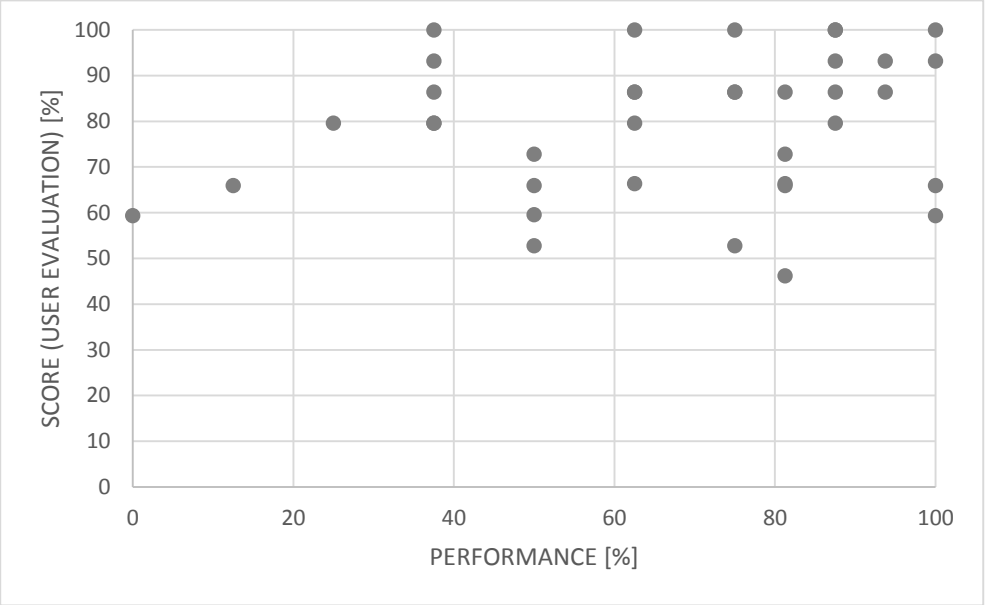

Figure 28. Correlation – Users self-evaluation vs. actual performance

Task 2b. According to the Standard, what is "mean cylindrical illuminance" ? In what plane/planes is it measured? What are its required lighting levels?

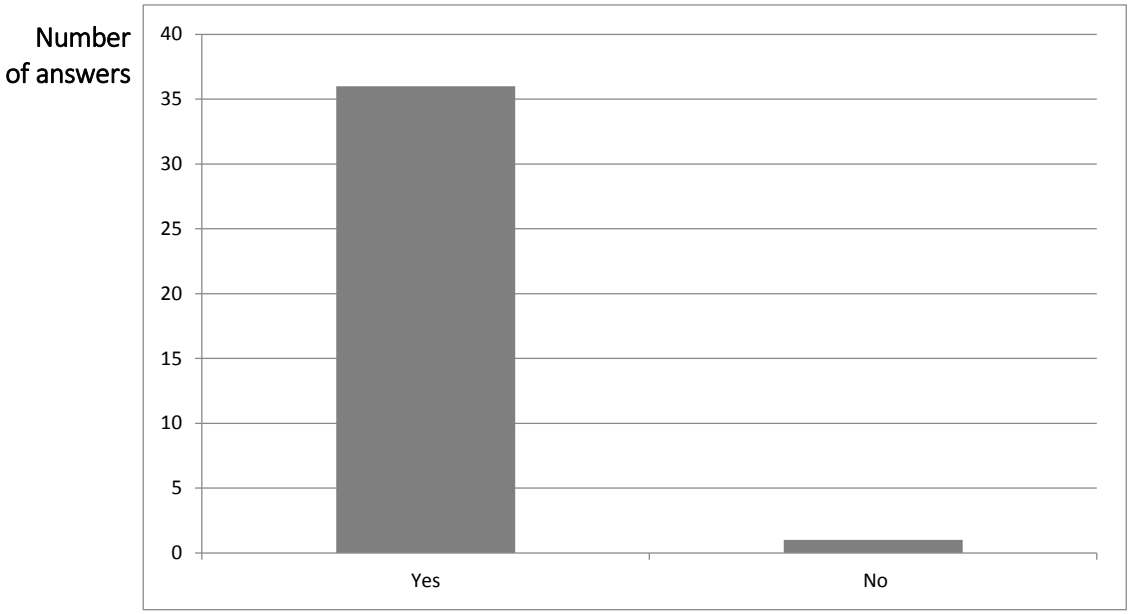

Figure 29. Were you able to find the information?

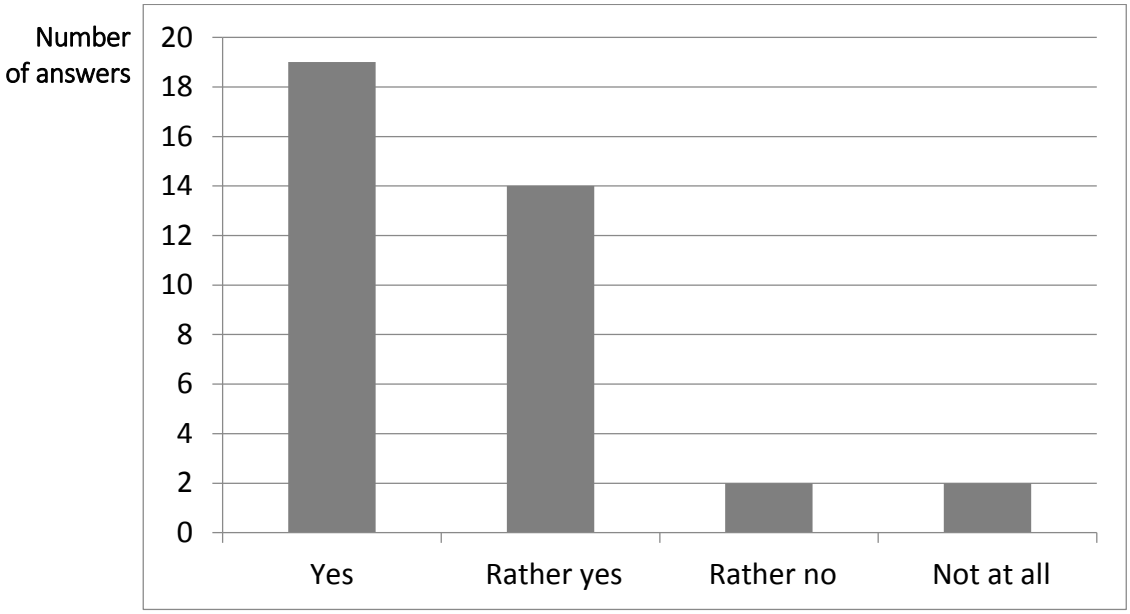

Figure 30. Did you find the information where you expected to find it?

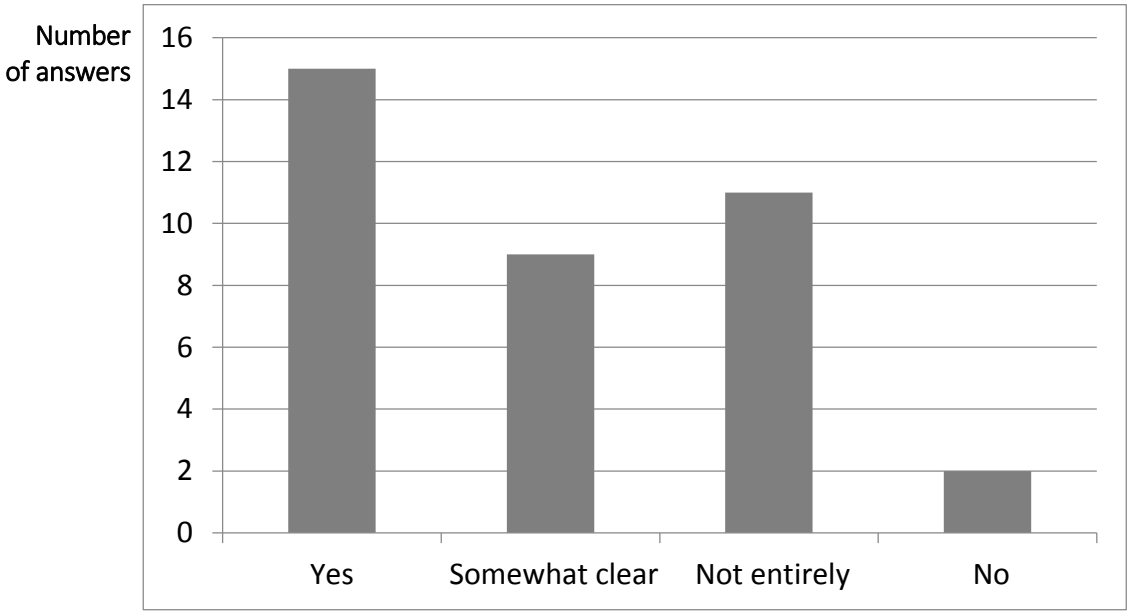

Figure 31. Is the information clear to you now?

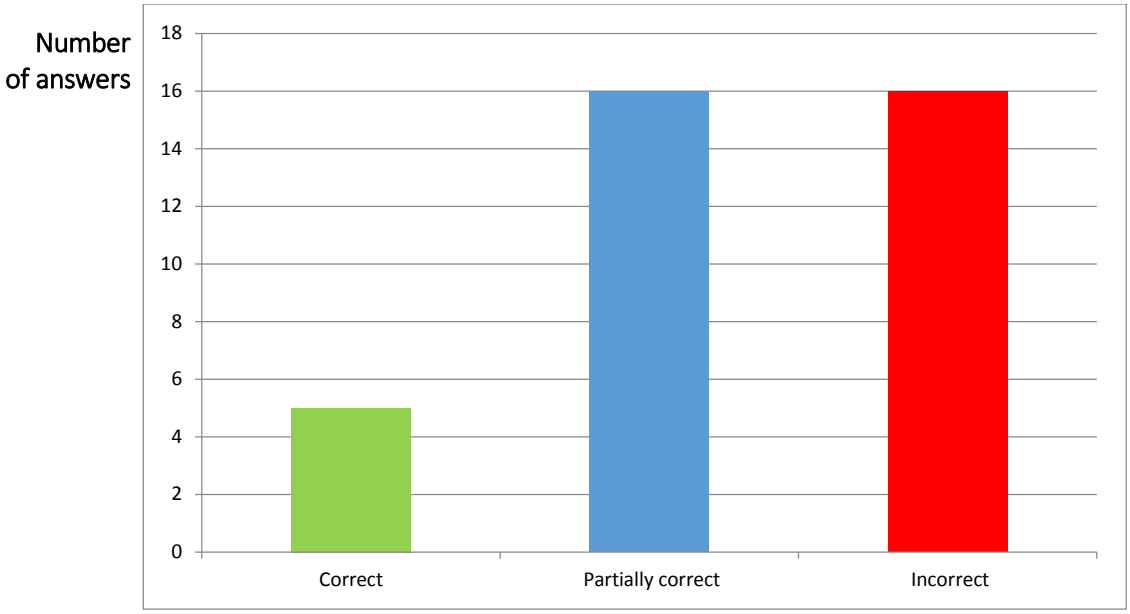

Figure 32. Evaluation of answers

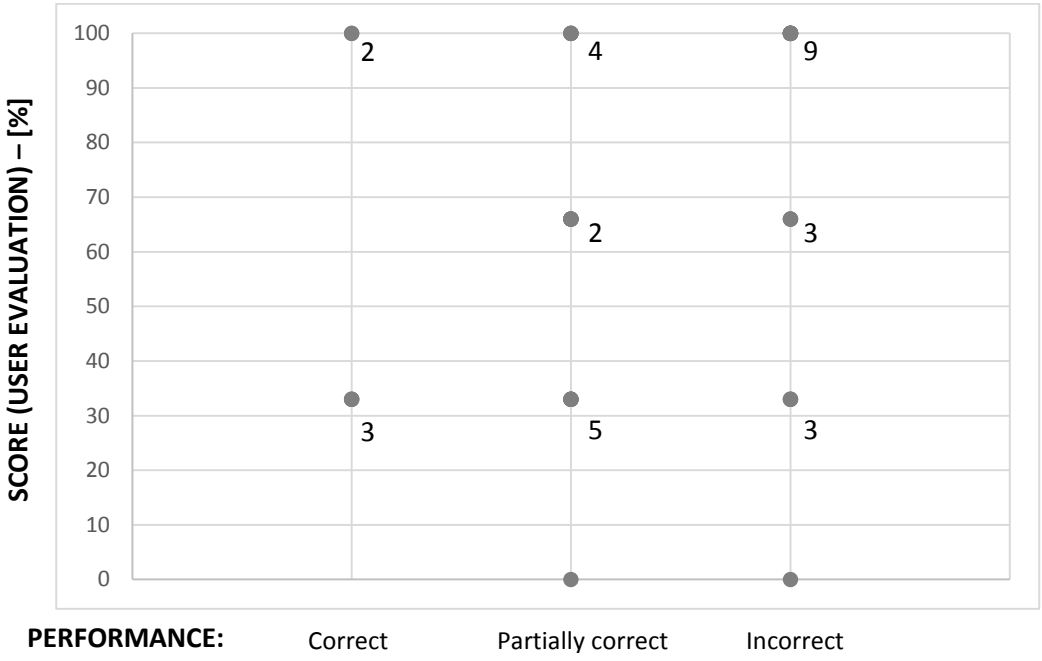

Figure 33. Correlation – Users self-evaluation vs. actual performance

Stage 3: Using the Standard in a practical real-life example

Task 3. You must develop the lighting design of an office space, in which activities such as office work (writing, reading, working on computers), as well as meetings will take place.

The design will also include a small eating area, a corridor and toilets. Extract from the Standard all required lighting values and regulations that apply to your project.

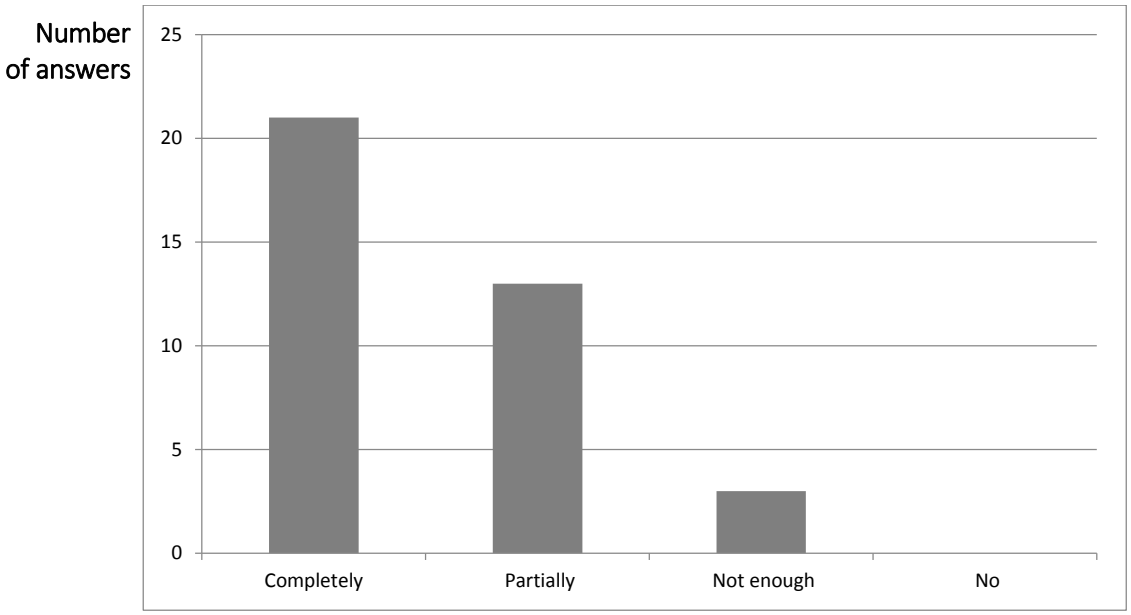

Figure 34. Were you able to find the information in the Standard?

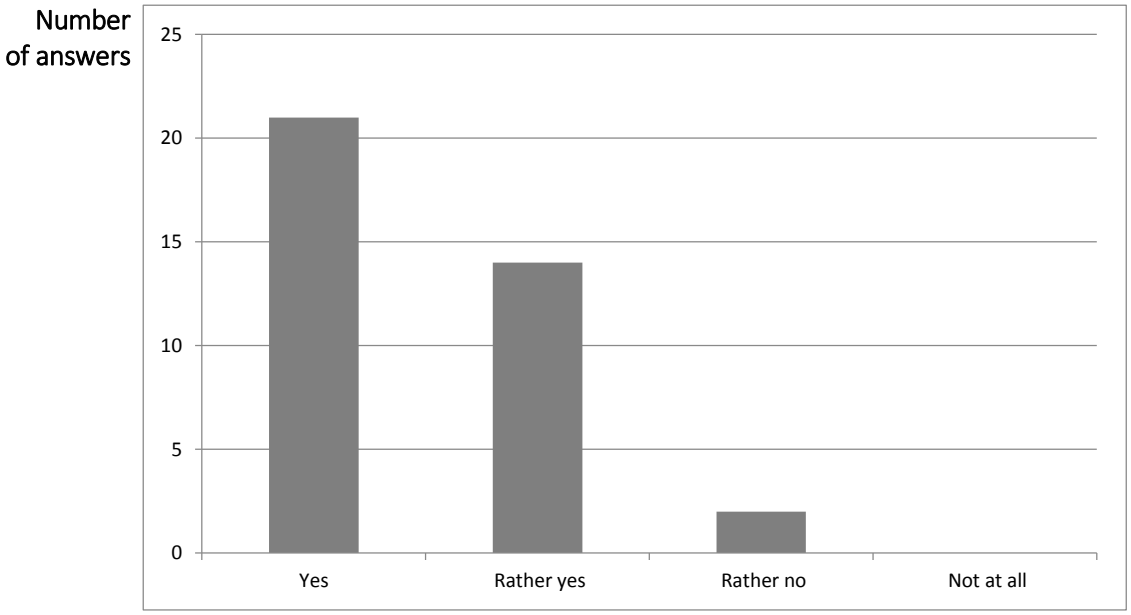

Figure 35. Did you find the information where you expected to find it?

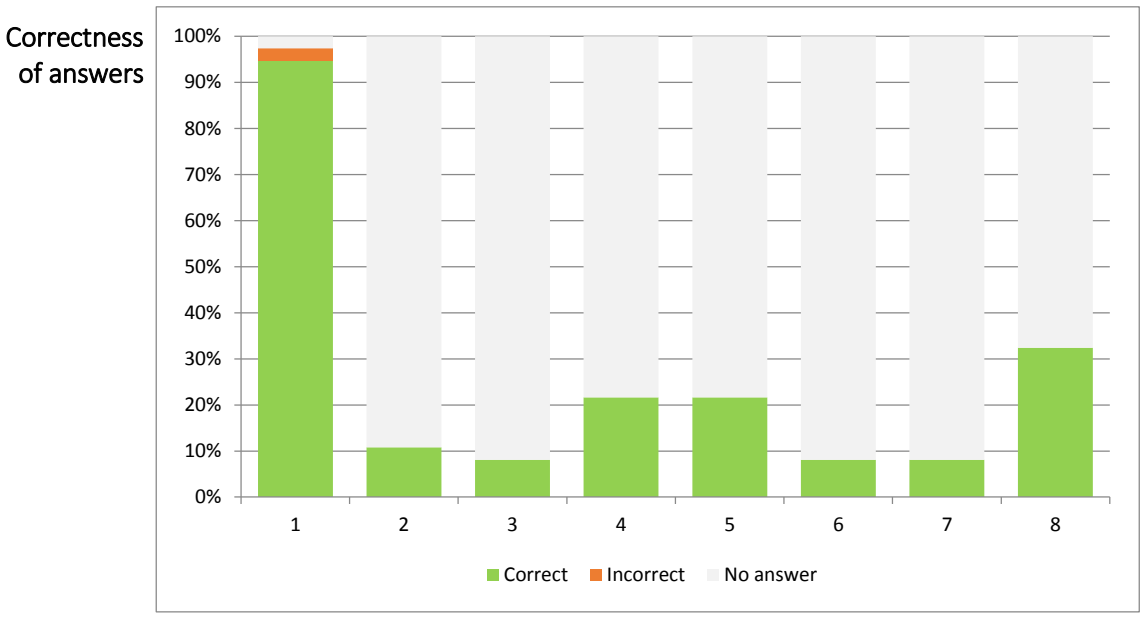

Figure 36. Evaluation of the answers

1 – Requirements from Tables (5.3)

2 – Recommended reflectances of surfaces (4.2.2)

3 – Maintained illuminances on the major surfaces (4.2.3)

4 – Illuminance on IMS (4.3.4)

5 – Illuminance on background area (4.3.5)

6 – Shielding against glare (4.5.3)

7 – Mean cylindrical illuminance (4.6.2)

8 – Average luminance limits of luminaires, which can be reflected in flat screens (4.9.2)

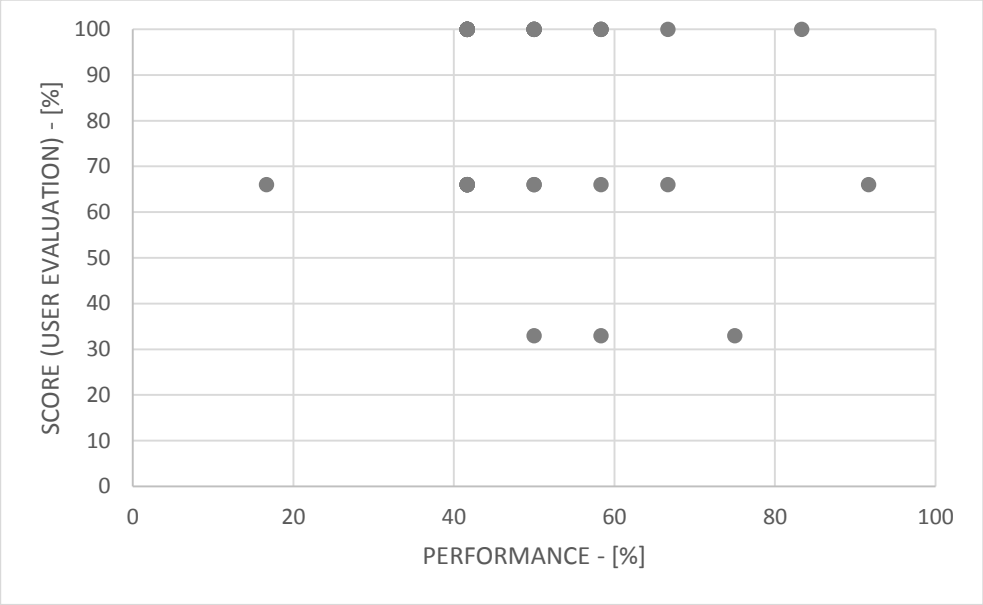

Figure 37. Correlation – Users self-evaluation vs. actual performance

Throughout the experiment the participants were asked for feed-back after each question in order to evaluate the standard's level of verifiability – in what measure can a user be sure that the information extracted from the standard is correct and complete for the task.

At the end of the tasks, a form of final feed-back questions regarding the overall experience of working with the standard was completed by the participants, as shown in the following graphs.

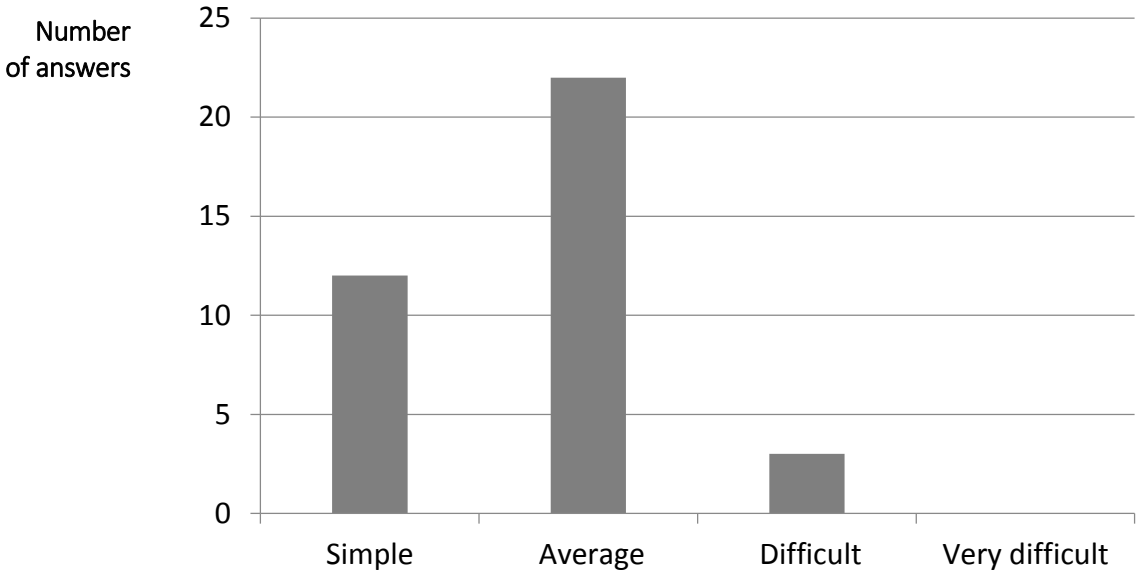

Figure 38. How simple was it to work with the standard?

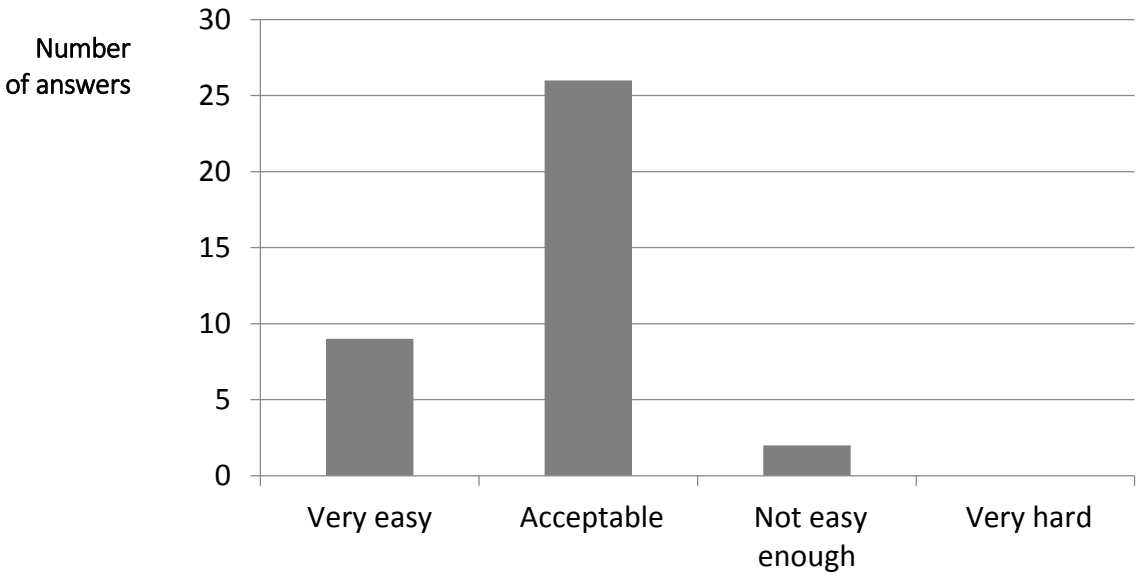

Figure 39. How easy was it to find information in the standard?

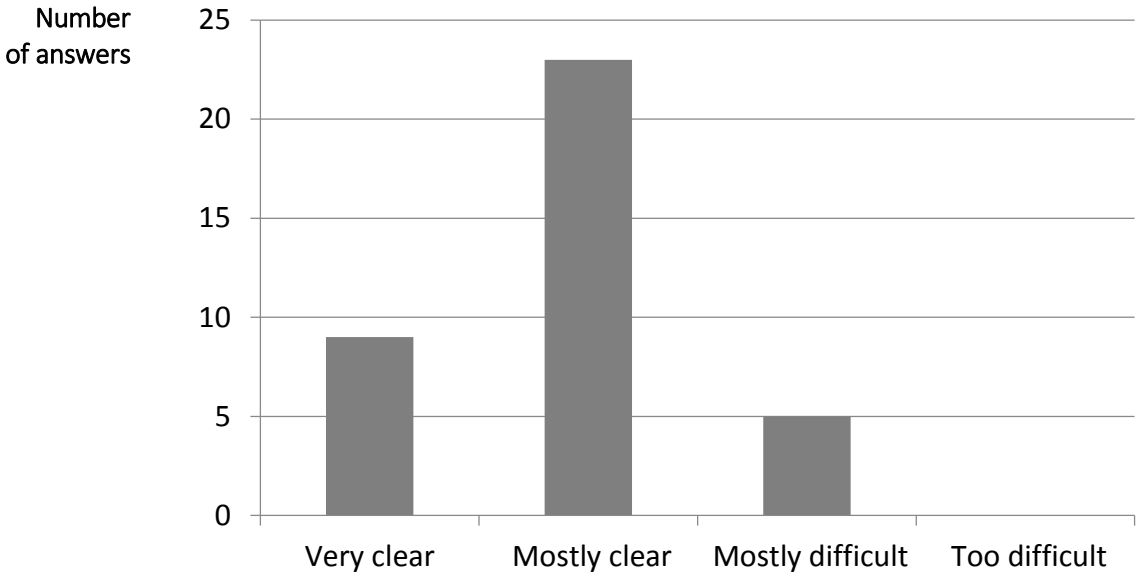

Figure 40. How clear is the language used in the standard?

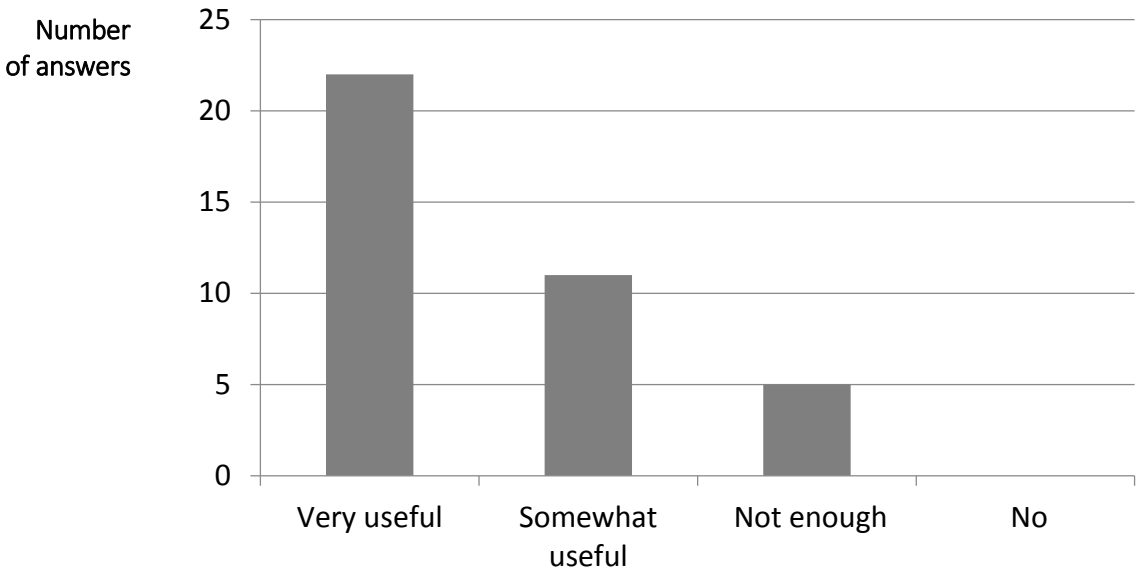

Figure 41. Was the table of contents useful?

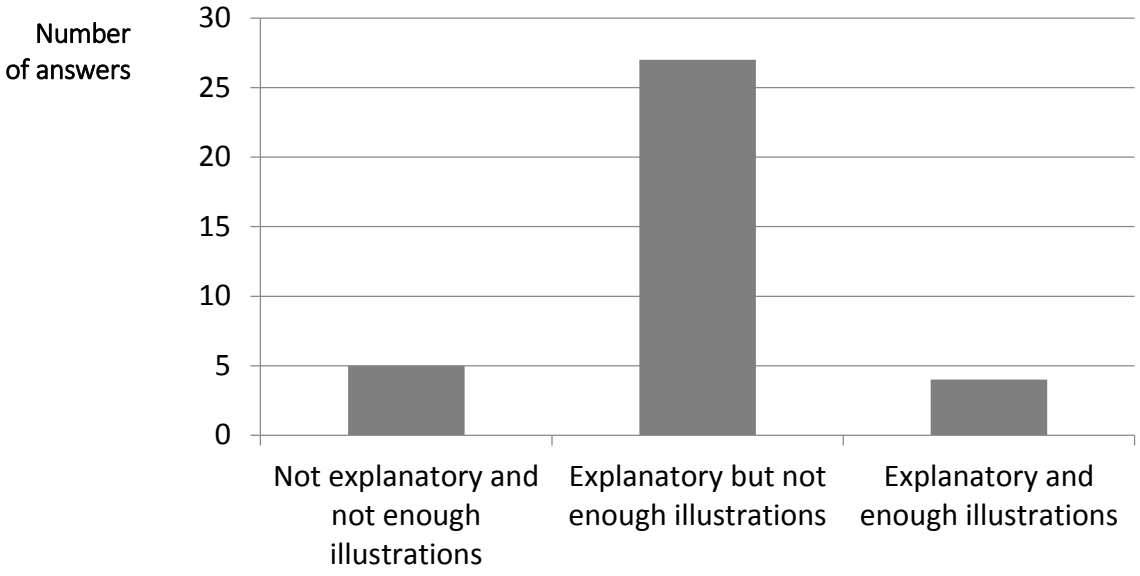

Figure 42. Please evaluate the illustrations in the standard

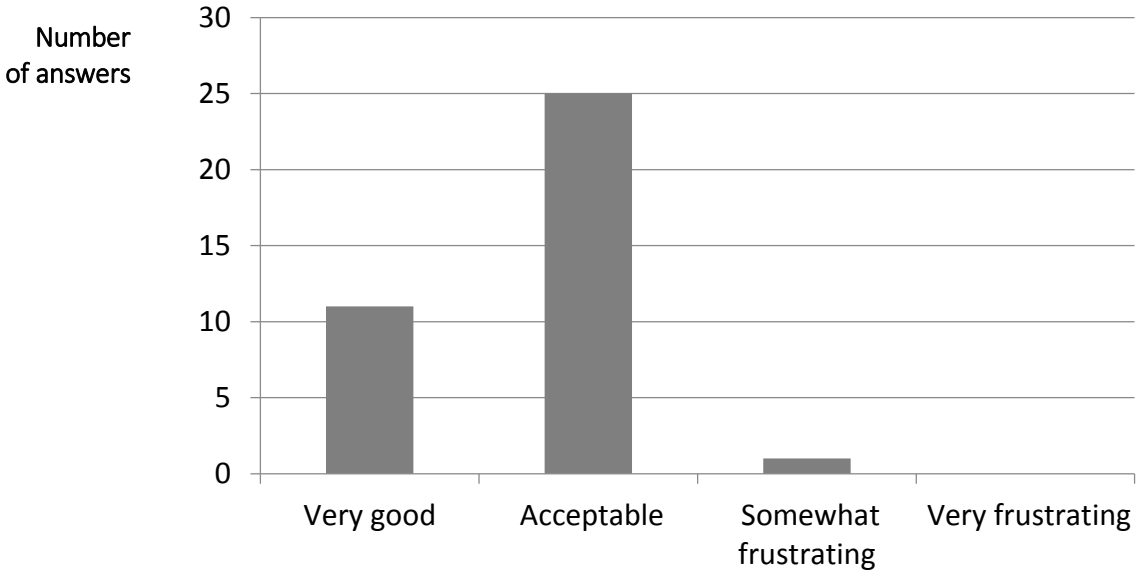

Figure 43. How pleasant was the overall experience of working with the standard?

4. DISCUSSION

4.1. Usability in the lighting design practice

The topic of usability of standards in the lighting design practice was approached by first doing a series of interviews, which gave the opportunity of a more in-depth discussion, and after gathering the most important conclusions from the interviews, the questionnaire enabled them to be backed up by a wider range of lighting professionals.

4.1.1. Interviews

The most relevant discussion that can be extracted from the interviews conducted with lighting professionals is that of the identified problems in the way the standards are written, as well as the received suggestions on how they could be improved.

The overall assessment of lighting standards in general, and of the EN 12 464 in particular, is that the way standards are structured makes them clear only to those who use them on a regular basis, but could be problematic for people who use them for the first time or less regularly. A more user-friendly approach, including a better search function, more and better graphics, as well as better formatting were suggested.

Another recurring issue was that of the clearness of requirements, and although most interviewees agreed that there is a level of vagueness in the standards in this regard, there was an ambivalence in judging this situation, which is at the same time a possible cause of faulty design and an opportunity for design flexibility, all depending on the user.

A series of complaints about the lacking depth of research in the areas of energy efficiency, human vision anatomy and new technologies that goes into the development of standards, would suggest that these areas should

be improved if the standards are to be efficient in respect to their core function – the promotion and facilitation of quality lighting design.

After the experience of the first interview, the questions have been adapted in order to get answers which are more to the point in regard to the usability of standards. It has been observed that when talking about usability, it was important to refer to specific attributes that define it in formulating the questions, rather than asking general questions about the topic of usability, which is not a clear concept for anybody who is not particularly invested in it.

Usability is defined in ISO 9241-11 "Guidance on Usability", "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". The three all-encompassing attributes of usability were the main points followed throughout the interviews.

Effectiveness

In terms of effectiveness, all interviewees have responded that the standards give them the needed input, which points to a high level of effectiveness. However, later discussions about information which is not sufficiently detailed and integrated in the requirements, means that the Standards could be more effective.

> *"The best solutions come up from restrictions, from client needs, from users, from standards, to have some framework you can develop some valuable insight." (Interviewee 2)*

The only respondent who said that he is not getting the input he needs from the standards, followed this affirmation with an argument about the structure of the standards, which worsens with every new addition, making it cumbersome to read and understand. This view has not been considered in the assessment of effectiveness, as it has to do with efficiency.

"If it's a standard that comes out once and doesn't change then, the next, let's say, 20 years, it's easy to read. But after the first, and second, and third edition, nobody can read it because it's crowded up, points that change." (Interviewee 5)

Efficiency

Efficiency is a multi-faceted attribute of usability and has been the main topic of discussion in the interviews. As a general conclusion, it is the opinion of the interviewer that standards are currently not at an adequate level of efficiency.

Most interviewees agreed that some of the content (definitions, explanations, calculation methods) is understandable only after reading it 2 or 3 times. It is important to note that these are people who work in the field, and it might be concluded that for people who read this content for the first time, the information could be even harder to understand (this will be checked during experiments with students). It was also stated that European Standards are mostly better in explanations as the American or international ones (Interviewee 4).

The issue of vagueness is present in areas of the standards, as stated by interviewees, although this is seen mostly as an opportunity to interpret the standard and come up with valuable solutions.

However, only an experienced, independent lighting designer can use the vague parts of the standards to bring quality to a project. It is doubtful that vagueness is a good characteristic for the text of a standard, when less experienced people would try to use it.

"There are some areas where you think it could be better written or made clearer, or whatever, but it's hard for me to say because I'm quite into this area, but I think that if someone

who is not constantly working with the standards or with lighting design, for example who needs to do it once.. six months for example... that he will not get all the information which is needed." (Interviewee 3)

Also, the impossibility of verifying that a requirement is met after a project is completed might mean that requirement is not very useful.

"[…] for example the Unified glare rating, the UGR factor. The program can calculate it, there is a formula that you could calculate it by hand, let me say, but it is really a headache to check this on site. To prove that the calculation is done in a right way or that the fixture is acting as per calculation. And this happens in many things […] it's really hard then to make a clear assumption at the end if the project is well done or not" (Interviewee 4)

A recurrent issue discussed has been that of the adequacy of the standards in relation to the latest technology, of mainly LED light sources. Requirements in the standards are considered not detailed enough to integrate the quality of lighting, as these sources have parameters which are far more complex than previous light sources, parameters which must also urgently be regulated. At the same time, the energy saving properties associated with the latest the technology are of little use as long as requirements are introduced which call for the use of greater number of light sources than previously. It is generally considered that energy consumption is already too high, with existing standards, because all standards are industry driven.

"As we know, the most of the LEDs are direct lighting, not reflectors. So this means the uniformity most of the time is not so good as for example with the less efficient compact fluorescent down lights. Because the LEDs will give more spikes as the compact fluorescent. […] So this means you have to put more near distances between the down lights to get the better uniformity, in fact of the spikes, as with the compact fluorescent. […] So at the same time they are talking about less energy, which is simply not possible." (Interviewee 4)

In order to have the standards in line with the latest technology, it was the general opinion in all interviews that they should be updated a lot more often that they currently are.

"They should be redone often for this, because with the technological development is so fast, especially now, that it is not enough to have it every 10 years or so. I think it should be updated every 2 years or so." (Interviewee 2)

Some requirements in the standards are not complying with the reality of human vision, and therefore following them may lead to solutions which are not efficient.

"Standards could also be better, for example if you take building related to health, hospitals or other buildings for sick people, where lighting could be a positive factor, then you would say we need more requirements than just how much lux, because lux doesn't say anything. Still they use all these chemical tubes there, where you don't have the whole spectrum of light, so there it could be interesting to use natural

light, with halogen, with LED maybe, with the whole spectrum."

External factors which could affect lighting design, such as interior design and the choice of finishes and colors are not sufficiently taken into account by the standards.

"Because if then there is smoke and dust and all this dirt, the lux levels will not be as you measured it in the clean environment, with the nicely painted walls. But it's nothing wrong, according to the standards." (Interviewee 4)

In working with the standards, an important issue was that of the search function – better when it comes to searchable digital formats, but overall not really well resolved by the standards.

"It would be fine if in the standards are not such a lot of footnotes and these links between the first and the last page. These links are not really helpful. It would be fine if it is as in a travel guide, because there already you have a link to the Internet, a link to the other page, digital link between these (links) pages, so that you search for it, for an easy word, so you have a link between these two. In the digital world it shouldn't be really a big issue." (Interviewee 5)

"Often, I don't take the standard and look at it, I do a quick search in Internet. It can be faster." (Interviewee 2)

"Search is very important. I don't know, do they have some index, some glossary in the end, because this would be also nice to have some alphabetical order… where you click and you go to the right page… this would be helpful." (Interviewee 2)

The graphics in the most used standards could also be better, although the interviewees were not very concerned with this aspect, and tended to rank the layout design and graphics based on what was familiar to them.

Satisfaction

As working experience, within the process of lighting design, working with standards have been often defined as “necessary”, “useful”, “ok” or “fine”, which points to a level of neutrality when assessing the level of satisfaction of working with standards. The general conclusion is that working with standards is a pleasant experience, as long as one is familiar with them. The experiments with students will show whether the level of satisfaction is different with people using them for the first time.

The core issue according to the interviewed lighting professionals is the fact that standards are being developed in restricted circles by bodies closely associated with the luminaire and lighting technology industry, with a detrimental impact on the motives behind the required values and regulations.

> *“For example, the most of these standards are developed with big lobbying from the industry, so not all the light levels given are really needed.”*
>
> *“The thing which could be better is the energy consumption, the budget and the quality of lighting which I think could be different if there would be some more independent people with know-how working on the standards.” (Interviewee 4)*

Extracted from these individual summaries is a list of problems relating to standards and their usability, as well as a list of suggestions about how they could be improved, according to the interviewees.

PROBLEMS RELATING TO THE USABILITY OF LIGHTING STANDARDS

- The way standards are structured makes them clear only to those who use them on a regular basis, but could be problematic for people who use them more rarely. It is easy to find information within a standard if you are familiar with the format of standards.
- There are areas where standards are vague, especially when it is extremely hard to verify on site if the requirements are really achieved (ex: the UGR factor) – it is sometimes hard to make a clear assumption at the end if the project is well done or not.
- Some requirements in the standards are not complying with the reality of human vision, and therefore following them may lead to solutions which are not that efficient (for example, uniformity of lighting is much more important but less considered in the standards as actual illuminance levels)
- There are parts in the standards where certain requirements tend to lead to a narrow spectrum of solutions, even though this would not be absolutely necessary. This sometimes limits the choices of the architect / lighting designer in relation to the lighting atmosphere. In the case of good designers, without standards many things could be done better.
- Not all light levels are really needed. (for example, illuminance requirements on ceiling and walls of offices)
- The values in the standards are generally too high (according to I4).
- Sometimes the standards are not detailed enough to focus on the quality (example: color properties of LED light sources)
- Requirements which are highly dependable on the interior design, finishes, etc., and are calculated in an abstract environment are not reliable, even though in line with the standards.

- The quality of lighting design could be much better without the standards for energy saving.
- Energy consumption would be much higher without standards, however, even the current standards could be improved from the point of view of energy efficiency.
- The fact that only the real power (W) is to be measured, and not the apparent power (VA) in attesting the efficiency of luminaires, is a mistake of the standards. The difference between these values is a crucial factor for the efficiency of luminaires.
- Standards are not in line with the latest technology, because the technological development is faster than the procedures associated with regulations.
- The fastest way to find something in a standard is through a quick search on the internet. Internet and Google is used to find information from the standards.
- The index page and structure of standards as they are now are not very user friendly, if you are not familiar with them.
- Standards get crowded up after being updated a few times.

SUGGESTIONS ABOUT IMPROVING THE USABILITY OF LIGHTING STANDARDS

- Digital format is preferred for its search function. If there is no search function, the paper format is preferred.
- The language used in the standards should be more clear.
- Standards would be more usable if professionals in the field (lighting designers and technicians) would be consulted in writing them.
- It would be better if instead of minimum/maximum values, a range would be given, which would allow for more energy efficient solutions.

- Standards would be better if they were based more on scientific research about the human anatomy and human vision.
- Standards should be updated much more often in order to keep up with the technological developments (approximately every 2 years).
- The search function is very important for standards: index, glossary at the end in alphabetical order and the possibility to go directly to the relevant page.
- A more intelligent search function would be preferred.
- A clearer structure would be helpful.
- An overview at the beginning, to have a clear idea about the structure of the standard from the beginning.
- Footnotes and links between pages far apart are not helpful. Digital links would be helpful and shouldn't be a big issue.
- It would help if every line in the standards would have a number, in order to more easily make references to certain points.
- Graphics are important for understanding and working with standards.
- It is better to have the explanations directly on the illustration, rather than under it, in legend form.
- Colors help in reading a table faster.

4.1.2. Questionnaire

Based on the principal conclusions and topics discussed during the interviews, the questionnaire was devised as a tool of confirmation or negation of some of these topics, each meant to evaluate one of the three main components of usability – effectiveness, efficiency and satisfaction, as shown in Table 3. As seen in results and discussed below, the conclusions of the interviews were mostly confirmed by the wider investigation allowed through the use of a questionnaire. The answers were, like the questions,

very precisely directed at specific topics regarding the usability of the standards, and their individual outcome was extensively discussed in the interviews discussion section.

Effectiveness

Effectiveness was evaluated by six questions regarding the actual content of the standard in terms of required lighting values and regulations. Although in general the standard was evaluated as effective by the majority of the respondents (See Figure 5), when asked about specific issues, the evaluation was less positive.

The issue of vagueness was seen as an opportunity for flexibility by a little over half of the respondents, with almost the same number considering it a rather negative aspect (See Figure 9), which would suggest the fact that they encountered problems because of it. A number of 17 respondents consider that the standard sometimes limits their choices in trying to come up with energy efficient designs (See Figure 10). Considering that most of them have a long experience regarding adequate lighting levels, it is reasonable to question the required values in the standards in this regard. A great majority of the respondents think that new technologies, human health research and context factors affecting lighting should be considered more in the development standard requirements, as these areas are clearly lacking (See Figures 12, 13 and 15).

Efficiency

Efficiency was evaluated in what regards the searchability of the standard, the accessibility of its language and the verifiability of acquired lighting values once the project is done. Although the overall evaluation of these 3 factors was more towards the positive (See Figures 7, 8 and 14), there is a correlation with the amount of experience of the respondents (See Figures 18 and 19). This correlation confirms the conclusions of the interviews that the standards are harder to grasp by new or infrequent users.

Satisfaction

Finally, the satisfaction component of usability was evaluated by questioning the measure in which the users feel creatively restricted by the standard, with a great majority leaning more towards a negative impact on their flexibility as designers (See Figure 11). An overall evaluation of their experience of working with the standard however yielded a more positive result, with 73% finding it rather good (See Figure 17).

The question of outside interests behind the standards is one which is quite delicate and many did not offer any specific response when asked, but half of them do seem to suspect that there are such interests, while those who were convinced replied that manufacturers have an influence and many times participate directly in the development of standards (See Figure 16).

4.2. Usability in direct tasks

Although interviews with professionals and the subsequent questionnaire provided some valuable insight into the usability of lighting standards, the issues discussed centered more around very in-depth issues regarding their content, and less on very practical issues that new users might experience when trying to use the document. It was therefore necessary to develop and conduct a usability experiment.

4.2.1. Experiment with students

The experiment was developed in order to assess basic usability characteristics of the EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places" standard, such as searchability, intuitive design, clearness, while working with it in a sequence of tasks with specific presumed difficulties.

The first stage of the experiment was meant to give the participants the opportunity of a first look at the standard, in order to create a general idea about what it contains and how it is structured. At the same time, by having

a general look, the 15 minutes assigned for this first task were also meant to be of use in accomplishing the following, more precise tasks.

The first stage of familiarization with the document revealed that, at a first glance, the standard is mostly understandable, main chapters are identified correctly, along with the very important section of lighting requirements in the tables at the end (See Figure 23). The standard's subject and content seems "clear" and "somewhat clear" to an equal proportion of the participants, even though many of them have had no prior contact with other standards before (See Figure 20). When asked about more particular aspects about the structure of the standard's chapters, the answers tend to be more vaguely positive, most of the users choosing the more reserved positive answer – "rather yes" and "probably yes" instead of "yes" when asked whether they were able to identify the most important chapters and whether they would be able to find specific information in the standard after this first familiarization with the standard (See Figures 21 and 22). This could mean that even though the standard communicates fairly well the topic it addresses, the fact that it does not present a systematic method of working with it is intuitively perceived even at a first glance.

The next 2 tasks, 2a and 2b (See Appendix E) were developed around areas of the standard where either the searchability of information or the clearness of the language used were presumed as problematic by the author.

Indeed, when asked to evaluate their experience, the first set of terms: "task area", "immediate surrounding area " and "background area" of Task 2a were not found as easily, even with the use of the table of contents (See Figure 24), but once found, they were understood quite quickly and mostly correctly by the participants (See Figure 27). The reason for this is the fact that the required information was extracted from a part of the standard that is not so clearly structured and/or represented in the table of contents. It was the author's conjecture that the information would not be found so easily, even though it is accompanied by one of the very few graphic

illustrations in the whole standard, which should have been at least noticed during the familiarization stage, if the illustration was good. As remarked by many of the experiment participants, not only was the illustration of the 3 concepts not noticed in the familiarization stage, but it was also overlooked as they were specifically searching the terms in Task 2a, illustrated by it.

In evaluating the answer, most participants were able to find and accurately reproduce the meaning of the three terms, but when it came to defining their lighting requirements, many were not able to find this information. That is because the main required values are contained in the last chapter of the standard, in the values tables. Even though most participants marked this chapter as important in the familiarization stage, it was not clear to them what these values represented in reality, and therefore were expecting to find this information closer to the definition of the terms. The link to the tables at the end is mentioned next to the definition, but because the description text is so dry and poorly structured, it is very easy to miss it, as shown by the experiment.

The second term, “mean cylindrical illumination” of Task 2b was immediately found, thanks to the fact that it is mentioned in the table of contents, but understood only partially or even completely incorrect (See Figures 29 and 32). Even worse, when evaluating their own understanding of the term, there was no correlation between the accuracy of the answer and the self-assessment of the participants’ actual understanding (See Figure 33). This means that the language of the standard is sometimes not only difficult, but misleading, cutting drastically on its effectiveness. It was the author’s conjecture that the language used in defining this particular term, among others not present in the experiment, is needlessly cumbersome. At the same time, concepts like this, which are perhaps more difficult to grasp, should be accompanied by a good quality graphic illustration, since they are not at all abstract or impossible to represent, and it would speed up and facilitate considerably the use of the standard.

The final task presented the participants with a real-life situation, in which they would have to acquire from the standard all applicable requirements for an office space with various functions (See Appendix E).

Participants encounter no problems in extracting information from the requirements tables at the end, whose ordering by type of space and function was of great help.

However, many other general lighting requirements are the topic of other chapters in the standard as well – glare, contrast, requirements for walls and ceiling surfaces, and other relevant information for all types of projects, including offices. The vast majority of the participants in the experiment failed to extract these other requirements from the rest of the standard (See Figure 36), even the ones addressed in previous tasks. At the same time, most considered that they had accomplished the task completely and had no impulse to look at the rest of the standard, as observed by the experiment supervisor (See Figure 37).

This proves once again that the standard can be misleading when it comes to practical matters of following a correct sequence of steps to retrieve information needed for a project, making it very inefficient for new users.

Based on Table 4, the particular components of usability were analyzed by different parts of each task, as follows.

Effectiveness

The experiment measured the effectiveness of the standard in what regards the participants' ability to find and understand information in the tasks 2a, 2b and 3. Since the tasks were each targeted at these particular usability characteristics, the tasks scored differently in regards to their searchability and to accuracy and completeness of answer.

While the terms in task 2a were not immediately found and not in the expected place (See Figures 24 and 25), the term in task 2b was quickly and intuitively found by most participants, thanks to the table of contents (See Figures 29 and 30). Task 3 proved that even though part of the requirements

for an actual project are quick to find thanks to the neatly organized tables at the end of the standard, other important requirements throughout the standard are not even being considered (See Figure 36).

Accuracy and completeness of answer also varied for each task, and the motives for the outcome are different. While the terms in task 2a were fairly easy to grasp once found, their lighting requirements were not immediately associated with the values tables at the end of the standard, and so the task was incompletely answered by half of the participants (See Figure 27). Task 2b specifically targeted a poorly defined term by the standard, and indeed the answers were not only confused and incomplete, but often completely wrong (See Figure 32). Task 3 was accomplished only partially due to the fact that most participants did not have the impulse to search for requirements outside of the tables at the end (See Figure 36). This is however completely understandable when considering the unappealing form of the standard throughout, seeming to give just theoretical information, and the presence of the organized tables at the end, that seem to contain the practical lighting values in their entirety.

Efficiency

The efficiency of the standard was considered in the experiment in terms of intuitive design, by asking the respondents to trace their steps in working with the standard and asking them whether the information was found in an expected place or not. This feature is of course linked to searchability, so most information which was easy to find was so because of its intuitive placement within the standard and/or to its mention in the table of contents (See Figures 25, 30 and 35).

Another even more important aspect of efficiency is the topic of verifiability – the measure in which the standard creates an environment in which one can be sure that the information retrieved is correct and complete. This aspect was verified by correlating the correctness and completeness of answers with the participants' opinion about their own

performance. It is clear in all instances that the standard is severely lacking in this regard, as there is no correlation whatsoever between the two – participants who have performed poorly rate their experience the same as those who performed well, with apparently no clue that their answers were either incomplete or incorrect (See Figures 28, 33 and 37). This is due to the lack of a clearly stated procedure to follow in using the standard.

Satisfaction

Satisfaction of working with the standard was investigated throughout the experiment through questions about the feeling the standard gives to participants at each stage and in general, by the short questionnaire at the end of the tasks. The first stage of familiarization with the standard, as well as the following tasks contained a few questions about their first encounter and whether the standard seems clear to them, and the answers were mostly positive, even if sometimes reserved (See Figures 20, 21 and 22).

The answers at the end summed up this conclusion as well, with most of the participants stating that their interaction with the standard was an acceptable one, although not ideal (See Figures 38, 39, 40, 41 and 42). As suspected, it was the opinion of most participants that the illustrations in the standard should be given more importance (See Figure 42).

4.3. Recommendations for future lighting standards development

Drawing on the experience of professionals, the results of the experiment with students, as well as conclusions from previous studies, a few basic guidelines of usability could be summarized, that would help in creating better standards. Most of these conclusions are in line with the findings of previous studies on the usability of standards.

- Clearly define the design goals and benefits by following the standard
- Clearly define the scope of the standard in an accessible manner

- Provide a procedure with steps that must be followed in order to correctly and completely apply the standard to specific projects
- Provide a clear chapter hierarchy with a corresponding table of contents that enables efficient searching through the standard
- Avoid over-complicated language
- Use quality graphics and pictures to explain difficult terms and concepts
- Integrate, to a greater degree, issues regarding energy efficiency, human vision anatomy and new technologies
- Provide reasonable methods of verification of the requirements or provide requirements that can be verified
- Provide intelligent search and browsing features for the digital version of the standard, characteristic of contemporary interface applications
- Give priority to quality lighting practices promotion rather than outside interests

5. CONCLUSIONS

5.1. Contribution

This study contributes to the evaluation of usability of standards by showing problems and suggestions from professionals regarding the content of lighting standards, as well as performance results from the interaction of first time users challenged with using the standard to accomplish specific tasks.

The study also provides a viable methodology of research into the topic of evaluation of standards, as well as a framework of relevant features regarding the usability of such documents and their mapping on basic usability components.

5.2. Future Research

Although employing various research methods, this study is mostly limited to the usability analysis of the EN 12464-1:"Light and lighting – Lighting of work places – Part 1: Indoor work places" standard, which is the lighting standard most used in Europe. It would be interesting to study standards used in other parts of the world, on lighting as well as others, and possibly make comparative studies between standards on the same topics, in order to pinpoint the best usability practices in writing standards.

6. REFERENCES

Allwood C.M., Kalen T. (1997). Evaluating and improving the usability of a user manual. *Behaviour & Information Technology, vol. 16, no. 1*, 43-57

Bevan, N. & Spinhof, L. (2007). Are guidelines and standards for web usability comprehensive? *Human-Computer Interaction, Part I, HCII 2007, LNCS 4550* (pp. 407–419) Springer-Verlag.

De Souza, F & Bevan, N. (1990). The Use of Guidelines in Menu Interface Design: Evaluation of a Draft Standard. *Proceedings of IFIP INTERACT'90: Human-Computer Interaction 1990* (pp.435-440).

EN 12 464 "Lighting of Work Places – Part 1: Indoor"

Halonen L, Tetri E & Bhusal P (2010). Guidebook on Energy Efficient Electric Lighting for Buildings. Annex 45. Chapter 4: Lighting and energy standards and codes, pp. 59-72

ISO 9241-11 "Guidance on Usability"

ISO/IEC 9126-1 "Software Product Quality Model"

Mosier, J.N., and Smith, S.L. (1986). Application of guidelines for designing user interface software, *Behaviour and Information Technology 5, 1 (January-March)*, pp. 39-46.

Nielsen, J. (1994). Heuristic evaluation. *In Nielsen, J., and Mack, R.L. (Eds.), Usability Inspection Methods*. John Wiley & Sons, New York, NY

Pak B., Verbeke J. (2011). Usability as a key quality characteristic for developing CAAD tools and environments. Sint-Lucas School of Architecture, Faculty of Architecture and Arts, Association KU Leuven Belgium

Raynham, P. (principal author) (2012). SLL Code for Lighting. CIBSE

Thovtrup, H., and Nielsen, J. (1991). Assessing the usability of a user interface standard. *Proc. ACM CHI'91 Conf. Human Factors in Computing Systems (New Orleans, LA, 28 April-2 May)*, pp.335-341.

7. LIST OF FIGURES

8. LIST OF TABLES

9. APPENDIX

9.1. Appendix A – Interviews transcripts

Interview 1

Date: 05 December 2014

Interview duration: 20 minutes

Recorded: audio

Language: English

USER PROFILE (as provided by user)

Profession: Lighting designer

Education and Work:

HTL – Steuerungs- und Regelungstechnik

ABB Gebäudetechnik

Abendschule FH techn. Projektmanagement

Zertifizierung Lichttechniker

INTERVIEW

I = Interviewer

AL = Interviewee (name initials)

I: Please tell me a little about you and your experience in the field.

AL: Yes, that is quite easy, because I know myself quite well. I think you want to know more about my profession, in this field. First of all I graduated in a technical college in Austria, then I worked for 13 years (of *ADP*, as *undistinguishable*) as electrician. After this, I went to University and graduated in Technical Process and Project Management and then I changed to lighting. Then I started by Targetti Austria first, and meanwhile I was there since 8 years and now I own a company what is exclusive for Targetti lighting.

So first I say it was a technical thing, then it was electrician thing, and after that it was very interesting, more lighting itself, how to say, that was my thought, to come into this field, yes,

but meanwhile I am very interested how lighting really works. I am a certified lighting designer, but, normal, I am a representative of the lighting industry, through selling.

I: So, the topic of my paper is usability of the standards.

AL: I already know... You need the standard of the European 12464.1, the standard?

I: No, not in particular, standards in general.

AL: To define it, here now, there is this standard regulative. There is this one, so first when you ask me about a standard, we should define from which standard we are speaking.

I: Any standards that you regularly use in practice.

AL: In my field... alright. This one, 12464 for indoor and outdoor lighting. That is the regulative now for this (undistinguishable).

I: So, now we are going to speak mainly about this one.

AL: Maybe, we will see the questions.

I: In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them?

AL: I think the first thing, the first part of lighting design is not the topic of standards, the first topic is to understand what is the need of the human child in this room(?). So I think the first step is to build together with the client, with the user of the lighting design, to build the same vision, to understand what he needs, and to have the same vision. That means not to put the glasses of (undistinguishable) people on the head, and to understand really what he needs, even he is not professional, of course, he isn't, otherwise he wouldn't ask me, to really understand what he wants, what is the usage of the lighting design / of the lamp that he wants. The first step – the needs of the human child, I think.

The second step for me would be to have, how is it in English, Pflichtenheft, to have a book of its needs, to have it [written] down, that you understand, that he reads it, and when he reads it, he says "Yes, I meant this" – client's brief.

After this, (undistinguishable), then the lighting design starts. Only at this point, so the first step the lighting design starts. You say "Okay, with my professional [expertise], I can... I mean that you need this, this, this". Um, the regular thing is for me, only the minimum standard. Really, the minimum standard. So, for me usually, what we plan, what we do, what we build, should be much more than only this standard, but it must fulfill this standard. When you take note on the standards, mostly it is a thing of definition. So if you know the standards like this, in your little finger, then you can interpret it, for you. Like, small example, in office, it's this

standard, this thing what is described in several pages, every (undistinguishable) in the whole world, in office. Then you can define to say "Okay, your work surface is like this [defines a small area with hands on table], or your work surface is like a big thing, yes? So you can make this 500 lux in the middle, this field, or you can make it for the whole room, minus 0.5 meters. So you can define it for yourself, or even you ask mister architect: "How do you use it? How is the usage of this?". So that's the big thing that you have standards, regulative, what are the minimal needs they have to fulfill, but you can define for your own, if you know them.

I: Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process.

AL: For sure it makes the work easier. Yes, for sure, because that's the one thing, (undistinguishable) the standard is for everybody, for human child, for every person, the lighting designer, the same, okay? That's of course one of the native issues for a standard, to be for everybody the same. So it makes the life easier to have it, to count on it, to base on it, and recognize the conversation is to base on it, because it is the minimum, to base on it, yes, to interpret it, for that, for the vision of your client's brief, and to make the whole plan not only for the standard, for more than that. So, for me, it makes the life easier.

You can compare it, maybe to compare it. In the new technologies today, LED technologies, um, it is clear that the standards are behind this development of LED. So what happens? Nobody has any idea how to use this and this and this LED. So the industry itself make their own standards like Zhaga books, yes, but it is only a technical standard for (undistinguishable), in my opinion it is nothing serious, it is nice, but nothing serious, but they are most standards of LED, of the Kelvins, of the binning, of all this, no standards. And this makes the life much [more] complicated. Every lighting designer has to read every book, has to experience with every LED [product], with everything, make their own measurements. That happens now with the new technology, because there are no standards. The standards are behind this. In fluorescent lighting, in halogen lighting, in HID, metal halide halogen, everybody knows these are the things, these are 3000 Kelvins, not [so] with LEDs. 3000K can be 3000K measurement, but from the feeling it's completely different. So it is quite clear, nowadays, even everybody who (undistinguishable) on standards, must really say that standards make life easier. Only take the situation nowadays, they find out they make the life easier, in context what is today with LEDs without standards. Everybody's clear that standards make life easier.

I: Are the standards interpretable or clear?

AL: How every standard what is not law. The standard is not law, yes, law is having interpretable. Low is interpretable only for laws, for legal people. Standards are always interpretable. So standards are interpretable. Who knows the standard best, who knows how to interpret it, yes, know how to play it. My opinion is that who is able to interpret it, I think that he is over able to build a better lighting plan. Yes? Because who has no idea to build a lighting plan, yes, should read the standards, and should fulfill the standards, finished. Who has an idea who make it better, should fulfill the minimum as standard, and he knows to interpret it, and so he makes a better plan. (Undistinguishable)

I: But do you think there is a risk that somebody who doesn't really know, to interpret it in a bad way?

AL: Not at all, not at all. Because there are so many people [undistinguishable) who are able to interpret the standards, who understand the standards, and so the one who has no idea from the standard and thinks he's able to interpret it, he has no chance because he would be killed by the competitors, however.

The standard is clear, what is written there.

I: So, now we've been talking about that one standard, but you've probably read many others. In my study I am going to compare for example the Indoor Working Places Standard, the 12464-1, and the SLL Lighting Handbook - this is from the UK.

AL: Ok, I don't know that.

I: And then there's the Lighting Handbook from IESNA, in North America, this really huge book. There are one type of standards which really look like any legal document, with no formatting, and then there's also these handbooks of lighting guidelines, which are made by other bodies. Do you see a difference in the usability when we are talking about the standards when they are issued by an authority...?

AL: Honestly, I can't answer you this, because I don't know them, yes, from the international field. So I only can guess. I believe that when a clever guy, clever woman, lies [sits] down, what she feels and what is valid for her, can be much better than any regulative and any standard. But a standard has to fulfill (undistinguishable), legal topics, so we must fulfill everything, and that makes a standard complicated and makes compromises in the standards, and so I can guess that standards in North America, in Abu Dhabi, in Middle Europe, in UK, every standard has this own characteristic, yes, that it should be valid for everything, and so it is interpretable and maybe valid for nothing. So, in my opinion the standard is fine to be based on it, but it

needs a person who is able to interpret it, to build it out yes? Because I know how standards work, how they commit it. Yes? There are some people around, most of them are from the lighting industry, yes, and they try to bring some things in it that they also need, really to be a good lighting book, a good guideline, but also to have some selling points, yes? And then the software, like Dialux, and other things, comes behind. In the same manner, sponsors it from the same companies, yes, so that is how a standard works, how it is invented. So when, now you come and tell me "I say that a standard is like that, please take care of 1, 2, 3, that's my opinion, maybe this is better. So is more free. Yes? I know it was a little bit abgehoben [loose], but so (undistinguishable) because I don't know the other standards, yes, but in my opinion, I think in the whole world the standards work the same. Committee of people who have whole other interest commit something what is a fine, but maybe not the best what could really be in a lighting plan. Job of the lighting designer, to bring that out.

I: I am making a research study about the possibility of changing the way standards are being written. If you would be consulted in creating a new version of the standard you use, what would be the main points you would change to make it more usable? Why?

AL: I am very glad that I must not do that. Because, it is like that, it is something and you know, speaking of lighting standards, yes, and also to go back to the roots, yes, lighting, for me lighting is a thing what has much more emotion. Yes? Lighting is emotion – to do it for humankind, to do it for people, its emotion. And then we are now speaking here about standards, what is nearby legal, yes? So, bring this together. And there are a lot of people who doesn't need any standard and make perfect lighting plan that for sure will fulfill the standard, because he has the emotion, the feeling, (undistinguishable). So for me it is a thing in this, in between I am – emotion and standard. Yes, so I am glad I don't have to write it down, but to make it, the standards, because you can't put all the emotion from this by legal document. So, for me, I can't change it, because I don't want to do it.

I: When you think about the level of usability of the standards, find a single word which would define it.

Al: Interpret it! Yes, it's two words, but...

I: Ok, so that's it. Thank you.

AL: You're welcome. Much luck with your degree.

I: Thank you.

Interview 2

Date: 15 December 2014

Interview duration: 22 minutes

Recorded: audio

Language: English

USER PROFILE (as filled in by user)

Profession: Lighting designer

Age: 57

Experience in the field of lighting (duration): 18 years

What are the tasks you perform at your job?

- Concept design
- Lighting simulation
- Detailed design
- Drawings (plans, details), visualizations
- Tender documents
- Implementation phase
- Evaluation of fixtures, measurements (Laboratory)
- Development of lighting fixtures
- Other: Networking

Do you use standards in the lighting design process?

- Yes

Which standards/codes/guidelines do you use regularly in your daily work? As much as possible, please order them after relevance/frequency of use.

- 12464
- 13201

INTERVIEW

I = Interviewer

MP = Interviewee (name initials)

I: In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them.

MP: You know, in private areas we have some rough guidelines, but it's not that we plan completely, you know, from the standards. It's more like to create an atmosphere and something that's tailored to the users… day light also. With some educational components. So we try to… they have some imagination, what they think lighting is and we come and try to feel what they want and they get what they need. And when it's in public spaces and so on, of course the standards are very important.

I: Do you use them in all phases of the design process?

MP: First we use them to get some framework, you know, how much is needed, where and in interaction with the architect to… you know, when the surfaces are defined, if they are dark, bright, whatever, so, that's when we use them. And then later, when it gets more detailed, then we do some… then we bring something out, and then when it's more detailed we re-check them.

I: In the verification phase… So in all phases…

MP: Yes… In between not so much. Except when… you know, sometimes it happens that, you know it, when you specify something, and some other product is chosen, then we have to evaluate and judge the products, to see if they are really… But this… usually it's in the very beginning and the end.

I: Do you prefer to use standard in their digital form or printed? Which is easier to use and why?

MP: I like more digital, my sister likes more printed.

I: Why do you like more digital?

MP: Because it's… very often you print something and then it's there, you read it one or two times and then it disappears in the pile of paper. And if you're a little bit organized in the computer you can find it easily and also the search function is very good. So that's what I like about.

And it would be nice to have some intelligent search function, to say, if you search for some term, then similar terms… like in… with Apple, with Spotlight. So you search something and then… so a more intelligent digital version of this.

I: What information do you look for in the standard you use? Explanations about lighting design criteria / Calculation methods / Lighting requirements values?

MP: Mostly lighting requirements values, and contrast and glare, all of these values, we cross-check. The other thing when we design, we try to get more stuff from the feeling point, try to visualize the space and then it's cross-checking it and evaluating with the needed… For instance, the very difficult thing in (indistinguishable) there was a big conflict between the interior designer and the lighting designers. Because he… this hotel… very low level, very… and we said "at least there has to be the option to have this 100 something lux – 200 lux in front of the elevators. It was very hard to… and he said "oh, a few lights here and there is enough, and we said it's important to be able to do it, you know, lighting thing is another thing… you know, to have it dim down, and to…

HR: Our daily discussions with the operators…

I: Do you read a new issue of a standard when it comes out, to familiarize yourself with it, or is the information so straightforward, that you only need to use it when it is needed in a project?

MP: Of course when it comes out it's discussed in LTG meetings, other colleagues have heard about it, have read it, so it… I try to read it as soon as possible. And sometimes if I have a project where it's very important to go with the standards, then we say to one of our employees to go deeper into it and sort of get familiar with it, and be the "agent of the standards".

I: Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process?

MP: No, they are necessary. If you want to stay out of liability field, then it's good to follow the standards, to meet the standards.

I: But it doesn't affect your design in a bad way?

MP: Well, it's, no, it can be also, you know, I think it's never good if somebody comes and says "do something". The best solutions come up from restrictions, from client needs,

from users, from standards, to have some framework you can develop some valuable insight. Otherwise it's too diffuse. It's good to see what they want.

I: Does the standard give you the input you need?

MP: Yes.

I: Are the standards in line with the latest technology?

MP: They try, but this… I don't know, they should be redone often for this, because with the technological development is so fast, especially now, that it is not enough to have it every 10 years or so. I think it should be updated every 2 years or so.

I: Have you found mistakes in any of the standards you have read?

MP: I don't know. I haven't found any. But maybe there is… But it's always with the… even with the standards there is many ways to do something. It's not one way to do it, but you can say "Don't do this and it should be like this and the contrast will be this", so it's… I think it's helpful.

And sometimes you feel that there is, it's also a snapshot of time, because people are discussing it, experts, developing standards, and not everybody is involved, and some things are in, some are not in. But I think they try to do it as good as possible. I assume.

I: Are the explanations and definitions clear and easily understandable?

MP: More or less, yes. After reading two or three times…

I: Have you ever found some information which is vague?

MP: Vague, not precise… you know, maybe here and there, it happens, yes. But it's a snapshot, it can't be perfect. So it's ok, they try to do this as good as possible. Another thing is they have to adapt it more often.

I: Do you think the quality of lighting design would be lower if no standards were to be used?

MP: It would, for sure. I mean now there's some minimum, so like a safety net. I think some people still can fall over, but… but otherwise [if] everybody would do as they want it would bring maybe more fighting, more suing…

I: If lighting design was to be practiced without standards, could this lead to safety issues?

MP: Yes.

I: If there were no lighting standards to be followed, how do you think this would affect the energy consumption of lighting in buildings?

MP: Are the standards so much about energy consumption? It's more about levels and contrast and glare... I think... It depends who is working for who. I mean there are some projects when maybe the lighting designer gets some money from somebody and the fee depends on the turnover of the project, they would bring more light, and more expensive light, and if it's the other way around, then I think there would be more highs and lows. I don't think the standards mainly is as energy related, they are more related to health and safety.

I: The standard you use most often. Is it a satisfying experience overall? Or is it rather a tedious, unpleasant part?

MP: It's ok. I mean it's not my better reading, to fall asleep, but as I said before, we use it in the beginning to create the framework, and then to check, cross-check in the end.

I: Is it easy to find what you need? Inside a standard, and even between standards, you know from their title what information to find and where?

MP: I mean the standards we use are so separate, like Exterior Lighting, Street Lighting and Interior Lighting, there is no touching point, and no cross-referencing.

I: How about inside the standard, when you are looking for an information, is it easy to find?

MP: Yes, but, often, I don't take the standard and look at it, I do a quick search in Internet. It can be faster.

I: Does the design of the standard make a difference in your experience of working with them?

MP: You mean the layout… Yes, it is important. It's not enough to have just one word document.

I: Difference in perception of satisfaction of using one standard or another – Experiment showing the same table/graphic from two different standards.

(About the tables): I prefer this in standards context (tables) [12 464].

(About the graphic): This… here is too much happening [SLL]. Maybe it's also what you are used to. Like the patent files, they also have a certain appearance. I think it is not necessary to make them colorful.

I: What would, in your opinion, make a standard more usable? (More useful, efficient, user-friendly)? Why? You already told me about the smart search function…

MP: Yes, search is very important. I don't know, do they have some index, some glossary in the end, because this would be also nice to have some alphabetical order… where you click and you go to the right page… this would be helpful.

I: Anything else?

MP: Maybe sometimes, a clear structure. It's… I can't remember how the chapters… It would be nice to have some overview, and then you go easy into the chapters, so even with the manual search, to make it more easy.

I: By structure you mean the contents page?

MP: Yes, the contents page, which should be quite clear what it contains… Mainly it's about finding things fast.

I: Do you think the titles are not very clearly indicative of what is inside, or is it also the graphical part?

MP: Could be… You mean in the contents… It could be more, not much, but slightly more user friendly. To move faster inside the document. Because often, either you are very familiar, and you know where to go, or you haven't read it for some time, and then you start to search again.

I: When you think about the level of usability of the standards, find a single word which would define it.

MP: Yes, it's quite useful. Useful, I would say. Or necessary, if you have to find a single word…

There's no way around. It really helps when you, also in terms of legal standards, to cue the decision, so it helps for the client, the investor, to find his decision, and to make him sure it is the right decision. And also helps you against questions or doubts of electrical planners, electricians, the building company or whoever… they want to save money, and so you can say "But we have to…", so it's quite a good anchor point.

I: Thank you very much!

MP: Welcome!

Interview 3

Date: 14 January 2015

Interview duration: 23 minutes

Recorded: audio

Language: English

USER PROFILE (as filled in by user)

Profession: Lighting designer

Age: 28

Experience in the field of lighting (duration): 6 years

What are the tasks you perform at your job?

- Concept design
- Lighting simulation
- Detailed design
- Drawings (plans, details), visualizations
- Tender documents
- Implementation phase
- Evaluation of fixtures, measurements (Laboratory)
- Development of lighting fixtures

Do you use standards in the lighting design process?

- Yes

Which standards/codes/guidelines do you use regularly in your daily work? As much as possible, please order them after relevance/frequency of use.

- 12464-1, 12464-2, 13201 + Brands and client's standards
- OENORM 1051, EN 1838
- Special guidelines (tunnels, etc.)

INTERVIEW

I = Interviewer

DK = Interviewee (name initials)

I: In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them?

DK: The standards come actually sometimes already into the concept design into play. So, either the European standards, or special standards for the area or client standards, like Hilton, Marriott and so on. When we make the concept design we create the ideas of how to illuminate de rooms, the areas, whatever it is. And usually we also have an idea of what this room could be – a corridor, whatever. So already in this process we need the standard in order to know how much we need there. Sometimes when we only want to show the idea of the concept, for example corridor will be solved by linear lighting then we don't make the calculations and check the standards in this step. So we only say in simple presentations "down lights" or whatever, and we put there for example just exemplary 3 pieces, but maybe there will be 2 or 4. But usually in the concept design already. And then in the detail design.

I: And also in the verification phase?

DK: From the concept design, from the first time we use it, until the end usually, yes.

I: Do you prefer to use standards in their digital form or printed? Which is easier to use and why? What would you say the advantages of each are?

DK: Well, the advantage of the printed form is for old people like me, so old fashioned guys want to read it, and that's easier to read it, actually, and you can mark things very, in a fast way. The digital form, like the pdf is of course very, has some advantages, because you can just... with CTRL and F search for something very easy. In the printed form you would have to... ok. [Search through]. But I personally like the printed format better because you can really make your mark-ups and usually you have some things where you know how many lux you need there, 100 or whatever, and the rest you don't need all the time, so you would make mark-ups in the documents. But this is, with the new technology, with tablet and so on, I'm sure people use also the pdfs, and other electronic formats.

I: What information do you look for in the standard you use? Explanations about lighting design criteria / Calculation methods / Lighting requirements values?

DK: Usually only the values because the rest I already know. But, again, in special cases, for example tunnel lighting, which is a very complicated thing, I would also read every other part of the norm. But interior lighting, the 12 464 for example, is quite a simple norm and I already know all the facts. Also the 13 201.

I: Do you read a new issue of a standard when it comes out, to familiarize yourself with it, or is the information so straightforward, that you only need to use it when it is needed in a project?

DK: It depends on the standard. Usually I try to stay on track and to understand what is new in the new version of the standard. For example in the 12 464, the old standard was from 2008 and then 2013, I think, we got the new standard, where they put requirements for walls and ceilings. We already knew that because we got the information from the market or from newsletters, but I checked again these areas and tried to understand what... from the moment that we got the standard. Because from the moment when the standard is out it is valid. So we have to take care of it in the new projects in Europe of course.

I: Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process?

DK: Both. So, sometimes of course, it makes the work easier because when it's written in a very... let's say open-minded way, then you have the information about the 100 lux in the corridor. And you can decide how you can reach that. Sometimes it's quite complicated, as for example in office, where you have to illuminate the walls and the ceilings, and you're quite restricted in how to solve these problems. So it goes both ways.

I: Does the standard give you the input you need? Do you always get the necessary information?

DK: It depends on the standard again. So with the 12 464 I would say yes, with the 13 201 – Street lighting, also yes but there are some, I read much many tunnels, they were not really clear, and also some parts are also not very clear written. So you can interpret things, which is also ok.

I: Are the standards in line with the latest technology?

DK: Yes, and usually they give the values, so the information is how much you need to reach to illuminate in a proper way. What technology you use is your thing. So you could use halogen lighting... well, halogen not anymore, but LED or metal halide or whatever to reach this thing. But I think because of several reasons the standards are maybe not in a... maybe yes, the newest technology, but all the facts that we should know about, the human eye and so on is maybe not always taken care of. For example illuminance or the intensity of lighting is a relative thing. There is brightness and there is darkness and we only see a brightness when there is a darkness. So the most important thing is the uniformity. For example in street lighting, I personally think that we don't need to be that bright, we just would need to be more uniform, you know? And what happens in reality, when... you know, theory and reality... we have the standards, there it's written... let's say 1.5 candela and some kind of uniformity and people try to reach the candela but don't really take care about the uniformity, but that would be the more important point, you know? Because, in my opinion, if there is a value given of 1 candela in street lighting... I am talking mostly about street lighting, that we could also live with 0.5 candela, but with a better uniformity.

I: Have you found mistakes in any of the standards you have read?

DK: No, not really, there are some areas where you think it could be better written or made clearer, or whatever, but it's hard for me to say because I'm quite into this area, but I think that if someone who is not constantly working with the standards or with lighting design, for example who needs to do it once.. Six months for example... that he will not get all the information which is needed, you know... maybe.

I: Also no contradictions... for example not being able to reach some value because of the technology or...

DK: For example this thing about the offices, where you need to illuminate the wall and the ceiling now, you need there 50 or 75 lux. This is not possible with every technology, for example with the ceiling mounted luminaires, which was ok before, because there was no restriction on walls and ceiling. Then, again, the question is that some scientists... the illumination around the focus area is maybe not that important and I am not talking about the task area and the adjacent area, but the wall and the ceiling. Some scientists say that

we even see better if there is a difference... contrast. If you look at your own desk in winter or in darkness, when you have there 500 lux that is really bright. And when everything is lit around you, for example with sunlight, you have there, let's say, 2000 lux and on the walls next to you 1500 for example, then your task area is not that bright anymore, because again the intensity is a relative thing, it's not fixed. So maybe it was not necessary for example to get that requirement. Because, again, this could be... this is a thing that should be decided by, in my opinion, an architect, or a lighting designer who says "I want to have nice accents and the rest should be darker – not dark, but darker", and the other one says "No, I want everything bright". And now we have this requirement and there we cannot move so freely as we wanted, or could.

I: Are the explanations and definitions clear and easily understandable? I think you already answered this…

DK: It depends on the standard, again. So, sometimes yes, and again, my question is... are they for people who are not totally into this topic? I don't know. For me, most of it is clear, some things I cannot really... I would do differently, but in general its ok – for me.

I: Have you ever found some information which is vague?

DK: Yes, of course, but then again, maybe this is not a bad thing. It depends.

I: It leaves room for interpretation?

DK: Exactly, which can be good, but can also be very bad of course. But that's the thing, then you would need a very good lighting designer, or independent one, who could bring this into the terms of the client or the project.

I: Do you think the quality of lighting design would be lower if no standards were to be used?

DK: Definitely, yes. And the quality would... let's say, other standards could also be better, for example if you take building related to health, hospitals or other buildings for sick people, where lighting could be a positive factor, then you would say "We need more requirement than just how much lux" because lux doesn't say anything. Still they use all these chemical tubes there, where you don't have the whole spectrum of light, so there it could be interesting to use natural light, with halogen, with LED maybe, with the whole spectrum. But, and if you would have no standard at all, then it would happen what

happens now in projects where they don't care about the standards, they use the cheapest thing to do something they think that might be ok. Usually if you don't have a standard and you have a good lighting designer, who understands his work, then it could work, because then he knows for example, in a restaurant you don't need 500 lux, but you want accents and bla bla bla... but if you maybe don't have a good architect who understands what light is, and the lighting designer only is someone who wants to sell light, then you can get everything.

I: If lighting design was to be practiced without standards, could this lead to safety issues?

DK: Yes, of course, of course.

I: If there were no lighting standards to be followed, how do you think this would affect the energy consumption of lighting in buildings?

DK: Again, it would depend on the one who makes the lighting design. Usually, if there are not only those standards, but also the energy requirements standards, which say for example, you need 12W/sqm as the maximum. If we don't have these standards and requirements, we would automatically get something out of it, the cheapest solution usually. If you have a good lighting designer, who tries to make the best for the project, you automatically would get a good value of lighting design and energy consumption. But without any standards, it doesn't work. You could test this on the road, if you say there are no laws anymore, what would happen? It would happen what happens in China and India, that the guy with the Lorry would drive in the middle of the lane, and the strongest... so here again, when no laws, then do whatever you like.

I: The standard you use most often. Is it a satisfying experience overall? Or is it rather a tedious, unpleasant part?

DK: No, it is ok. I'm usually mostly working with the 12 464, which is for indoor and outdoor, this works quite ok, it's not complicated or anything, and also the street lighting norm is also fine, so usually it's more complicated when you work with the brands standards like from Hilton or from Marriott, where, well, those guys would need for example a good lighting designer to make new standards, which would be more appropriate for example.

I: Do these standards come in contradiction with the regular standards?

DK: Sometimes. But usually there are... yes, sometimes, yes, and usually they are just crazy. For example 650 lux on a vanity area, in a vertical lane, or such stuff. When you cannot meet the energy requirement anymore, you know. So it's quite complicated sometimes.

I: Is it easy to find what you need? Inside a standard, and even between standards, you know from their title what information to find and where?

DK: Usually yes, it works because normally, before people write a standard they read one first, so they are quite similar to each other. Special standards are, again, you have to read them from the beginning to the end to understand what's going on.

I: Does the design of the standard make a difference in your experience of working with them? The graphic design...

DK: It could help, actually, sometimes. If it's better prepared then I could very easily understand what they actually want to achieve. There is a very good standard now, which is new, for Abu Dhabi... so they have very nice graphics... that could help, yes.

I: Difference in perception of satisfaction of using one standard or another – Experiment showing the same table/graphic from two different standards.

DK: This is very, very clear, you know [pointing at British standard], so in here, you have to read [the explanations under the figure]. It's also fine but if you were stressed and [in] time pressure, you just have to look for a second in this one and "aa, yes, I know what it is", but this is a difficult German written norm, very technical, this is also ok if you have read it several times first. But this is just easier. So here you just see actually that if they made a proper graphic, not very... this is no 3d graphic, but it works quite fine, you know. This could help the reader very well. And again I'm used to this norm [pointing to 12 464), so I know what they want, but the question is again, what if someone uses it every 3 months, or whatever?

I: I will be doing some experiments with students, which study the area, but with the standard they are not that familiar.

DK: That should be interesting.

[Looking at the tables comparison]:

DK: Well, this is nearly the same, because the norms are...

I: Just from the graphical point of view...

DK: A, well, this is of course better [pointing to SLL], because of the background color, it's very is to… It is not a big deal, of course, but this helps, you know. And again, it is also not that technical, because of the font. It's quite nice made. But here [SLL] we have 4 areas in one sheet, and here [12 464] we have 8 or more, so this is more practical for anyone who has to print it and to pay the printer ink, which could be also a topic.

I: What would, in your opinion, make a standard more usable? (More useful, efficient, user-friendly)? Why?

DK: Well, they would, the guys who write these standards, if they would actually talk to people who use those standards, so making a research like you're doing, they could for example, take the 12 464, going to, let's say, 3 lighting designers, 3 guys from the industry, and so on.. and asking them, "ok, where do you think are the problems and what do you think we could do better?". So, this kind of criticism could help to make it a wonderful standard, of course. I know that when they make a new version of it, that they are coming together, to make the standard, but usually the lighting designers or the people who have to work for the money, who have no lobbies, do not have the time and the money to attend there. So you just have to have a look at the board members of these standards. I know some of the guys who wrote this [12 464], or who worked on this, and this is mostly, a guy from the European government, or council, who has nearly no idea of lighting, or luminaires, and the others are... they work for companies like Zumtobel, or whatever. So, and the question would be "How would lighting designers, or how would other technicians change these standards?" So, that could make sense.

I: When you think about the level of usability of the standards, find a single word which would define it.

DK: Helpful. Actually, it is.

I: Thank you!

DK: You're welcome!

Interview 4

Date: 14 January 2015

Interview duration: 17 minutes

Recorded: audio

Language: English

USER PROFILE (as filled in by user)

Profession: CEO / Head of design

Age: 55

Experience in the field of lighting (duration): 25 years

What are the tasks you perform at your job?

- Concept design
- Detailed design
- Tender documents
- Implementation phase
- Evaluation of fixtures, measurements (Laboratory)
- Development of lighting fixtures

Do you use standards in the lighting design process?

- Yes

Which standards/codes/guidelines do you use regularly in your daily work? As much as possible, please order them after relevance/frequency of use.

- EN 12464, EN13201, CIBSE, Operator
- Standards, IES indoor/outdoor

INTERVIEW

I = Interviewer

HR = Interviewee (name initials)

I: In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them?

HR: Yea, most of the time the standards come in in the early beginning, because in some projects it's really critical to have the latest standards, either because of government reasons or because of operator's reasons. And then we are trying to develop the design along with the standards, by trying to have a strong look on the, let me say, to create nice designs within the standards.

I: Do you prefer to use standard in their digital form or printed? Which is easier to use and why?

HR: I like the printed form more. Simple. We have the digital one as well, but I personally like the printed one.

I: Why would you say that?

HR: For me it's, how to say, it's more comfortable to have something between the fingers, and to read it, it's more real as on the screen. Just... personally.

I: What information do you look for in the standard you use? Explanations about lighting design criteria / Calculation methods / Lighting requirements values

HR: Sometimes about criteria, because this could be an important topic, for example glare or reflections, or whatever, by developing the concepts, especially if it is a field which we are not so often in, because the standard things we know from experience how to work with it. And then values, yes. Calculation methods… most of the calculations are now done by programs, by professionals of the team, so this is a chapter which I will leave to the guys who are doing it.

I: Do you read a new issue of a standard when it comes out, to familiarize yourself with it, or is the information so straightforward, that you only need to use it when it is needed in a project?

HR: Normally I take care of it as soon as there is the need of it. This means if we are starting a new project, which is started after a new standard was issued, then I am starting to check the standard where is the difference to the old version, and to see what it is we have to take care about.

I: Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process?

HR: I would say it makes it not more complicated, but without standards I am definitely sure that we could do some things better. For example, the most of these standards are developed with big lobbying from the industry, so not all the light levels given are really needed. So, if there would be a range from 2… for example, instead of saying 100 lux minimum is the requirement, instead the minimum could be between 50 to 150 lux, for example, and you could work within this range, you would have a better possibility to save energy and to make something nice. Because the difference for the human eye is not so big between 50 and 100 lux, if the eye is already adapted to the surrounding. So there is no need for 100 lux in the most of the cases if the surrounding surfaces are nicely lit. If it is a dark environment, certainly it is a different issue, but that's the point.

I: Does the standard give you the input you need?

HR: Most of the time. Most of the time, even if sometimes it's not easy to understand, but it is.

I: Are the standards in line with the latest technology?

HR: The standards normally are quite independent from technology in my opinion, because the standard will not, in the most cases, will not tell you which technology you need to use. The standard will take care about values and about quality of lighting. Sometimes it happens that the standards are not detailed enough to focus on the quality. For example, with the old fashion lighting sources, you know exactly about color range and nanometers. With LEDs it's quite different. And this makes it also different how the 100 lux are looking at the end. And this is a little bit the thing which is not taken care [of] right now in the standards, because if the range of color is bad, then 100 lux are, from the measurement, fine but at the end it looks not like 100 lux. You know what I mean?

I: Yes.

I: Have you found mistakes in any of the standards you have read?

HR: Not really.

I: Are the explanations and definitions clear and easily understandable?

HR: The European ones, mostly better in the explanations as some American or international ones. Operator standards sometimes quite complicated.

I: Have you ever found some information which is vague?

HR: Yes. How to say, for example the Unified glare rating, the UGR factor. The program can calculate it, there is a formula that you could calculate it by hand, let me say, but it is really a headache to check this on site. To prove that the calculation is done in a right way or that the fixture is acting as per calculation. And this happens in many things, even with the street lighting, this glare thing, sometimes if you read how to measure it and how it's calculated, the words about the fixtures, it's really hard then to make a clear assumption at the end if the project is well done or not. And this is the point. It happens from time to time that there is some information not clear or quite complicated. Or, for example (the measurements, or) the lux levels for emergency lighting. The program is calculating more or less with all the walls in black. When you go to measure emergency lighting, the walls are painted in which color ever, and you will check if the lux levels are there, which you have calculated if the walls are black. You know what I mean?

I: Yes

HR: So this is a big difference and it is wrong, simple. Because if then there is smoke and dust and all this dirt, the lux levels will not be as you measured it in the clean environment, with the nicely painted walls. But it's nothing wrong, according to the standards. So there are definitely some things which are not [good] for working.

I: Do you think the quality of lighting design would be lower if no standards were to be used?

HR: Sometimes yes, sometimes no, depending on the guy who is doing it. So it could be that if this is an idiot, definitely it will be a low quality, if this is a clever one, it could be much better as with the standards, especially on the energy consumption. This or that – both are possible.

I: And also possibly different interests of the ones who are doing the design?

HR: For sure. The most of the time the problem is not (facing, how to say) doing projects with or without standards, the most of the problem is the understanding of the client. What does it mean to use quality or to implement something.

I: If lighting design was to be practiced without standards, could this lead to safety issues?

HR: I would say yes. In some cases, yes.

I: If there were no lighting standards to be followed, how do you think this would affect the energy consumption of lighting in buildings?

HR: I think in the most cases the energy consumption will be much higher, nevertheless, even with these standards, the way that they are used in the most cases, the energy consumption is too much.

I: So, maybe a mistake of the standards would be the fact that the values are...

HR: Too high, yes. Because all these standards are industry driven. For example, a good example is the circuit breakers. Circuit breakers are depending directly on the copper cables which are used – the diameter of the copper cables. Because this diameter will allow for some Amps, and the circuit breaker has to take care that the Amps are not too high for the diameter of the copper cable, otherwise the cable will burn. Ok? So we had for the same cable, for example, 1.5 sqmm, we had circuit breakers in the past with 16 Amps, with 12 Amps, and with 13 Amps. And even with 16 Amps nothing happened. You know what I mean? So, it was not, as far as I know, not one accident recorded if there is a proper installation, that the 1.5 sqmm copper cable will not take the 16 Amps on permanent load, because why? Because most of the time there are not 16 Amps permanent. So it happens from case to case. And then this is the same with lighting. So if we are saying 500 lux on the task area, its fine, but if you have no furniture, you have to apply 500 lux everywhere. Instead of saying ok, let us have 300 lux, this is fine if no furniture is there, and if somebody has problems, he will get additional light to reach the 500. This would save a lot, but the industry will sell less.

Even the new issue with the walls and the ceiling. As we know, the most of the LEDs are direct lighting, not reflectors. So this means the uniformity most of the time is not so good as for example with the less efficient compact fluorescent down lights. Because the LEDs will give more spikes as the compact fluorescent, have most of the time wider angles. So now they are giving values for reflections on walls, on ceilings, with a better uniformity. So this means you have to put more near distances between the down lights to get the better uniformity, in fact of the spikes, as with the compact fluorescent. You got the point? So at the same time they are talking about less energy, which is simply not possible. Because,

with the new values on the walls and on the ceiling you need more energy to get these values as they should be.

I: The standard you use most often. Is it a satisfying experience overall? Or is it rather a tedious, unpleasant part?

HR: No, it's fine.

I: Is it easy to find what you need? Inside a standard, and even between standards, you know from their title what information to find and where?

HR: Most of the time, yes.

I: Does the design of the standard make a difference in your experience of working with them?

HR: I would say yes, definitely. The way that things are described or graphics are looking, definitely making it easier or you will need more time to understand what they are talking about.

I: Difference in perception of satisfaction of using one standard or another – Experiment showing the same table/graphic from two different standards.

HR: I would prefer something like that, definitely, because then there is no need to read or to search what does it mean [pointing to SLL graphic]. It's all there what you need with one view, you know exactly what they are talking about. Here [12 464] you have the "3", ok, what does the 3 mean? And that's it, it's not so simple, let me say. Tables, I see not a big difference. For the tables it is clearly described here and there and if it is with or without color, there I see no difference.

I: What would, in your opinion, make a standard more usable? (More useful, efficient, user-friendly)? Why?

HR: Useful… I think usable… the standards are in most cases, except some very seldom used ones, like we found out with the tunnel norms, for example, which is a very complicated thing. The really thing which could make the standards better, from my point of view, is if they are created through independent sources. Means then the energy consumption and all this stuff, even some quality issues, would get… would find their way into the standards. But in principle, the standards are usable. So, that's… it's only most of the… The thing which could be better is the energy consumption, the budget and the

quality of lighting which I think could be different if there would be some more independent people with know-how working on the standards.

I: When you think about the level of usability of the standards, find a single word which would define it.

HR: Practicable.

Interview 5

Date: 15 December 2014

Interview duration: 17 minutes

Recorded: audio

Language: English

USER PROFILE (as filled in by user)

Profession: Electrician

Age: 59

Experience in the field of lighting (duration): 40 years

What are the tasks you perform at your job?

- Concept design
- Lighting simulation
- Detailed design
- Drawings (plans, details), visualizations
- Tender documents
- Implementation phase

Do you use standards in the lighting design process?

- Yes

Which standards/codes/guidelines do you use regularly in your daily work? As much as possible, please order them after relevance/frequency of use.

- 12464
- EN 1838

INTERVIEW

I = Interviewer

HV = Interviewee (name initials)

I: In the lighting design process, could you please describe the steps of the process, where the standards come into play, and how do you use them.

HV: We use it in the first phases, like, the design phase it starts, with the base phase, we have to look which regulation we use. The first step.

I: And then in the detail phase, the verification phase?

HV: Of course in all other phases.

I: Do you prefer to use standard in their digital form or printed? Which is easier to use and why?

HV: We have it in digital form, and we have it also, some of them, in paper form. Nowadays, I can also use it in digital form, if I can search there. Sometimes the pdf is not searchable, then I use the paper one.

I: So an advantage for the digital form is when you can search?

HV: Yes.

I: What information do you look for in the standard you use? Explanations about lighting design criteria / Calculation methods / Lighting requirements values

HV: Normally I look for the things I don't know. Most of the things I remember, and when I don't remember I look there. Normally I look about the lists, and sometimes about the lux per use of the room, because they are very well detailed there and some other tables, really. [Tabellen, eigentlich], lists. Not really the text, but the lists are very helpful. Lists and values.

I: Do you read a new issue of a standard when it comes out, to familiarize yourself with it, or is the information so straightforward, that you only need to use it when it is needed in a project?

HV: Normally the new regulation comes out and I will be informed about any other medium. The best way to get it into my brain is to get the information from a company or a guide who is working in the regulation institute. I prefer to stay at Light Days or Lichttechnischegesellschaft, or Zumthobel, or else. Normally they make once a year a planner day, a design day, for the offices who design, and then I get there the new regulations and will be informed. Otherwise I read it in the newsletters of some companies and I buy it then, and then I look short over it. So, three possibilities. The best way is to get the presentation – what has changed, and what is new.

I: Do the standards make the work easier (giving input and information) or does it act as a constraint in the design process?

HV: No, it's helpful, the regulations. Because the new way is that you don't have any regulations, there is nothing forbidden and nothing allowed, and it's just [the state of the art technology] (Stand der Technik) and that's not really helpful. So we need regulations.

HR: It's also mainly to judge at the end.

HV: Yes, we need it, we need regulations.

I: How usable do you think the standards are? Does the standard give you the input you need?

HV: Hmm… no. If it's a standard that comes out once and doesn't change then, the next, let's say, 20 years, it's easy to read. But after the first, and second, and third edition, nobody can read it because it's crowded up, points that change. Some regulations, not in light design, but in some other, in electrical design, are not usable.

I: Are the standards in line with the latest technology?

HV: They are not. Because it takes a lot of time that they get law, especially in the electro-technical regulations. There it needs 5 or 6 years till they get into the law. They are regulations, they are designed 5 or 6 years ago and they are not in law, so they are only in progress, and it takes so long because our government change every 5 years and sometimes they wait for the next one.

I: Have you found mistakes in any of the standards you have read?

HV: Of course.

I: What kind of mistakes?

HV: For example, in the regulations it is not allowed to have... In eine Mehl Mueller staubt es, aber der Brandmelder muessen Staubgeschuetzt sein, koennen aber von ihrer Technologie nicht staubgeschuetzt sein. Das war ein Punkt, da haben wir dann eine Ausnahmegenehmigung (exception permission) vom Ministerium gebraucht. Das Gesetz auf 5 Jahre, es war eine Ausnahmegenehmigung dann auf 10 Jahre. Da verschiebst eine auf die nechste, und die naechste, und die ueber-nächste Regiuerung.

HR: You know, wenn Mehl produziert wird, die Getreide gemalen wird, dann staubt es irrsinnig stark – dust, there is a lot of dust. And the fire detectors, like this one, need to be protected against the dust. As soon as it is protected, it will not work anymore. And this was the problem, it was described in the standards that they should be protected. On the other hand, at the same time, they will not work if they are protected, so they got a special permit to use them without protection. This is a typical mistake of standards.

I: Are the explanations and definitions clear and easily understandable?

HV: Not always. You have to read it twice or three times that you understand each column, and each sentence, because sometimes the sentences are not short, as your questions, they are long and there are a lot of columns.

I: Have you ever found some information which is vague?

HR: Einige Punkte gibt schon immer wieder.

HV: If I say yes you ask me for an example and I don't have one. (laughing) No, I didn't find. (laughing)

I: Do you think the quality of lighting design would be lower if no standards were to be used?

HV: Of course. Yes.

I: If lighting design was to be practiced without standards, could this lead to safety issues?

HV: Of course.

I: If there were no lighting standards to be followed, how do you think this would affect the energy consumption of lighting in buildings?

HV: It will rise up, yes. For example in Switzerland they have already a regulation that stand by consumption is not more than 1W. It will also get lower in the European Union,

and now a normal lamp, stand lamp for an office has 15VA and perhaps 2W, and the 15VA isn't measured, only the W, so the power consumption rises up, nobody pays for it, and if we don't have any regulations, it wouldn't work. That was now an example, if you need it.

HR: Now is nobody paying for it, but this may change in the near future.

HV: Yes, with smart meters you pay also for the VA, for the Volt Amper, so then you pay for it and don't know it. And formally it is a Cosmos fee from 0.1 I think.

HR: We have this problem with LEDs, that you get 50% more VA than what is written in the specifications.

HV: For LED we need very urgent regulations.

I: The standard you use most often. Is it a satisfying experience overall? Or is it rather a tedious, unpleasant part?

HV: No, standards are ok, and I use it and I need it. It doesn't make sense that I say we need it and then I say it's not… no, no, yes, we need it.

I: Is it easy to find what you need? Inside a standard, and even between standards, you know from their title what information to find and where?

HV: Today with internet and Google and all this searching machine it's very easier than in the past.

I: But the standards themselves, are they searchable?

HV: If you buy a standard that is searchable, then you find everything in it.

I: Does the design of the standard make a difference in your experience of working with them?

HV: It would be fine if in the standards are not such a lot of footnotes and these links between the first and the last page. These links are not really helpful. It would be fine if it is as in a Reisefuhrer travel guide, because there already you have a link to the Internet, a link to the other page, digital link between these (links) pages, so that you search for it, for an easy word, so you have a link between these two. In the digital world it shouldn't be really a big issue.

I: Difference in perception of satisfaction of using one standard or another – Experiment showing the same table/graphic from two different standards.

HV: For me as an old fashioned man it's... I know this one [points to the British standard], I don't know, for me, in 1984 I had my first computer, one of the first IBM computers, they use green and white, so it's not really a new design [the British standard]. You understand? (laughing). So for me ok, it's nicer, but if it's easier to read, I don't know, for me as an old man, it's bigger letter and it's not a landscape, it's portrait [points to EU standard].

I: How about these two? [graphical illustration]

HV: Of course this is better than this one, because this is not really very good [prefers EU standard]. And for me it would make sense that every single sentence or Absatz has a number to search for it because, as you see, there are a lot of things that are only with point or underline or either thing, it would be fine if every column, if every sentence has a number. If I write a memorandum, each sentence has a number, so that on the telephone I can say: "Please, point 75" and not "Second page, third sentence, left from the picture". If you make now regulations, I don't think so... (laughing).

I: What would, in your opinion, make a standard more usable? (More useful, efficient, user-friendly)? Why?

HV: Each line has a laufende Nummer. It would be easier.

I: When you think about the level of usability of the standards, find a single word which would define it.

HV: Awful. (laughing)

HR: Manche sind wirklich grausam.

HV: It was easy. Thanks

I: Thank you.

9.2. Appendix B

Questionnaire Form

Questionnaire on the usability of lighting standards, as part of the study "Usability of Building Performance Standards in View of Design Support"

User Profile

What is your profession?

_____

What is your age?

_____

How many years have you been working in the lighting area?

- ☐ 1 year or less
- ☐ Between 1 and 5 years
- ☐ Between 5 and 10 years
- ☐ Between 10 and 25 years
- ☐ Over 25 years

What are the tasks you perform at your job? (Multiple choices are possible)

- ☐ Concept of lighting design
- ☐ Lighting simulations
- ☐ Lighting drawings (plans, details), visualizations
- ☐ Tender documents for lighting projects
- ☐ Implementation of lighting projects
- ☐ Evaluation of lighting fixtures, measurements (Laboratory work) Development of lighting fixtures
- ☐ Other: _____

Do you use standards in the lighting design process? Mark only one oval.

- ☐ Yes
- ☐ No

Do you regularly use the standard "12464-1: Light and Lighting – Lighting of work places"? If not, please provide the name of the Standard you use most often in your lighting practice. Mark only one oval.

- Yes
- No

The following questions refer to the Standard you use most often or to the Standard "12464-1: Light and Lighting – Lighting of work places" if it is familiar to you.

How would you evaluate the Standard? Mark only one oval.

- Very effective
- Effective
- Mostly ineffective
- Completely ineffective

Do you prefer the printed version or the digital version of the Standard? Mark only one oval.

- Digital
- Printed

How easy is it to find necessary information in the Standard, without using other resources (Google, etc.)? Mark only one oval.

- Very easy
- Rather easy
- Rather difficult
- Very difficult

How accessible is the language used in the Standard? Mark only one oval.

- Perfectly accessible
- Accessible
- Rather complicated
- Very complicated

Does the Standard state the design requirements in a clean and unambiguous manner? Mark only one oval.

- Perfectly clear and unambiguous requirements
- Some ambiguous requirements, enough for design flexibility
- Some ambiguous requirements, generally detrimental to lighting practice
- Highly ambiguous requirements

Do the minimum requirements of light levels in the current Standard limit the flexibility in designing energy efficient solutions? Mark only one oval.

- Not at all
- Seldom
- Sometimes
- Yes, very often

Do you think that the Standard limits the designer in proposing creative solutions? Mark only one oval.

- Not at all
- Seldom
- Sometimes
- Yes, very often

Does the current version of the Standard sufficiently consider new technologies (e.g. LED)? Mark only one oval.

- Very much
- More or less
- Not enough
- Not at all

Do requirements in the Standard address real-life issues that can affect lighting? (For example surfaces, colors, dust, smoke, etc.). Mark only one oval.

- Very much
- More or less
- Not enough

- [ ] Not at all

Is it easy to verify that all requirements in the Standard have been met after the project is completed? Mark only one oval.

- [ ] Yes, all
- [ ] Most
- [ ] Few
- [ ] None

Do you think that recent research results about lighting and human vision/health are sufficiently included in the current Standard? Mark only one oval.

- [ ] Very much
- [ ] More or less
- [ ] Should be better
- [ ] Not at all

Do you think that besides scientific findings about good lighting practices, there are other interests behind the Standards? Mark only one oval.

- [ ] Not at all
- [ ] Rather not
- [ ] Probably
- [ ] Definitely

If you think there are other interests, what are they?

_____

How would you evaluate the overall experience in working with the Standard? Mark only one oval.

- [ ] Very good
- [ ] Rather good
- [ ] Rather negative
- [ ] Negative

9.3. Appendix C –

User profiles of questionnaire respondents

Profession	Age	Experience in the field of lighting
Lighting consultant	26	Between 1 and 5 years
Lighting consultant	46	Over 25 years
Lighting Designer	39	Between 10 and 25 years
Lighting Designer/Architect	29	Between 1 and 5 years
Lighting consultant	35	Between 5 and 10 years
Lighting Designer	29	Between 1 and 5 years
Freelance lighting consultant	57	Between 5 and 10 years
Manager	46	Between 5 and 10 years
Lighting Designer	30	Between 1 and 5 years
Manager	34	Between 5 and 10 years
Electrical technician, Manager	55	Between 10 and 25 years
Sales manager	59	Over 25 years
Marketing manager	42	Between 1 and 5 years
Electrical technician	54	Between 10 and 25 years
Lighting company manager	41	Between 10 and 25 years
Electrical technician	57	Over 25 years
Light technician	27	Between 5 and 10 years
Marketing manager	24	Between 5 and 10 years
Architect	40	Between 5 and 10 years
Freelance	46	Between 10 and 25 years
Lighting designer	28	Between 10 and 25 years
Planer	55	Over 25 years
Research engineer	52	Between 10 and 25 years
Lighting Designer	26	Between 5 and 10 years
Lighting Designer	26	Between 1 and 5 years
Light technician	38	Between 10 and 25 years
Light technician	32	Between 10 and 25 years
Technical specialist	41	Between 10 and 25 years

9.4. Appendix D

Experiment Version 1 – "Think-aloud" experiment protocol

A series of experiments with Building Science and Technology students and (at least 2) architects will be conducted in order to assess the usability of the 1*2464-1: Light and Lighting – Lighting of work places, Part 1: Indoor work places*, which is the most used standard in the field of lighting design within Europe.

The experiment will be held individually with each participant, employing techniques established as effective in the field of usability testing. (Rubin, Chisnell, 2011)

The experiment will be maximum 1:20 hours long, will be audio-recorded, and will contain 4 parts, as follows:

Stage 1: First contact and familiarization with the document – 20 minutes

Usability assessment by "think aloud" method

The user (Building science student) will be presented with a printed copy of the 12464-1 Standard, and will be asked to have a look at it, in order to familiarize him/herself with the document for the upcoming tasks which will be based on it.

> Task description:
>
> The user will be encouraged by the interviewer to understand what kind of useful information the document contains, in what way it is structured – which are the main chapters, and where to find the requirements which could be relevant in developing a lighting design project.
>
> Although writing/drawing on the Standard itself will not be possible, sticky markers will be available, as well as paper and pen, that should only be used if wanted.

Through-out the 20 minutes of familiarization, the participant will be asked to talk out loud whatever they are thinking while investigating the document – remarks about their first impressions, how they are going about the process, but also problems they encounter and thoughts about what would be more helpful.

The talk-through will be audio-recorded and notes will be taken by the interviewer about the actions of the participant. Although in this stage, the interviewer is mostly passively observing, questions about the process may be asked if participant is not talking enough.

Being well aware that 20 minutes is not usually enough for getting a detailed picture of the entire document, this will put the pressure on the participant to establish a clear mental structure of the Standard, as far as possible, and to quickly take note of the critical parts, that may be required later on in the experiment.

Stage 2: Finding and understanding specific information – 20 minutes (2 x 10 minutes)

Usability assessment by "think aloud" method and task results

The user will be asked a series of 2 questions about specific information within the standard. The task each time will be to find the information and explain what they have understood after reading it.

The 2 questions vary in difficulty from easy to difficult (as assessed by interviewer), and are chosen in such a way that they do not interfere with the task in Stage 3 of the experiment.

The questions are as follows:

1. According to the Standard, how are the "task area", "immediate surrounding area" and "background area" defined? What are their dimensions? What is the value of the illuminance required for each area?

2. What is the "Mean cylindrical illuminance"? Which area does it apply to within a working space, and what is its required value according to the Standard?

Through-out the 10 minutes of each task, the participant will be asked to talk out loud whatever they are thinking while trying to find the answer: remarks about the steps they are taking and why, but also problems they encounter and thoughts about what would be more helpful.

The talk-through will be audio-recorded and notes will be taken by the interviewer about the actions of the participant. Although in this stage, the interviewer is mostly passively observing, questions about the process may be asked if participant is not talking enough.

Stage 3: Using the Standard in a practical real-life example – 20 minutes

Usability assessment by "think aloud" method and task results

A task is given to the participant, which would be normally found in a lighting design daily practice situation.

As revealed by the interviews with field professionals, the Standards, either national, international or operator developed, come into play early on in the design process. Depending on the size of the lighting design office, the task of checking the relevant Standards will be undertaken by the lighting designer himself, or by an employee appointed with extracting the relevant information from the applicable standards.

The task:

You must develop the lighting design of a "Co-working" space, in which activities such as office work (writing, reading, working on computers), as well as meetings will take place. The design will include the kitchen, corridor and toilets areas.

Please extract from the standard all required values for the mentioned space.

Through-out the 20 minutes of the task, the participant will be asked to write down the requirements that apply, and also talk out loud whatever they are thinking while trying to find the answer: remarks about the steps they are taking and why, but also problems they encounter and thoughts about what would be more helpful.

The talk-through will be audio-recorded and notes will be taken by the interviewer about the actions of the participant. Although in this stage, the interviewer is mostly passively observing, questions about the process may be asked if participant is not talking enough.

Stage 4: Evaluating the user experience – 20 minutes

Usability assessment by questionnaire answers and further comments

After the experiment, the participant will be invited to add any comments regarding the whole experience, as well as possible suggestions about the ways in which the standard could have been better written/structured/designed in order to make it more usable.

Questions regarding the efficacy, efficiency and satisfaction in working with the Standard will be asked in order to channel the thoughts of the participant towards the main traits associated with usability. (Nielsen, 1993)

The discussion will be audio-recorded.

After the tasks are completed and final comments are recorded, the participant will be asked to fill out a questionnaire about the experience of working with the Standard. The short discussion before this, should leave the participant with a fairly clear idea about his/her evaluation.

Final questionnaire:

A. USER PROFILE

1. Study field (present and past)

   _____
   _____
   _____

2. Age

   ____

3. Have you worked with similar Standards before? (not necessarily about lighting)

   _____
   ___

B. USABILITY EVALUATION

1. Were you able to find the information you needed within the Standard?
   a. Yes
   b. No
   c. Partially

2. How simple was it to work with the Standard?

○	○	○	○	○	○
VERY EASY TO WORK WITH					VERY HARD TO WORK WITH

3. How well structured is the information in the standard?

○	○	○	○	○	○
VERY WELL STRUCTURED					VERY POORLY STRUCTURED

4. How clear is the information in the Standard?

VERY CLEAR VERY UNCLEAR

5. How pleasant was the overall experience of working with the Standard?

VERY PLEASANT VERY UNPLEASANT

9.5. Appendix E

Experiment Version 2 – Tasks slides

Task 1

Familiarization with the Standard

1. Create a mental picture of the Standard, for future use

What does the Standard contain?
Which are the most important/useful chapters?

2. Write down your first impressions

How usable is the Standard?
What problems do you see?

3. Use sticky notes to mark important places

Which are the pages you would mark for fast use in a lighting project?

Task 2a

Finding and understanding specific information

1. According to the Standard, how are the following concepts defined?

1. "TASK AREA"

2. "IMMEDIATE SURROUNDING AREA"

3. "BACKGROUND AREA"

Please use your own words, do not copy text from the Standard.

2. What are their dimensions? (meters)

How do they relate to each other?

3. What are their required lighting values? (lux levels, uniformity)

Where is this information in the Standard?
How do they relate to each other?

Task 2b

Finding and understanding specific information

1.According to the Standard, what is "mean cylindrical illuminance" ?

Please use your own words, do not copy text from the Standard.

2. In what plane/planes is it measured?

3. What are its required lighting levels? (lux levels, uniformity)

Task 3

Using the Standard in a real lighting project

You must develop the lighting design of an office space, in which activities such as office work (writing, reading, working on computers), as well as meetings will take place. The design will also include a small eating area, a corridor and toilets.

1. Extract from the Standard all required lighting values and regulations that apply to your project.

2. For each piece of information, write down the number of the chapter where you found it.

9.6. Appendix F

Experiment Version 2 - Answers form

Task 1

Time: 10 minutes + 5 minutes user evaluation

Write down your first impressions, comments, problems:
(to be filled out while looking through the Standard)

_____
_____
_____
_____
_____
_____
_____
_____
_____

User evaluation

(to be filled out after the 10 minutes of familiarization with the Standard)

Do you now have a clear idea about what kind of information you can find in this Standard?

a. Yes b. Somewhat clear c. Not entirely d. No

Were you able to identify the main chapters and what they contain?

a. Yes b. Mostly yes c. Mostly not d. Not at all

Would it be easy for you to find specific information in the Standard?

a. Yes b. Probably yes c. Probably not d. Not at all

Please write down the numbers of the chapters you marked:

_____
_____
_____

Task 2a

Time: 15 minutes + 5 minutes user evaluation

Your explanation *(written and/or sketch):*

User evaluation

(to be completed after the 15 minutes of the task)

Were you able to find the information in the Standard?

a. Yes b. Mostly yes c. Mostly no d. Not at all

Where in the Standard did you look in order to find it? (if you looked in various places, please write them down in order - write only the chapter number)

_____

_____

_____

Did you find the information where you expected to find it?

a. Yes b. Mostly yes c. Mostly no d. Not at all

Is the information clear to you now?

a. Yes b. Somewhat clear c. Not entirely d. No

Task 2b

Time: 10 minutes + 5 minutes user evaluation

Your explanation *(written and/or sketch):*

User evaluation

(to be completed after the 10 minutes of the task)

Were you able to find the chapter about this concept?

a. Yes d. No

Where in the Standard did you look in order to find it? (if you looked in various places, please write them down in order - write only the chapter number)

_____

_____

_____

Did you find the information where you expected to find it?

a. Yes b. Mostly yes c. Mostly no d. Not at all

Is the information clear to you now?

a. Yes b. Somewhat clear c. Not entirely d. No

Task 3

Time: 15 minutes + 5 minutes user evaluation

Write down all relevant requirements for the task, found in the Standard *(for each piece of information please provide the corresponding chapter number where you found it)*

User evaluation

(to be completed after the 15 minutes of the task)

Were you able to find the information in the Standard?

a. Yes, completely b. Partially c. Not enough d. No

Where in the Standard did you look in order to find it? (if you looked in various places, please write them down in order - write only the chapter number)

_____

_____

_____

Did you find the information where you expected to find it?

a. Yes b. Mostly yes c. Mostly no d. Not at all

Final user evaluation

How simple was it to work with the Standard?

a. Simple b. Average c. Difficult d. Too difficult

How easy was it to find information in the Standard?

a. Very easy b. Acceptable c. Not easy enough d. Very hard

How clear is the language used in the Standard?

a. Very clear b. Mostly clear c. Mostly difficult d. Too difficult

Was the table of contents useful?

a. Very useful b. Somewhat c. Not enough d. No

Please evaluate the illustrations in the Standard:

a. Not explanatory, and not enough illustrations
b. Explanatory, but not enough illustrations
c. Explanatory and in sufficient number

How pleasant was the overall experience of working with the Standard?

a. Very good
b. Acceptable
c. Somewhat frustrating
d. Very frustrating

Other comments, problems, suggestions:

Thank You!