Computerizing Decision Making In Architectural Interior Design

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Abstract—This paper intends to examine the employment of BIM (i.e. Building Information Modeling) software in the process of decision making related to architectural interior design for transforming qualitative design parameters derived from applying environmental psychology principles (a.k.a. space science principles) into numerically measurable and assessable variables. By means of that, the highly important user-stimulated design parameters are being dealt with as numerical variables in order to obtain a clear vision of space-specific user-stimulated design needs as well as the priority of their consideration. In this regard, BI-Evaluation Matrices are sought to be composed with the intent to obtain numerical means of evaluation for the different interior design proposals.

Index Terms—Architectural, Design, Building, Information Modeling..

I. Introduction

As in (Augustin, 2009) sixteen various factors influence the 5 main criteria (being communicating, comforting, complying, challenging and continuing) of well-designed interior spaces of educational facilities. Nevertheless, these 16 factors, which have been grouped into 4 attribute categories, are not all quantitatively measurable. This is the reason why this paper is concerned with using BIM-applications for examining factors of the fourth attribute category, namely the indoor environmental attributes’ category.

And as to these factors, lighting has been found to be the most influential factor when it comes to the psychological and emotional impact of interior spaces on space users, especially students. Several references have revealed the direct impact of indoor lighting conditions on students’ cognitive and behavioral responses, mental as well as psychological state and above all creativity potential. That is why other indoor environmental qualities like humidity, air velocity, temperature and noise are out of the scope of this research.

And the focus of this BIM-application is all dedicated to the examination of indoor daylight conditions. Therefore, the interior spaces of the department of architecture in Alexandria University’s Faculty of Engineering are subjected to study.

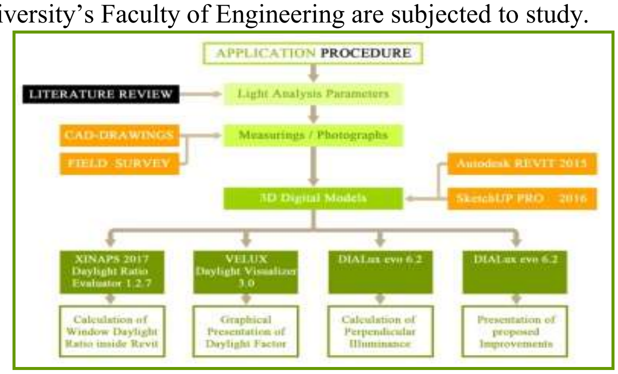

Fig. 1. Application Procedure

II. APPLICATION PROCEDURE

A. *First Step*

The first step to be taken was determining the light analysis parameters through the review of appropriate sources of literature. Next, necessary measuring was made by means of the official CAD-drawings of the architecture department subjected to study and photographs of openings and light fixtures were taken. Then, two 3D computer models were built using Autodesk Revit® 2015 and SketchUp Pro 2016. In the following step, internet research was conducted to find out about the most appropriate software for daylight and artificial lighting analysis. Four different computer programs were utilized to obtain graphical as well as numerical results concerning lighting analysis parameters (Fig. 1).

B. *Second Step*

After a 3D model of the tested department was built in Revit® 2015, Xinaps Daylight Ratio Evaluator 1.2.7, which is a plugin for Revit®, was installed and run to obtain numerical analysis for all of the department windows in terms of daylight ratio and whether it meets the required LEED standards or not. Daylight ratio is calculated by subdividing the total window glass area by the total floor area for each of the department’s rooms. Results

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are obtained as tables in ".doc" format shown on the previous page. As can be seen in Fig. (2), 64.15% of the examined department's windows meet the required daylight ratio of 15% as defined in (LEED, 2017). It is self-evident that the focus here will be on spaces directly related to students' daily routine at the department, as it is intended to examine whether the educational spaces in architectural schools have an impact on students' psychological state, creativity potential and thus their overall performance or not. Thus, formal and informal educational spaces are given most of the attention in addition to gathering and circulation spaces as these also play an important role in informal knowledge exchange between students and temporary learning activities as was revealed through literature review. Professor offices and administrative spaces as well as unused labs (like the materials lab) will therefore be neglected; although Xinaps has generated results for these spaces as well. Results have shown that out of a total of 5 design studios, 4 lecture rooms, 1 auditorium, 3 library rooms and 4 laboratories 7 do not meet the required window daylight ratio. These are illustrated in Fig. (3) highlighted in yellow.

Fig. 2. Xinaps Daylight Ratio Calculations

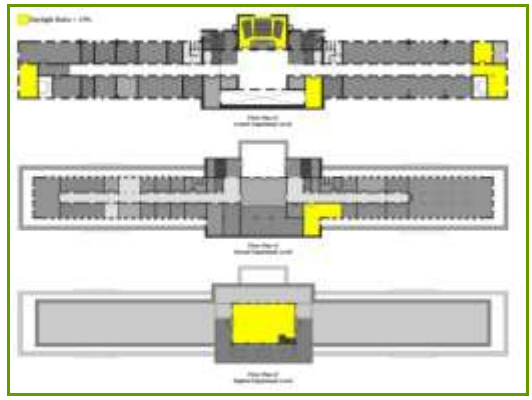

Fig. 3. Spaces not meeting Daylight Ratio Standards

C. Step 4

In this part of the application, VELUX Daylight Visualizer 3.0 is employed in order to obtain 2D graphical presentation of monthly Daylight Factor (DF) values for the time span between September 21st and May 21st, as this is the time of most intensive usage due to the fact that studios remain unused during summer vacation. Yet, more attention has been given to the winter months, as the calculation of daylight factor has to be made under overcast sky condition. And as can be seen in figures (4.1) and (4.2), clear sky condition is dominant during the summer and spring seasons in Alexandria (i.e. the time between mid April and almost mid October).

VELUX Daylight Visualizer 3.0 generates DF calculation outputs as 2D heat maps as well as isoline diagrams. The purpose of this step is to examine whether the department's interiors-particularly design studios, lecture halls and labs-achieve the internationally accepted minimum daylight factor of 2% (Council, 2017). A sample output is shown below.

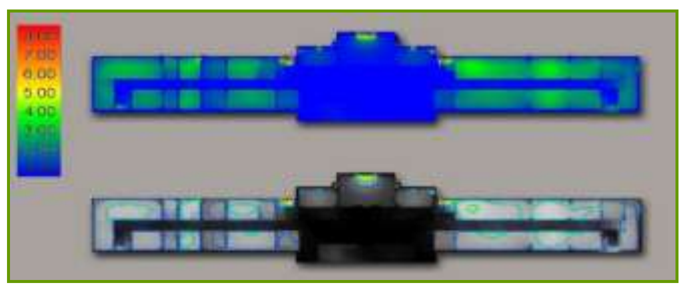

Fig. 4. VELUX Visualizer Daylight Factor Sample Output

Results have shown that in the time span from September 21st to May 21st almost all educational spaces fulfill the required minimum daylight factor value of "2.00". The only space completely out of range is the auditorium, which preserves the value of one for all tested months. Both computer labs and the urban design studio miss the required DF value in three and one month respectively. For the rest of spaces, DF values vary. This is due to two main factors namely orientation and number and size of windows in relation to floor area.

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II. DIALUX EVO 6.2 FOR DAYLIGHT ASSESSMENT

In this part of the application, the application DIALUX evo 6.2 was employed for obtaining numerical as well as graphical presentation of daylight illumination in the department's educational spaces, particularly in design studios. A 3D digital model was built up using the software. Next, a daylight scene was set up with clear sky condition to run the calculation of perpendicular illuminance on September 23rd at 9 a.m., as this is the daylight requirement defined by the U.S. Green Building Council (Council, 2017), as well as on winter and spring beginning. Calculations were made at the height of 0.80 m as this is the height of drawing tables, thus the working plane level in the examined design studios. And calculation results were presented as numerical tables, heat maps and isoline diagrams like in figures (5) and (6) respectively.EDITORIAL POLICY
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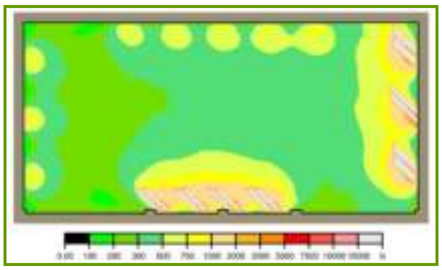

Fig. 5. First Year Studio Illuminance

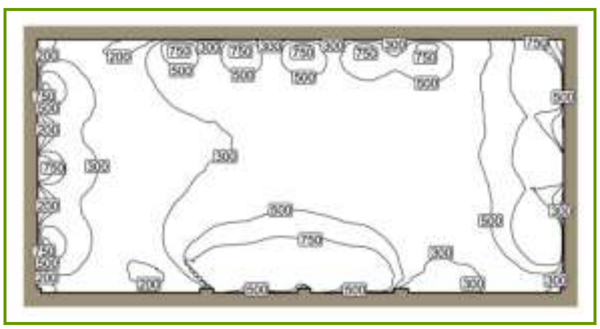

Fig. 6. First Year Studio Illuminance Values

The free German software DIALux evo 6.2 is used to calculate perpendicular illumination values on the equinox of September 23th as well as on winter and spring beginning for all of the department's spaces. Calculations have been performed for existent openings without taking any of the available shading devices in consideration with the intent to assess illumination levels as such in a pre-step for choosing appropriate shading solutions. Then the acquired calculation results are compared to the required illumination levels. These are, as defined in (Lighting, 2017) and (Neufert, Neufert, Baiche, & Walliman, 2000), up to 500 Lux for classrooms, lecture halls and offices, and up to 750 Lux for drawing studios. Figures (7) and (8) illustrate this comparison.

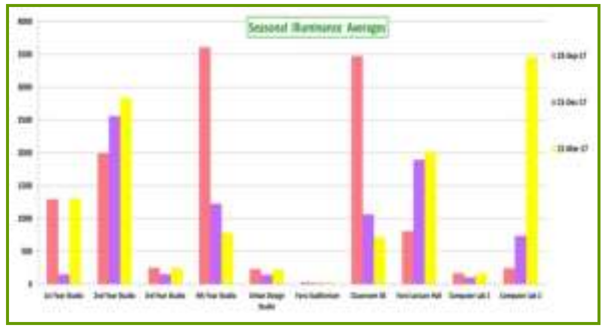

Fig. 7. Seasonal Illuminance Averages

ID	SPACE USE / LUX LEVELS	AVERAGE	Fulfillment of Required Minimum	AVERAGE	Fulfillment of Required Minimum	AVERAGE	Fulfillment of Required Minimum
	Calculation Date	23-Sep-17		21-Dec-17		21-Mar-17	
1	1st Year Studio	1293	YES	147	NO	1300	YES
2	2nd Year Studio	1994	YES	2559	YES	2830	YES
3	3rd Year Studio	248	NO	151	NO	244	NO
4	4th Year Studio	3687	YES	1226	YES	781	YES
5	Urban Design Studio	229	NO	141	NO	234	NO
6	Farsi Auditorium	29.7	NO	17.9	NO	28.2	NO
7	Classroom 36	3472	YES	1062	YES	720	YES
8	Farsi Lecture Hall	888	YES	1893	YES	2017	YES
9	Computer Lab 1	166	NO	103	NO	161	NO
10	Computer Lab 2	243	NO	738	YES	3497	YES

Fig. 8. Comparison of Seasonal Illuminance Values

As can be seen in the table above, comparing the average Lux levels of educational spaces with the required values -750 Lux and 500 Lux for studios and lecture rooms respectively- has shown that 2 of the 5 examined studios do not fulfill the required value at any time of the academic year (3rd year and urban design studio), while 1st year studio fails to fulfill it in the winter season only. Whereas two of three examined lecture rooms successfully achieve the required value of 500 Lux and even exceed it. Only, the auditorium's averages are far below the minimum in all seasons.

IV. MEASURING ALTERNATIVES

Here the evaluation of interior design alternatives is performed from a target-oriented BIM-supported perspective. Therefore, a modified interior 3D-model of 3rd and 4th year studios was built up and tested using the same computer application from the previous step, DIALux evo 6.2. Figure (9) shows the modified design.

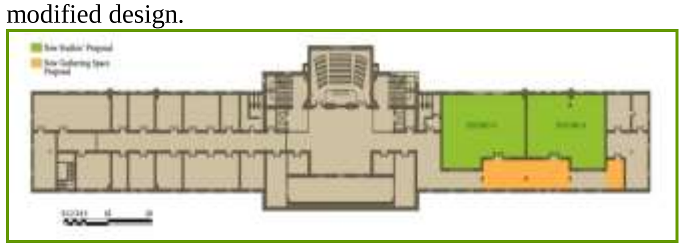

Fig. 9. Studios' Layout Modification

As can be seen in figure (9), minor interior layout changes have been made with the intent to enhance daylighting conditions in both 3rd and 4th year studios. While 3rd year studio daylighting levels are far beyond the required minimum of 500 lux (Fig.8) in all three tested seasons, 4th year studio experiences excessive values of daylight accompanied with several spots of irritating direct solar radiation. This is illustrated in figure (10) showing DIALux evo output diagrams for existing illumination condition in both studios.

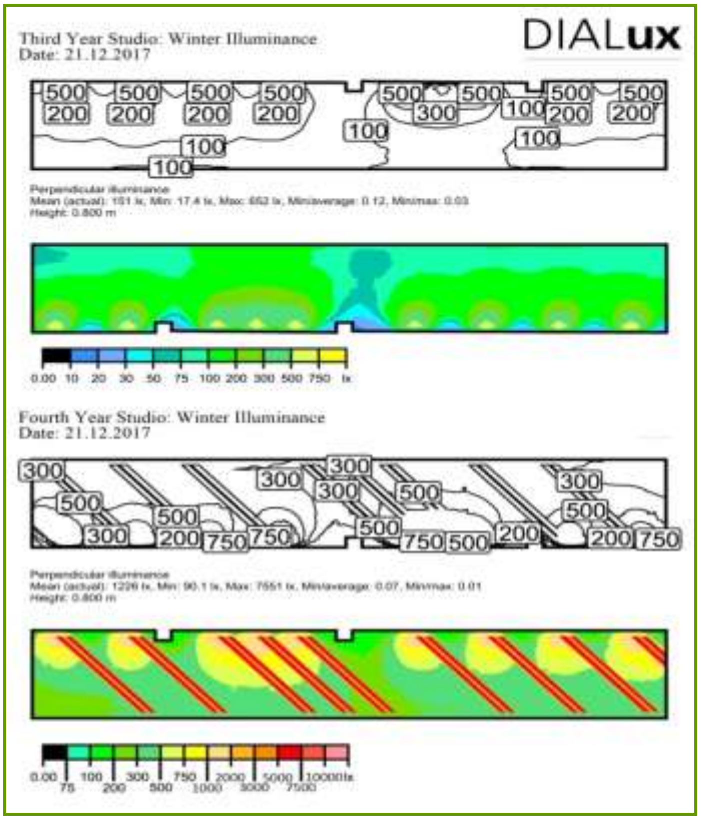

Fig. 10. Studios’ Existing Daylight Illumination Condition

The proposed changes in studios’ layout shown in figure (9) have following implications:

- 3rd year studio’s area has increased by 1% reaching a new total area of 222m2.
- 4th year studio’s area has decreased by 5.9% reaching a new total area of 207m2.
- Both studios have now more square-like length to width area proportions which -as previously explained in chapter 2- enhances interaction between students and stimulates collegiality. Furthermore, the new area proportion allow for more flexibility in terms of furniture layout that now can vary according to the changing studio needs (group work, discussions, model-making, etc.).
- Both studios have now a north orientation.
- Original 40cm thick interior studio walls have been replaced by 20cm thick movable partitions with interior windows. This enables occasional cross-studio collaboration between students of the two years.
- Original 40cm thick corridor-facing studio walls have been replaced by glass partition walls that allow for indirect sunlight penetration as well as visual contact between studio interiors and the outside spaces creating an open-plan studio environment.
- Altering corridor width has been used to create gathering spaces for impromptu meetings to stimulate mutual inspiration and knowledge exchange between students.

Then, the proposed studios’ layout changes have been put to the test using DIALux evo 6.2. Results for both -the already existing and the modified- designs have been registered in a comparison table. And each design has been attributed with a daylight grade accordingly. Grades of A,B,C,D and F have been given according to internationally acknowledged lux levels’ recommendations which specify an acceptable range of 500-1000 lux for drawing studios and classroom interiors. Fig. (11) illustrates.

INTERIOR DESIGN	SPACE USE	AVERAGE	Fulfillment of Required Minimum	AVERAGE	Fulfillment of Required Minimum	AVERAGE	Fulfillment of Required Minimum	YEARLY AVERAGE	DAYLIGHT GRADE
	Calculation Date	23-Sep-17		21-Dec-17		21-Mar-17			
OLD	3rd Year Studio	248	NO	151	NO	244	NO	214	F
	4th Year Studio	3607	YES	1226	YES	781	YES	1871	F
NEW	3rd Year Studio	373	NO	119	NO	361	NO	284	D
	4th Year Studio	449	NO	150	NO	436	NO	345	C

Fig. 11. Comparison of Alternatives

V. CONCLUSION

The analysis of the interior spaces of the studied department of architecture has been carried out on three main levels:

a) Questionnaire
b) Measurements and Field Survey
c) BIM numerical presentation of performed calculations

This paper was concerned with presenting the application procedure of the point c).

Furthermore, literature review has revealed the five main characteristics of well-designed interior spaces (namely: being a) communicating, b) challenging, c) comforting, d)complying and e) continuing) and their proper means of realization through 16 interior design elements. And it does not go without notice that these five characteristics actually vary in importance depending on the intended use of the space to be designed, i.e. the type of the project. Obviously, in our specific study case of architectural school interiors the second characteristic –being challenging- is of crucial importance! For, being challenging as interiors implies providing opportunities for users to develop as a person, to be creative; they help users achieve their goals through their spaces. And of course, challenging students’ creativity to develop to its full potential is one of -if not the- most important target of architectural schools. This was numerically determined by means of calculating the impact factor for each of the five characteristics for this project type. Results are shown in figure (12). An important point to mention is also that the 5 study criteria are not equally influenced by the 16 examined interior design elements. Interior design elements sometimes even have contradictory influences on the various criteria. This is the reason why the impact factor of each of the 16 interior design elements has also been calculated for this type of project. Next, the actual impact rating of each of the interior design elements as well as the actual quality rating for each of the five characteristics was calculated for two alternative interior design proposals. Here, results of all of the previously described aspects are being combined into one final BI-Evaluation Matrix (i.e. Building Information Evaluation Matrix) that aims at providing a systematic means of decision making for the interior design process that considers and evaluates numerical as well as qualitative interior design attributes yet in a quantitative manner. In such a way, comparing design alternatives is made much easier; the evaluation is more objective as to the part of the interior designer and more user-centered. This can be seen in figure (13).

ID	COMMUNICATING	CHALLENGING	COMFORTING	COMPLYING	CONTINUING
1	Area per Person		Area per Person	Area per Person	Area per Person
2	Ceiling Height	Ceiling Height	Ceiling Height	Ceiling Height	Ceiling Height
3	Aspect Ratio	Aspect Ratio	Aspect Ratio	Aspect Ratio	Aspect Ratio
4	Studio Shape	Studio Shape		Studio Shape	Studio Shape
5		Daylighting	Daylighting		
6		Artificial Lighting	Artificial Lighting	Artificial Lighting	Artificial Lighting
7		Windows	Windows		
8		Views	Views		
9		Wall Paints	Wall Paints	Wall Paints	
10		Finishes		Finishes	
11			Textures	Textures	
12	Partitions	Partitions		Partitions	Partitions
13		Plants	Plants		
14	Art Pieces	Art Pieces	Art Pieces		
15	Furniture Arrangement	Furniture Arrangement	Furniture Arrangement	Furniture Arrangement	Furniture Arrangement
16		Pleasant Mystery			
IMPACT FACTOR	0.4375	0.875	0.75	0.625	0.4375

Fig. 12. Impact Factors of Design Quality Characteristics

As can be seen from the table above, the most important design quality criterion for architectural school interiors is that of being challenging with the highest impact factor of 0.875. In the second place comes the criterion of being comforting with an impact factor of 0.75, and then comes that of being complying with an impact factor of 0.625. And lastly come both criteria of being communicating and continuing with an equal impact factor of 0.4375. Thus, being challenging is the most important criterion to be examined when comparing alternatives of architectural schools' interiors. Table (7.2) on the next page shows further examination of the most influential interior design element for architectural schools' interiors by means of again calculating the impact factor.

ID	COMMUNICATING	CHALLENGING	COMFORTING	COMPLYING	CONTINUING	IMPACT FACTOR OF INTERIOR DESIGN ELEMENTS
1	Area per Person		Area per Person	Area per Person	Area per Person	[illegible]
2	Ceiling Height	Ceiling Height	Ceiling Height	Ceiling Height	Ceiling Height	[illegible]
3	Aspect Ratio	Aspect Ratio	Aspect Ratio	Aspect Ratio	Aspect Ratio	[illegible]
4	Studio Shape	Studio Shape		Studio Shape	Studio Shape	[illegible]
5		Daylighting	Daylighting			[illegible]
6		Artificial Lighting	Artificial Lighting	Artificial Lighting	Artificial Lighting	[illegible]
7		Windows	Windows			[illegible]
8		Views	Views			[illegible]
9		Wall Paints	Wall Paints	Wall Paints		[illegible]
10		Finishes		Finishes		[illegible]
11			Textures	Textures		[illegible]
12	Partitions	Partitions		Partitions	Partitions	[illegible]
13		Plants	Plants			[illegible]
14	Art Pieces	Art Pieces	Art Pieces			[illegible]
15	Furniture Arrangement	Furniture Arrangement	Furniture Arrangement	Furniture Arrangement	Furniture Arrangement	[illegible]
16		Pleasant Mystery				[illegible]

Fig. 13. Impact Factors of Interior Design Elements

As can be seen in the figure above, calculating the impact factor for each of the 16 interior design elements has shown that for the specific project type of architectural schools the top most influential interior design elements are a) ceiling height, b) aspect ratio and c) furniture arrangement with an impact factor value of 1. The second most influential group of elements is composed of a) area per person, b) studio shape, c) artificial lighting and partitions having each an impact factor of 0.8. Next are wall paints and art pieces holding the third place with the impact factor of 0.6. Then comes the group of daylighting, windows, views, finishes, textures and plants with a 0.4 impact factor. And the last place is held by the element of pleasant mystery having the impact factor of 0.2.

Both previous tables, figures (12) and (13) have been combined into one BI-Evaluation Matrix to compare and evaluate the different interior design alternatives for the architecture department subjected to study in this paper. Figures (14) and (15) on the next page illustrate the BI-Evaluation Matrices for the existing interior design case and the suggested alternative respectively. An important point to mention is that not all 16 interior design elements have been altered in the suggested project modification. Only 9 of the 16 elements have been modified and these are shown in figure (15) highlighted in purple. The comparison result between both matrices has been in favor of the suggested project. As to the existing project case, figure (14) shows that the overall fulfillment of the 5 interior design quality criteria is less than 24%, while the fulfillment of the criterion number two –"being challenging"- remains below average with only 40% rating. And regarding each of the 16 interior design elements separately, the matrix shows that ceiling height and art pieces are the only two elements with a criteria fulfillment rate above 50%. All of the other elements remain below and their average fulfillment rate of the five interior design quality criteria is 15.75%.

Fig. 14. BI-Evaluation Matrix for Existing Project

Fig. 15 BI-Evaluation Matrix for suggested Alternative

Contrarily, figure (15) reveals a very obvious leap in fulfillment rates related to the suggested interior design changes. Here, the overall fulfillment rating of the 5 criteria has reached a value of 58.07% and the average rating of the separate interior design elements has also improved by almost 23%.

Thus, numerical evaluation of interior design alternatives have favored the suggested modifications.

REFERENCES

[1] U. G. Council, "Daylight". Retrieved From U.S. Green Building Council: Http://Www.Usgbc.Org/Credits/Eq8, (2017, February 4).

[2] Leed, "Daylight And Views – Daylight". Retrieved From U.S. Green Building Council: Http://Www.Usgbc.Org/Node/1732573?View=Language, (2017, February 1).

[3] K. L. Lighting, "Home: Kellwood Led Lighting: Technical: Cibse Recommended Lux Levels." Retrieved From Kellwood L.E.D. Lighting: Https://Www.Kellwood.Co.Uk/Led-Lighting/Technical/Cibse-Recommended-Lux-Levels, (2017, January 26).

[4] S. Augustin, Place Advantage:Applied Psychology For Interior Architecture; Hoboken , New Jersey: John Wiley & Sons , Inc., 2009, Ch.

[5] E. Neufert, P. Neufert, B. Baiche, & N. Walliman, Architect's Data, Third Edition; Oxford: Blackwell Science, 2000.

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