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An approach to the assessment of environmental impact in retail architecture

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Abstract
Architecture has been an essential resouce in retail to keep products in suitable technical conditions, provide confort to costumers during the purchase process, and set up a communication bond across the attraction process moves to trigger the purchase. The addition of more architecture in commercialization of products (stores, supply chains, etc.) has been an inherent fact to historical retail development in intensity and extent. However, a glance of the whole retail system in any city provide the verification of coexistence and development of many architectural typologies used for retailing, formed with dissimilar ammounts of resources (energy, material, information, technology), that entail different environmental impacts.

Keywords: urban retail, environmental impact, retail architecture, input-output analysis.

1. Introduction

Simultaneously to growth of retail (1), the amount or architectural resources invested in product marketing also has rised, due to the increase in number and size of new models of shops: already in 2001, Harvard Design School quantified in about 2 billion m^2 the total retail area around the world (2). Experts say this increase is linked to development of trade activity, which has been bent on rise the sales capacity and the range on demand. Mass use of production systems, considerable amplification of supply (saleable product units and number of references), rivalry and changes in life standards, cause that the amount of architecture used in commercialization of products increases gradually. However, in any city, urban retail is composed of a range of architectural typologies that require uneven amounts of resources, and consequently, involve different environmental impacts.

The aim of this paper is to initiate in the identification of the impact associated to retail architecture considering in an environmental approach the resources that compound retail typologies (space available, structure, facades, building elements, furniture, energy, information), using as case study the city of Barcelona (Spain). Metodology includes a qualitative analysis of general issues of urban retail, and a quantitative analysis in which the amount of architecture used for retail in study cases is measured. Within the results obtained, it should be noted the development of a numeric model to assess the environmental efficiency of retail architecture (the relation between the obtained results (sales) and the resources employed (real estate investment)). Also, a ranking of retail architectural typologies is proposed, based in the simultaneous valuation of location, exploitation of urban pre-existences and architectural intensity (relation between architectural resources and m^2 available for the development of retail activity).

2. Achitectural diversity in urban retail: a living parallelism.

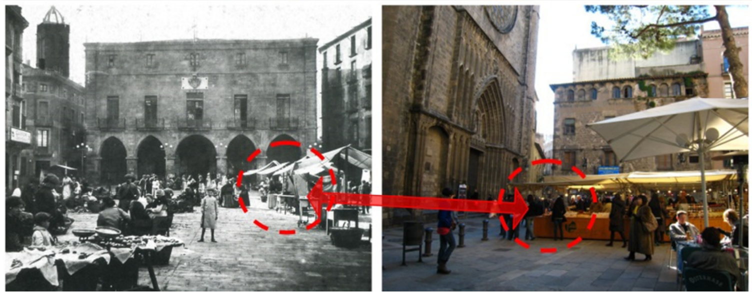
In the commercial system of Barcelona, it is posible to identify some peculiarities (fig. 1):

● In the same city coexist different retail architectural typologies, despite environmental and socioeconomic requirements are the same.

Some of architectural typologies found in Barcelona

● Even some “ancient” architectural typologies remain in the city nowadays, because despite socioeconomic evolution still they are proficient to commercialize.

Market stands in Barcelona



● It is posible to find simultaneously the offering of the same product using different achitectural typologies, despite the functional requirements are the same for all of them.

Figure1. Coexistence of architectural typologies used for commercialization of products in Barcelona, Spain.

¿Why do exist different architectural formats that operate simultaneously in the same context, and even are used for the commercialization of the same product? To understand the guidelines that determine diversity of urban retail, it is plausible to compare with biological theories that explain the behaviour and the relation between natural species with the environment and among them, setting up a parallelism between retail as human system and an ecosystem: in ecosystem different organisms strive to survive in apparent balance, such as different retail “organisms” in the city attempt to pursuing the transaction (to produce commercial exchange to survive).

● Diversity of shapes guarantee the response capacity of the system facing all possible (new and unexpected) context requestings (economic, environmental, social). The system could lose its response if the multiplicity of architectural formats decreases, that means, its complexity as a system. For example, comparing the retail systems of Barcelona and Kaolak (Senegal) it can be observed that the Barcelona system is more diverse architecturally tan Kaolak’s. However, this is reciprocal with the range of possible context requestings, but it would be totally unstable and improbable in Barcelona, because the complexity and diversity of its context requestings is considerably bigger (seasons, global products commersialisation, health and security regulations, etc).

● Like a biological organism, it could be assured that an architectural typology used in retail progress to gain independence facing uncertainty, and improve its capacity of response to challenges progressively bigger. Therefore, some tipologies have progressed more tan others. Even functionally they are good for sheltering the comercial activity, they don’t have or don’t require the same capacity of response facing the same challenge (image 1).

Image 1. Progress in retail architectural typologies used in Barcelona.

● Natural selection is a filter that allows innovations favouring the independence of the organism facing context uncertainty. More complexity would guarantee more possibilities of survival. However, not in all cases the adaptation capacity of an architectural format for retailing is directly proportional to the amount of architectural resources, since this capacity depends on the selective pressures produced by any aspect of the environment. Like a natural system, complex organisms adapts easier to different variable conditions, but simple solutions also survive facing the different selective pressures (image 2).

Image 2. Adaptation of retail architectural typologies facing selective pressures.

3. The role of achitecture in urban retail.

To understand the environmental impact associated to retail architecture, it is necessary to define the role or architecture in the commercialization process, from the identification and of different architectural typologies of retail premises (**PS**) in urban retail system (3). Typologies founded in Barcelona have been classified according to location, the use of urban pre-existences, and the real estate investment (figure 2):

Figure 2. Classification of architectural typologies of retail found in Barcelona.

In every typology it is posible to identify two main categories of functional requirements:

Shelter: minimum technical conditions that architecture should provide to allow the storage and exhibition of products and procure suitable conditions to commercial exchange (Table 1):

Product	- **Preservation:** protection of the product facing external factors that could modify their basic qualities (colour, texture, freshness, shape, etc). - **Storage:** stock availability to guarantee the satisfaction of demand fast and efficiently - **Healthiness:** exhibition and storage of products in hygienic conditions. This may vary according to the product and the socioeconomic context. - **Safekeeping:** protection against theft.
Commercial exchange	- **Environmental control:** environmental conditions (temperature, humidity) to commercialize comfortably. - **Lighting:** To guarantee general lighting conditions and to enhance the product. - **Support:** exhibition of products in a correct and suggestive way. - **Form of sale:** to provide the link between client and merchant acording to the form of sale (personalized sale, self service, serve-over, etc). - **Simultanously offer:** to benefit the offer of different products in suitable conditions. - **Security, regulations compliance:** to guarantee mínimum conditions of security according to local regulations (evacuation, fire, etc).

Table 1. Functional requirements of retail architecture

Communication: PS increasingly assumes the function of communicación platform between manufacturer and buyer. Through space compositional elements (Lighting, colors, materials, sounds, etc), PS attracts, persuades, seduces and convinces the buyer with the purpose of unleash the emotional process of purchase decision.

Architecture is a fundamental resource to respond to urban requestings (environmental, social, functional, regulations), allowing at the same time the development of commercial activity. All architectural typologies, regardless the amount of resources employed, should guarantee a mínimum of shelter and communication conditions to make possible the commercialization of products. Even in typologies with low architectural intensity, pre-existing urban resources are used (lighting, streets, paraments) to shelter the commercialization process, always with complementary elements to guarantee mínimum conditions. The investment of more architectural resources in PS (or a higher level or architectural response) allows to afford a more accurated responsiveness facing posible context requiements, satisfying at the same time additional needs in the commercialization process like storage and custody of products, attractive and suggestive exhibition of products, supplementary services, bigger isochronals, etc (image 3).

Image 3. Response levels of different architectural typologies.

4. Assessment method.

4.1 Background

Efficiency is the ability to obtain the planned objectives with **sufficiency** in the use of available resources. Considering architecture like material "input", The **MIPS** method (Material Input per Service Unit) (4) enables to quantify the amount of material resources used during the life cycle of a product, including the resources needed to obtain the benefits of its use (5). P. Sinivuori (6) employed this method to assess two universitary buildings, defining that the service unit of a building is the **net useful area during a determined period of time** (**S = m^2/years).** An assessment of the materials invested in every building is done, obtaining a MIPS value in Kg resources/ net m^2/year (a value linked not only to **m^2** available, but also to **useful life** of the building). Similar approach is the methodology proposed by Albert Cuchí Burgos, P.h.D in the document "*Informe MIES: Una aproximació a l'impacte ambiental de l'Escola d'Arquitectura del Vallés"(7)*: the environmental impact of the school of architecture is assessed, quantifying its energy cost during construction and useful life (energy needed to perform the school activities: lighting, HVAC, services, etc; in CO_2/year). This energy assessment is divided by **m^2 and the amount of university credits by year**.

4.2 Assessment method proposal.

Architectural Efficiency **(AE)**, is the relation between a functional unit (turnover, business hours, satisfaction of shelter and communication requirements), and the amount of architectural resources employed in a PS to obtain those results [1]. The Architectural Intensity **(AI)** is the amount of architectural resources employed in a PS related to a functional unit **S** (m^2 available to the development of commercial activity) [2].

$$\mathbf{AE} = \frac{\text{Obtained results (turnover, business hours, etc.)}}{\text{Used resources (AI: } m^2, \text{ kg/}m^2\text{year, kWh/}m^2\text{year, complexity)}}$$

[1] Architectural efficiency

$$\mathbf{AI} = \frac{\text{Architectural resources PS}}{\text{Funtional unit S}}$$

[2] Architectural Intensity

Considering architecture as a single resource, three units are defined to assess it like an input:

4.2.1 Material: consists of two measurable and noticeable elements:
A. Surface area: the space available to shelter an activity can be measured in m^2. In this case is evaluated only the surface of public access, named sales room **(SR)**. This includes the space for exhibition and fitting of products, the payment area, information and customer services.
B. Weight: the space available for commercialization of products and its architectural fence are made of elements that weight and are measurable. Considering the useful life of each one of these elements (with their simultaneous service to another uses of the building), the intensity is determined in **Kg/m^2/year** [3].

$$\mathbf{Kg/m^2\ year} = \sum \frac{(Kg/m^2\ C)*bc}{ul} + \sum \frac{Kg/m^2\ SR}{ul}$$

[3] AI in weight of architectural elements

Where:
C: weight of container structure.
SR: weight of elements in sales room
bc: building coefficient
ul: multipliyng factor according to the useful life of every element.

4.2.2 Energy: is used in retail spaces for climate control, to emphasize products, to create determined environments through lighting, sounds and images, to use the different appliances (payment systems, conservation and measurement, etc).

Through architecture energy flows are canalized. Therefore, the energy consumption of a PS is due not only to the fuctional needs of the commersialization process, but also to the elements and architectural features in SR. Then energy AI is determined in **kWh/m^2/year,** that is the amount of enegy needed for the development of comercial activity in a PS.

4.2.3 Complexity: architecture also is information. In PS architectural resources have an **arrangement** and an **order** that allow the satisfaction of shelter and communication in a specific manner. The level of complexity in a PS is its potential behavior diversity; and retail architectural fomats will become more complex **to increase their shelter and communication capacity.**

To identify the complexity level of a PS a valuation scale is settled, considering possible shetler and communication requiements. Thus, to every architectural tipology a level of complexity is determined considering a predominant functional criterion (shelter or communication), which compliance most of the architectural resources are intended.

This methodology has been applied in a sample of architectural typologies of PS detected in a working área of 1,00 km^2, intended for commercialization of two categories of products: bread (easy purchase decision/ usual purchase/low price); and women apparel (careful purchase decision/occasionally purchase/moderate price):

Table 2. Average Architectural Intensity (AI) per typologies and turnover range in commercialization of women apparel (font: author's compilation)

Typology	Name	turnover range	m2 Sprod	m3 Sprod	kg/yr Sprod	kg/m2 per yr	kWh/yr	kWh/m2 per yr	Tendency
flea market		1	24,00	72,00	107,83	4,49	3,96	0,17	shelter
market stand	La Llibertat		12,00	26,40	429,80	35,82	421,20	35,10	shelter
second hand	Humana		132,29	330.79	2046,37	15,47	6249,49	47,24	shelter
outlet	Tot-hom		120,00	300,00	2797,50	23,31	12760,56	106,34	shelter
retail premises 20-150 m2	Brownie	2	68,70	204,81	1924,44	28,19	8303,92	121,63	comm
	M212		60,00	240,00	2086,16	34,77	7458,24	124,30	comm
	erre de raso		80,00	240,00	2062,98	25,79	9541,84	119,27	comm
	Alegrías		80,00	360,00	2401,42	30,02	10190,80	127,30	comm
outlet	erre stocks		80,00	240,00	2065,29	25,82	11460,64	143,26	comm
Bazar	Casa Gracia	3	24,04	72,12	734,28	30,55	2225,84	92,60	shelter
retail premises 150 m2 +	Benetton		207,86	757,52	7010,72	33,73	24985,86	120,20	comm
	Mango	4	357,90	1252,65	12181,01	34,03	39352,50	109,95	comm
	Adolfo Dom.		143,43	502,02	4127,27	28,77	16875,64	117,65	comm

Table 3. Average Architectural Intensity (AI) per typologies and turnover range in commercialization of bread (font: author's compilation)

Typology	Name	turnover range	m2 Sprod	m3 Sprod	kg/yr Sprod	kg/m2 per yr	kWh/yr	kWh/m2 per yr	Tendency
Itinerant	artesanal market	1	4,00	8,80	33,74	8,44	99,00	24,75	shelter
	ocasional market		23,80	71,40	8218,90	345,33	4596,91	193,15	shelter
Internet	Matias		20,00	50,00	976,08	48,80	1378,60	68,93	shelter
Bakery + sale	Turris	2	44,80	174,13	2041,45	48,51	2887,52	67,44	shelter
	Bcn-reikjavick								
	Horno Fortino								
Oven + sale	Paul		35,00	122,50	1404,97	40,24	5543,32	158,23	comm
	Macxipa								
Sale + consume	La Boulangerie	3	19,33	65,12	760,93	41,23	2611,12	139,65	comm
	El fornet								
	El molí Vell								
small supermarket	Alimentació		2,52	6,29	98,37	40,30	360,62	125,68	shelter
	Alimentació								
	Alimentació								
supermarket	Caprabo	5	4,27	14,95	179,85	42,30	598,74	129,90	shelter
	Dia								
Restaurant/ catering	Bopan	4	10,29	42,30	400,44	38,65	1305,11	155,59	comm
	Sant Joan								

Where:
Turnover range: billing average calculated according to IAE tax.
m^2 Sprod: m^2 of sales room SR
m^3 Sprod: volume of sales room SR
Rep kg/yr Sprod: annual repercussion of architectural weight in Sprod
Rep kg/m^2/yr Sprod: annual repercussion of architectural weight per m^2 of Sprod
kWh/yr Sprod: annual energy consumption in Sprod
Tendency: predominant functional category (shelter or communication requirements)

5. Conclusion

- The result of the develompent of comercial activity in PS is measurable, through the amount of commercial transactions (sales) carried out in a specific period of time. This value is used to establish the profitability in a PS, through the relation between the resources employed and the obtained benefits. To evaluate the retail activity from an environmental scope, it is possible to define a similar equation, in terms of the amount of resources used to commercialize certain quantity of products, and the obtained results (transactions).

- In terms of architectural resources, it is possible to stablish a method similar to inputs/outputs balance, where the amount or architectural resources employed to create commercial premises is measured. The viability of setting up this relation is supported with the huge architectural diversity of PS identified in the city: this reality proves that the same product could be commercialized in the same socioeconomic context using PS with different architectural intensities.

- The three measurement units proposed allow an architectural valuation in different dimensions: space available, material resources, energy consumption during useful life, information. From the Architectural Intensity (AI) it would be possible to outline, like others architectural uses (ie offices or educational buildings), some reference values to set up boundaries between sufficiency and over-measurement in the use of architectural resources.

- With the suggested method it is posible to assess architecture like a whole resource. However, architecture is also the result of a construction process, Then to propose a more accurate environmental assessment method, it is necessary to consider also material features and the consumption of resources in different construction process.

- Considering that most of the retail premises in the city are located in existing buildings, in the environmental assessment of the elements that compound the SR would be a broader scope. Therefore, it would be possible to suggest a supplementary assessment method in which the most suitable architectural tipology is identified first, from the comparison of AI between options; and then to implement a more accurate study where environmental impact consequence of use of resources in conceptualization and useful life of PS is identified.

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Implementation of daylight as part of the integrated design of commercial buildings

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Abstract: *Today, there is an obvious lack of sufficient integration of daylight in building design. The literature has been reviewed in order to see if knowledge exists to formulate an improved daylight design methodology which may be consistently integrated with thermal comfort and energy use design. Based on findings in the literature, a proposal is given on how daylight calculations and evaluations may be implemented throughout the building design. Important features in the proposed design are: early implementation of simulation tools, implementation of climate-based daylight modelling, and coupling between simulation tools for daylight, thermal comfort and energy use to ensure consistency in the design. The design proposal has been tested and the results show that the method might lead to a design with satisfying indoor environment and low energy use. Yet, more research is needed to validate and to set proper benchmark values for newly proposed climate-based daylight metrics.*

Key words: daylight metrics, daylight prediction, discomfort glare, integrated design

Introduction

It may be a climatic challenge to design buildings with low energy use and high indoor environmental performance. Figure 1 illustrates how daylight, thermal comfort and energy aspects influence each other in a complex manner. There is a need for an integrated and consistent design approach to daylight, thermal comfort and energy use in order to be able to fulfil future energy and comfort demands.

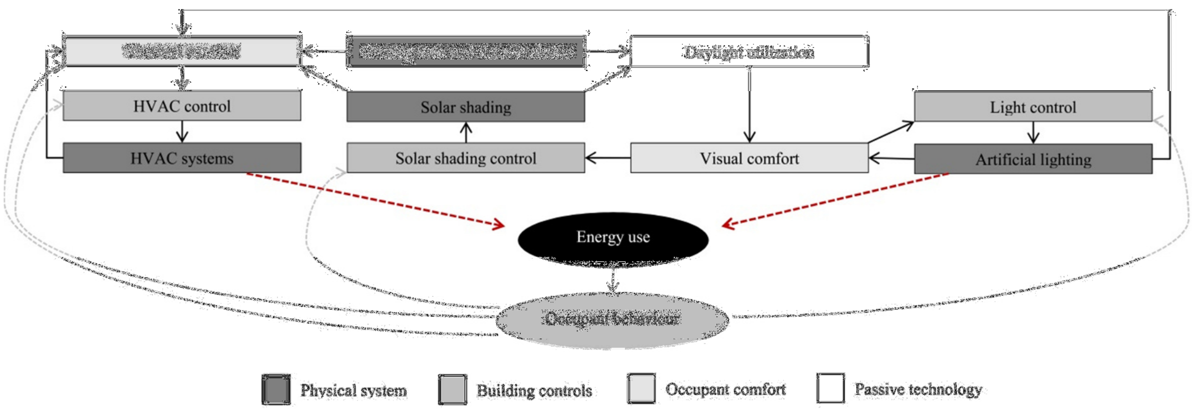


Figure 1: Illustration of interaction of daylight, thermal comfort and energy aspects.

At the present time, simulation tools are used, which makes it possible to evaluate both thermal comfort and energy use at the same time, yet there is an obvious lack of sufficient integration of daylight [1]. Daylight is an essential component within buildings both with its architectonic and aesthetic features and with is functional aspects. With regard to the latter, an effective daylight design combined with intelligent control for artificial lighting might lead to reduction of energy use for lighting and cooling, especially for commercial buildings where the occupied period usually coincides with periods of excessive access to daylight. Additionally, it is important to remember that daylight has positive health effects [2], and that occupants usually prefer daylight as their source of illumination [3]. These last features might actually be the most vital arguments for investing time an effort in daylight design.

However, several surveys conducted among building designers and researchers [4-6] revail that far from all conduct daylight analysis during their design. The aim of the present paper is to propose how daylight design may be implemented throughout the design of commercial buildings as an integrated part of the building design. The literature has been consulted in order to see if there is existing knowledge to formulate a three step design methodology for integrated daylight design. The following sections present the results from the literature review followed by a test of the proposed design methodology.

Literature review of daylight design

With respect to an integrated design, criteria for daylight may be used to assess if the daylight environment is satisfying, if artificial lighting needs to be added or if there is risk of glare and need for activation of solar shading.

Is the daylight satisfying or do artificial light need to be added?

The daylight factor (DF) has existed since the beginning of the 20th century [7], it is used as a measure for satisfying daylight and is currently the most commonly used daylight metric worldwide [8, 9]. The daylight factor is defined as the ratio between the internal illuminance at a point in a room and the unshaded, external horizontal illuminance under a *Commission Internationale de l'Eclairage* (CIE) overcast sky [9].

As an isolated measure, the DF does not contribute with much information regarding the real daylight level in a room as it only considers the static CIE overcast condition. Under these conditions there might e.g. not be need for use of solar shading, which may explain why use of solar shading commonly is neglected in daylight design [10]. Yet, it is well known that solar shading is indispensable for office workers to control solar gain and glare and its use influence daylight supply, thermal comfort and energy use. Further limitations of DF are widely discussed elsewhere [9, 11], and one thing seems certain: new climate-based daylight metrics (CBDm) should be used in the future as criteria for annual daylight, a selecton of CBDm are presented in Table 1.

The question is then which CBDm to use? UDI and $sDA_{300/50\%}$ might be preferable to use since they are developed based on occupant preferences in daylight environments. One advantage of $sDA_{300/50\%}$ is that the annual daylight level in the room can be expressed with one single number and according to the Illuminanting Engineering Society of North America (IES), $sDA_{300/50\%}$ ≥55 % has to be met in order for a space to be nominally acceptable daylit. $sDA_{300/50\%}$ has been accepted as daylight metric by the IES as part of an methodology for evaluating annual daylight [12]. However, from an integrated design perspective, UDI seems to give more interdisciplinary information. The UDI concept is divided into four categories [13]; UDI_fell short (UDI-f, 0-100 lux) indicate the time when required illuminance has to be maintained by artificial lighting, UDI_supplementary (UDI-s, 100-300 lux) indicate the time when artificial lighting needs to be added to the daylight to maintain required illuminance, UDI_autonomous (UDI-a, 300-3000 lux) indicate the time when the light level can be obtained by daylight alone and UDI exceeded (UDI-e, 3000 lux<) is associated with glare or overheating and indicate the time when solar shading might be needed. It might be a reasonable assumption that the IES threshold for satisfying daylight area of 55 % can be adopted for the UDI-a category as well.

Table 1: Selection of newly developed climate-based daylight metrics

Metric	**Information in the metric**	**Lower threshold [lux]**	**Upper threshold [lux]**	**Comment**	**Reference**
Daylight autonomy (DA)	Percentage of occupied time when a minimum work plane illuminance can be maintained by daylight alone.	500	-	Threshold commonly derived from standards for artificial lighting.	[14]
Useful daylight illuminance (UDI)	Percentage of work hours when daylight levels are useful for the occupants.	100	3000	Thresholds derived from literature study on occupant preferences in daylit offices. Upper limit is associated with glare/overheating.	[13, 15]
Spatial daylight autonomy 300/50% ($sDA_{300/50\%}$)	Percentage of analysis area that achieves the illumination threshold of 300 lux for 50 % of the analysis period.	300	-	Target value of *300 lux* was derived from a survey with daylight experts and building occupants in 61 day lit spaces.	[16]

Is there risk of glare?

Nowadays, extensive use of computers in the working environment has become common. Consequently, the line of sight is more horizontal than for reading and handwriting tasks on the desk, which makes discomfort glare from windows a more considerable concern [17]. Discomfort glare produces discomfort without necessarily influencing visual performance and visibility and still there is a lack of knowledge about its underlying process [17].

At the present time there is no international accepted measure to evaluate the discomfort glare from windows and/or solar shadings. However, there are recommendations given in the literature [18, 19] towards use of the newly developed metric Daylight Glare Probability (DGP) [20]. One major drawback is that it might be very time-consuming to carry out an annual DGP analysis. In order to address this problem, Weinold [21] has developed and validated two simplified versions of DGP; (1) DGP simplified (DGPs) based on vertical eye illuminance and (2) enhanced simplified DGP based on vertical illiminance at eye in combination with a simplified image. The validation showed in general good results for the enhanced simplified DGP and reasonable results were seen for DGPs when no peak glare sources where present. In a design process, a glare analysis might be most suitable for the detailed design stage, both because the annual glare analysis is rather time-consuming and because glare is direction dependent and should be carried out at probable work stations.

Calculation procedure

Early implementation of simulation tools are indispensable in order to make annual evaluations of horizontal illuminane and glare. Simulation tools based on validated and effective calculation engines should be used. Yet, it will be almost impossible at the present time to totally avoid the use of rules of thumbs and simple static calculations in the early design phase to make the first design proposal. Studies have shown that not all earlier published rules of thumb may be trustworthy or suitable for todays building design [11]. It is therefore important to use validated methods which yield reasonable results. Reinhart and LoVerso [11] have suggested a validated sequence of rule of thumb to come up with the first daylight scheme for sidelit rooms. This sequence is based on the DF, with all its limitations, and do therefore only consider the diffuse daylight. Further into the design, yet still early design phase, it will be necessary to implement use of simulation tools in daylight design in order to carry out climate-based modelling and reach a more integrated design approach.

Design proposal

Table 4 compresses a preliminary proposal for a daylight design in three levels of detail based on findings in the literature. Important features of the proposal are early implementation of simulation tools and adoption of climate-based daylight modelling from an early stage, which straightens integration with thermal comfort and energy analysis.

Table 2: Proposal of how daylight calculations and evaluations may be implemented as an integrated part of the building design based on findings in the literature.

Design stage	Proposed method	Daylight evaluation metric
Initial design	Use the validated rule of thumb sequence proposed by Reinhart and LoVerso [11] to draw up the first daylight scheem to find minimum required glazing areas; -initial assumtions regarding wall thickness, window head height, room width (w), mean surface reflectance (R_{mean}) and visual light transmittance (τ_{vis}) of the glazing have to be made. Use an effective simulation tool to check that the glazed areas are consistent with annual daylight requirements for UDI-a as well as for thermal comfort and energy use.	DF/UDI
Schematic design phase	Use a climate-based daylight simulation tool to verify the chosen glazed areas and glazing characteristics when use of solar shading is accounted for. In case of dynamic solar shading, use a simplified solar shading model and utilize UDI-e (3000 lux) as a threshold for activation of solar shading due to glare/ overheating. Exchange solar shading, lighting and occupancy profiles between daylight, thermal comfort and energy use predictive tools in order to achieve a model consistency for the integrated design.	UDI
Detail design phase	Keep using a climate-based daylight simulation tool, but if necessary make a more customised and product oriented simulation with respect to solar shading and installed lighting systems. Verify the daylight environmental quality with respect to useful daylight illuminance and glare.	UDI, DGPs/ DGPenhanced simplified

Test of design proposal

The design sequence is tested in design of a sidelit cellular office located in Oslo, Norway. It is assumed that the wall thickness is 500 mm (U-value= 0.10 W/Km^2) and that the glazing is placed in the middle of the wall, which gives an obstruction to the sky angle (θ) of approximately 10˚. Following room dimintions are set; floor to ceiling height = 2.75 m, window head height = 2.7 m and room width = 2.75 m. A glazing is selected with the characteristics; U-value=0.6 W/Km^2, g-value=0.49, direct solar tranmission=0.41 and visual light transmission = 0.71. Internal gains and values for heating, cooling and ventilation are set according to the Norwegian standard NS3701[22]. Table 3 gives the requirements set for indoor environment and energy use and Table 4 shows the results from the different steps of the design. Daysim [23] is utilised for the daylight analysis and IDA ICE [24] is used for the thermal and energy analysis.

Table 3: Requirements for indoor environment and energy use.

UDI-a	≥ 50% for ≥ 55% of analysis area
Operative temperature (T_{op}) during occupant hour	21-26˚C
Total annual specific energy demand	<70 kWh/m^2 year
Spesific energy demand heating	<20 kWh/m^2 year
Spesific energy demand cooling	<10 kWh/m^2 year

Table 4: Test of proposed design

Initial design

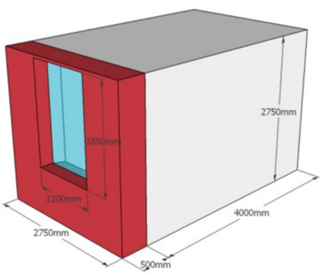
Rule of thumb sequence, for detailes see [11]:

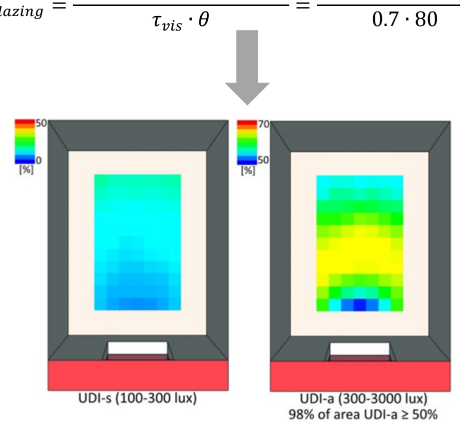
$$Window\ to\ wall\ ratio\ (\%) > \frac{0.088 \cdot DF}{\tau_{vis}} \cdot \frac{90^{\circ}}{\theta} = \frac{0.088 \cdot 2}{0.7} \cdot \frac{90^{\circ}}{80^{\circ}} = 0.28 \rightarrow OK$$

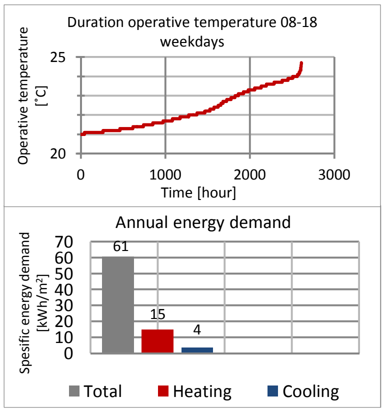
$$Depth\ of\ daylight\ area < minimum \begin{pmatrix} \frac{2}{1-R_{mean}} / \left(\frac{1}{w} + \frac{1}{h_{window-head-height}}\right) \\ (h_{window-head-height} - work\ plane\ height) \cdot tan\theta \\ 2 \cdot h_{window-head-height} \end{pmatrix} = \begin{pmatrix} \frac{2}{1-0.5} / \left(\frac{1}{2.75} + \frac{1}{2.7}\right) = \underline{\mathbf{5.4m}} \\ (2.7-0.8) \cdot \tan(80) = 21.7m \\ 2 \cdot 2.7 = \underline{\mathbf{5.4m}} \end{pmatrix}$$

Maximum depth of the daylight area is according to the rule of thumb 5.4 m. However, it is chosen to limit the depth of the cellular office to 4 m since this is a more reasonable size of a one person office; internal dimentions: 2,75m · 4,00m ·2,75m.

$$A_{glazing} = \frac{DF \cdot 2A_{total}(1-R_{mean})}{\tau_{vis} \cdot \theta} = \frac{2 \cdot 2 \cdot 61.8(1-0.5)}{0.7 \cdot 80} = \underline{2{,}2m^2}$$



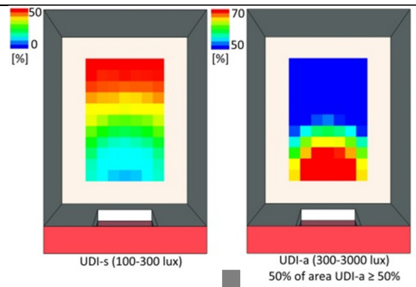


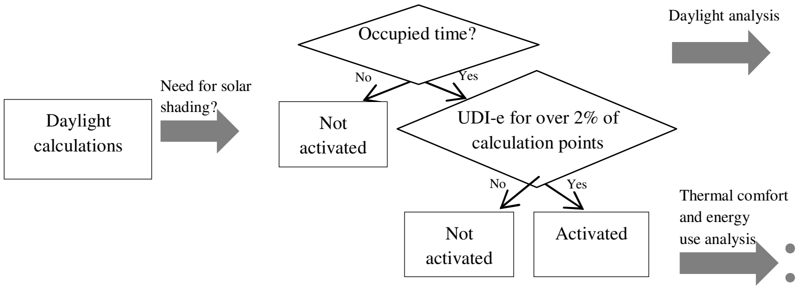


The initial design proposal satisfy the requirements for daylight, thermal comfort and energy use and is an acceptable design to develop further.Influence of consistent solar shading and lightig control will be evaluated in the following design stages.

Schematic design

A simplified model of dynamic solar shading is used in the daylight calculation which block all direct sunlight and transmitt 25% of the diffuse daylight.





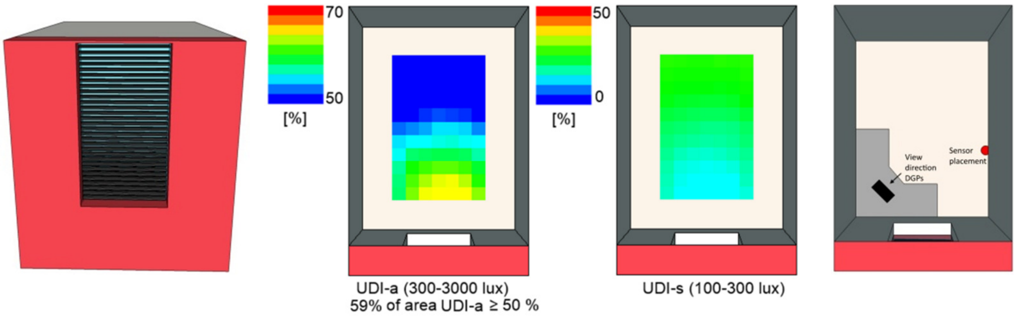
Artificial lighting profile

- Min/max T_{op} 21˚C / 25.5 ˚C
- Total energy demand 59 kWh/m^2 year
- Heating demand 20 kWh/m^2 year
- Cooling demand 3 kWh/m^2 year

The daylight does not satisfy the requireent completely. Yet, the simplified solar shading model might underestimate the daylight supply when closed and it will therefore be tested in if a more sofisticated solar shading might increase the area of satisfying daylight. If not, glazing characteristics or glazing area should be revised.

Detail design

It will be tested how a light grey external venetian blind system with a cut-off control strategy will influence the daylight, thermal comfort and the energy use. The solar shading is activated if external vertical irradiance>150 W/m^2 AND indoor air temperature> 24.5˚C OR if vertical illuminance>2000 lux at a sensor placed at the east wall behind the occupant work station at a height at 1.2 m. Since a cut-off strategy is used for the solar shading it is expected that peak glare sources will not be dominant and annual glare is evaluated according to DGPs.



Max **DGPs** for 95% of office time at working position = 0,39

- Min/max T_{op} 21˚C / 25.5 ˚C
- Total energy demand 56 kWh/m^2 year
- Heating demand 18 kWh/m^2 year
- Cooling demand 3 kWh/m^2 year

Visual and thermal environment is satisfying and energy requirement fulfilled.

Discussion and conclusion

The literature reveals that a significant amount of research is conducted within the field of daylight during the last decades. To obtain an integrated design it is essential to use the same underlying calculation assumptions of climate data and control strategies for solar shading and lighting in thermal comfort, daylight and energy use analysis. Based on findings in the literature a proposal is given of how daylight evaluations may be implemented throughout the building design. The design proposal has been tested in design of a cellular office located in Oslo, Norway and the results shows that the methodology might lead to a design with satisfying visual and thermal environment and low energy use. It is expected that use of the method might have implications on design of facades and room layout since e.g. problems of glare in rooms with large glazed facades or problems with insufficient daylight illuminance in the core of deep rooms might be discovered in an early design stage and poorly designed proposals might be reconsidered. In order for the proposed design method to be practical applicable for building designers, it needs to be implemented in a user-friendly integrated simulation tool. Additionally, more studies are needed to confirm the suitability of UDI and DGPs/enhaced simplified DGP as a future annual daylight and glare metrics.

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Sustainability assessment of shopping centres

Speakers:
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Abstract: *The way we live is intimately connected with the way we buy. The supply of goods is linked to quality of life and needs a rethinking in order to be able meet the challenges of climate change mitigation. An analysis of existing European retail developments and their impact on local energy consumption is therefore needed. A cross methodological approach has been used including questionnaires that were sent to owners and managers, tenants and customers of shopping centres in 5 different countries in Europe, site visits and interviews. The assessment was done by applying the framework described in EN15643.The results of the questionnaires indicate a high interest concerning energy efficiency both on side of customers and tenants and their willingness to introduce e.g. energy efficient heating system, cooling system etc. All in all the developed methodology enables an assessment of shopping centres and possible refurbishment measures regarding sustainability.*

Assessment, KPI, sustainability, shopping

Introduction

The way we live is intimately connected with the way we buy. The supply of goods is linked to quality of life and needs a rethinking in order to be able meet the challenges of climate change mitigation. An analysis of existing European retail developments and their impact on local energy consumption is therefore needed. New procurement measures are necessary in order to be able to develop business models for the building and infrastructure industry that allows a cost effective transition of our built environment. In a larger research project which focuses on shopping centres, aspects regarding "sustainability" will be defined and analyzed taking into account buildings as social arenas, venues for experience, their interaction with the surrounding infrastructure, and their urban integration or interaction with the local built environment. These aspects are often described as "socio-cultural and functional aspects" within e.g. building certification schemes and methodologies that address the sustainability assessment of buildings. The goal was therefore to define such socio-cultural and functional aspects and to derive performance indicators to be analysed with respect to shopping centres.

Objectives

In this paper we seek for a definition and analysis of socio-cultural and functional aspects to be considered for shopping centres, including:

(i) definition of typical shopping mall functional patterns

(ii) analysis of the interactions between the stakeholders,

(iii) studying inefficiencies related to the functional pattern,

(iv) development of key performance indicators for energy efficient interaction in and operation of shopping mall.

Methodology

A cross methodological approach has been used including questionnaires that were sent to owners and managers, tenants and customers of shopping centres in 5 different countries in Europe (Eu-28 plus Norway), site visits and interviews. The assessment was done by applying the framework for the assessment of environmental, social and economic performance (EN15643).

In order to assess the energy inefficiencies in a systematic and transparent way the sustainability criteria and indicators developed in the EU FP7 research project OPEN HOUSE[1] ("Benchmarking and mainstreaming building sustainability in the EU based on transparency and openness (open source and availability) from model to implementation") served as a structural basis. In a next step these sustainability criteria and indicators were investigated in terms of relation to energetic aspects. Therefore not only criteria with direct energetic context (e.g. energy needed for heating purpose in criteria "2.3 Thermal Comfort") were followed up, but also criteria with indirect energetic context (see Image 1).

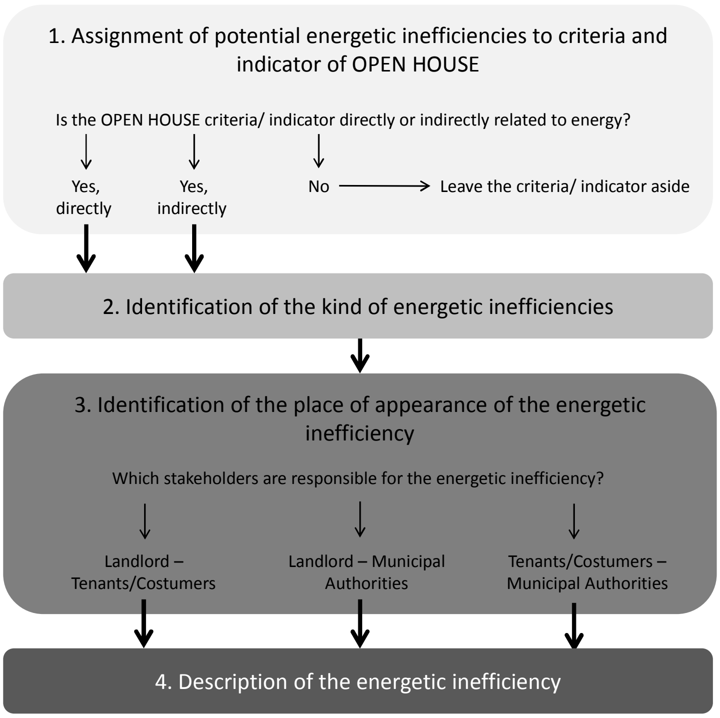

Image 1: Process of identifying possible energetic inefficiencies related to different sustainability criteria and indicators

Indirect energetic context can be the case if criteria specifying the use of specific equipment that needs energy in a second step (e.g. escalators in the criteria "2.1 Barrier-free

[1] http://www.openhouse-fp7.eu/

Accessibility”). In addition the term “energy” was not only understood as useable energy (e.g. electricity), but also as energy embodied in materials. After this the in literature (DGNB, 2012), (Grey, 2005), (Homolka, 2012), (Homolka, 2013), (Shhada, 2011), (Striebich, 2011), (Warrington, 2001) and by the help of experts identified potential energey inefficiencies were classified according to this criteria, set in relation to the place of appearance (e.g. field between tenant – landlord) and described into detail.

Results

Typical functional pattern can be defined as aspects establishing a framework to understand the activities within the shopping centre and its relationship with the surrounding environment both on a day to day basis as well as over the various time of the year. The definition of functional patterns helps in providing a basis for understanding of general use and the shopping centre as a social arena; it is not specifically related to energy efficiency or sustainability issues. To achieve a useful definition which may be used in relation to the majority of users involved in shopping centres it is suggested here that typical functional patterns for four main user groups should be defined. These are:

- customers
- tenants
- managers
- community

The stakeholders are influenced differently by the shopping centre: the customers are more interested in pleasant place and atmosphere, good shops, services and entertainment; they are also interested in comfortable indoor climate. Tenants and owners are more interested in reducing overheads and energy consumption. Their interests are more functional because management needs and their aim to achieve or improve profit margins. The needs of the four stakeholders influence the development, planning, design and location of shopping centres. Shopping entails different meanings for different consumer groups. Shoppers include all social groups and age ranges (Coleman). The functional patterns entail how to get the commodities as fast as possible, as smart and comfortable as possible or make use of shopping as a leisure activity. Shopping centres aim to encourage customers to spend more time in the shopping centres, and this is done by providing opportunities to do more than just shop. This is leading to improved architectural quality, with the creation of common spaces which are increasingly large and pleasant, and with introduction of more aesthetic elements which are not just about a more efficient business, but are intended to create a pleasant atmosphere (Malaspina, 2008).

Three of the four stakeholder groups were asked and answers are presented in Table 1. It can be seen that among the three stakeholders there is a large difference in range of importance when looking at inefficiencies in shopping centres. While customers rate the location, the wide range of products, the low prices and free car paring as most important, tenants answered customer satisfaction, Thermal comfort/indoor quality, worker satisfaction and cost as most important. Managers of shopping centres rated reduced energy demand, customer satisfaction, architectural quality and improved orientation as most important.

Table 1: Excerpt from three questionnaires

Customers: What influences the choice of shopping centre?	**Tenants: What do you see as most important when upgrading the SC?**	**Managers: What do you see as most important when upgrading the SC?**
1. Location 2. A wide range of products 3. Low prices 4. Free car parking	1. Customer satisfaction 2. Thermal comfort/indoor quality 3. Worker satisfaction 4. Cost	1. Reduced energy demand 2. Customer satisfaction 3. Architectural quality 4. Improved orientation
15. Energy efficiency 16. Access to battery charging for electric cars 17. Architecture 18. Green building certificate	16. Green leases 17. Entertainment 18. Acoustic comfort 19. Improved orientation in the centre	16. Energy efficient storage and loading areas 17. more meeting places 18. more parking space 19. acoustic comfort

Table 1 also indicates the least important items. It shows that customers rated energy efficiency, access to battery charging for electric cars, architecture and green building certificate least important. Tenants rated Green leases, Entertainment, Acoustic comfort and Improved orientation in the centre least important while managers rated Energy efficient storage and loading areas, more meeting places, more parking space and acoustic comfort as least important. As a result of the previous described method for identifying energetic inefficiencies a list was set-up including sustainability criteria of buildings and potential energetic inefficiencies related to different stakeholder (see Image 2).

2.4 Indoor Air Quality
Landlord – Tenants/Costumers: Tenants/costumers needs regarding indoor air quality are often not considered by landlords although it is very important for tenants/customers. => Over-/underestimation (e.g. open door policy vs. heating/cooling) and choice of inaccurate technical equipment => Ventilation rates are not defined by tenants **Landlord – Municipal Authorities:** Installations in shopping centers according to standards. => ventilation rates according to standards and not regarding local and regional characteristics **Tenants/Costumers – Municipal Authorities:** Tenants /costumers needs are not matching national or local standards and are therefore not considered (e.g. standard ventilation rates vs. ventilation rates adapted to CO_2 level or number of persons).

Image 2: Excerpt of the full list of potential energetic inefficiencies

Common findings of this analysis were that most of the energetic inefficiencies occur due to inefficient communication between the stakeholders and the installation of technical equipment not attuned to the specific circumstances and needs but to general standard technical design, that includes high safety margins due to high uncertainties. As a potential solution a integral planning team including all stakeholders could be established in order to match design and actual needs. In addition the whole lifecycle of the building should be included in the planning in order to avoid shifting problems from production to operation or even End-of-Life.

The development of key performance indicators for energy efficient interaction in and operation of shopping malls came to the following elements:

- Project briefings

- project's intended approach
- guidelines which the design and construction teams will seek to implement in design
- strategies which the design and construction teams will seek to implement in design

- Integrated Planning

- Multidisciplinary formation of the planning team
  - A Sustainability Consultant
  - a Construction Manager or General Contractor with at least 3 more integrated project team members
  - at least 2 appropriate stakeholders (e.g representative of the owner and future users) in at least 3 phases of project design and construction process.
- Qualification of the Integrated Project Team
  - members in architectural and engineering chambers or other qualified chambers or associations
  - demonstrate further education with focus on sustainability.
- Design Charrette / Preparation of consultation
  - At least 2 full-day (resp. 4 half-day) or more workshops with the integrated project team
  - at least 3 appropriate stakeholders PLUS the owner/owner's representative
- Integrated planning process
  - Meetings with the integrated project team at least twice per month or more often
- Participation of future building users and other relevant stakeholders /Community impact consultation
  - Participation, consultative involvement, and a co-determination of the users and other relevant stakeholders took place.
  - The public were involved, informed and consulted, and they could participate

- Handover & Documentation

- Handover & Documentation

  - Training on operating the building efficiently is given to BOTH technical staff (facilities managers) and non-technical end users, covering all environmental strategies (lighting, ventilation, heating and cooling)
  - A plain-language, illustrated user manual is compiled, including recommendations and information for users to minimize ecological footprint, covering all environmental strategies (lighting, ventilation, heating and cooling)
  - Detailed instructions for maintenance, inspection, operation, and care are compiled and a maintenance and repairs plan was drawn up; these instructions are specified for individual target groups (facility manager, etc.)
- Building Performance Improvement
  - The building has can evidence a reduction in energy and water consumption, and waste production over the years.
  - The building has achieved both ISO50001 and ISO14001
  - At least three organisations from the delivery team (architect, consultants, builders, subcontractors or client) can demonstrate that feedback from monitoring and evaluation has been communicated to their staff

The following energy related key performance indicators are the most used ones already:

- MJ Primary Energy Consumption (Operation)/ m²/year (if possible divided into heating/cooling/lighting/ etc.)

- MJ Primary Energy Non-renewable (Operation)/m²/year (if possible divided into heating/cooling/lighting/ etc.)

- average energy efficiency class of the building equipment

A key to successful application of the proposed key performance indicators is the use during the whole design process from project briefing to commissioning and beyond.

Conclusions

The evaluation of the questionnaires for customers, tenants and management/owner show some contradictory results. Therefore it is very difficult to take these into account concerning the aspect of energy inefficiencies.

Nevertheless the results of the questionnaires indicate a high interest concerning energy efficiency both on side of customers and tenants and their willingness to introduce e.g. energy efficient heating system, cooling system etc.

The development of key performance indicators for energy efficient interaction in and operation of shopping malls showed elements that need further analysis. A test of the key performance indicators in a real building project is planned for next year. This will give more information about applicability af the key performance indicators.

All in all, there are some social-cultural and functional aspects that can result in energy inefficiencies. Most of these aspects can be improved through good cooperation between landlords, tenants/ costumers and municipal authorities. Therefore already in early planning stages of refurbishment projects the important pre-studies have to be performed (economic studies related to kind of costumers and their expectations, energetic studies, studies regarding the infrastructure, etc.). These studies can serve as a basis for design and refurbishment decisions. The developed methodology enables an assessment of shopping centres and possible refurbishment measures regarding sustainability.

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Environmental renovation methodology in commercial buildings: the case of the Europa Palace in Vitoria-Gasteiz (Spain)

Speakers:
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Abstract: *This article summarizes the first phase of the environmental assessment of the Convention Centre Europe (PEV-G) in Vitoria-Gasteiz (01), as a part of a wider renovation and expansion project. The Green Building Council Spain (GBCe) in collaboration with Societat Orgànica (SO) (02) proposed a methodology and actions for an ongoing process of environmental improvement for the building, analyzing its activities and the behavior of occupants and maintenance team, between January 2011 and September 2013. Through different models we have studied the existing building and the extension and renovation scenarios using the methodology of a simplified life cycle analysis and considering the environmental vectors energy, water, materials and waste. Options for improvement have been identified considering passive solutions, active solutions and management of the building, thus environmental objective were established. Finally, the requirements of the tender for final project and construction have been drafted, as well as an environmental protocol for the not yet executed phases. This protocol is valid for other buildings in Vitoria-Gasteiz, the Basque Country and all of Spain, to be renovated in the near future.*

Renovation, refurbishment, methodology, LCA, energy efficiency

1. Project approach

The PEV-G (Figure 1) will be renovated and extended to reach an operational capacity of 2.5 times compared to the current. The conference and reunion south wing (on the right of the plan) will be refurbished without change of use, the north wing (on the left of the plan) will be renovated changing its use from sports into exhibition activities, and a large audience hall will be added to the center wing.

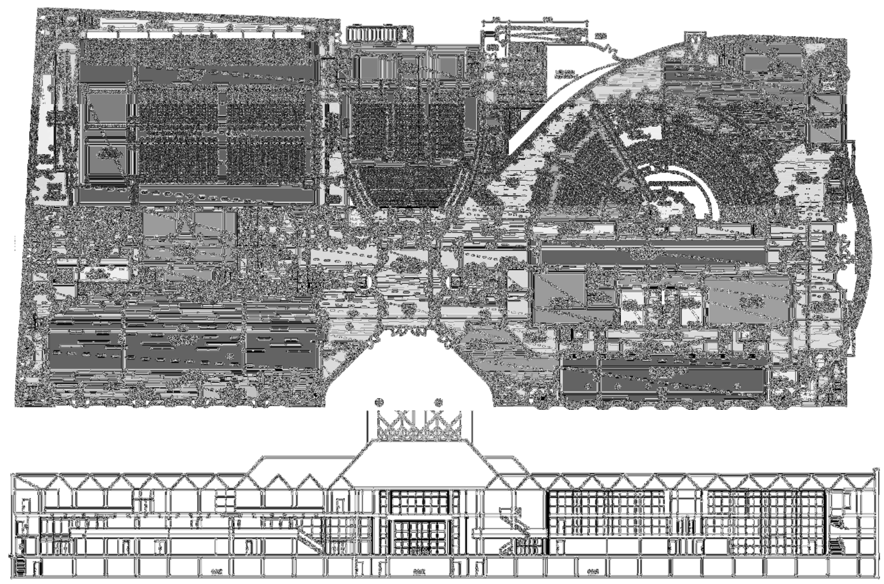

Figure 1. Ground floor and longitudinal section of Europa Palace Vitoria-Gasteiz

The complexity of developing a process of reducing environmental impacts throughout the renovation and extension of the building requires to consider how to interact with multiple factors: the deadlines set by the city council, the phases determined between them, the environmental work to be developed in each of these phases and the stakeholders involved before, during and after the process; all has to be integrated into a work plan (Figure 2).

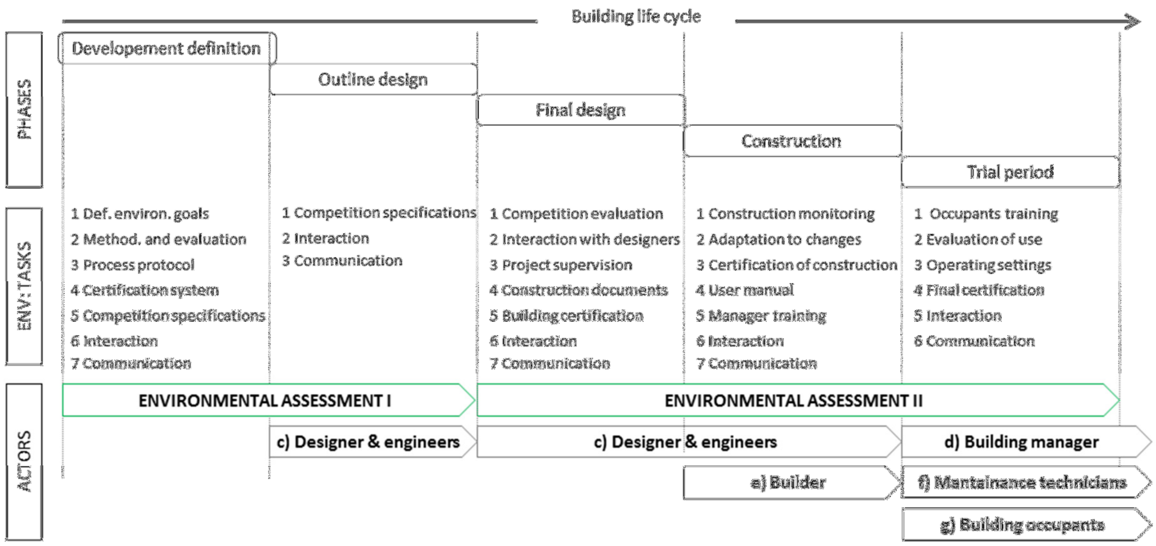

Figure 2. Working and tasks plan for the environmental renovation and extension of the PEV-G

Communication actions aimed at raising awareness of the transformation of the PEV-G in the community of Vitoria-Gasteiz, take place throughout the process, particularly on website (04).

2. Vision and environmental goals

The renovation and extension of the PEV-G had to define a strategy in order to obtain habitability and comfort at a reasonable cost of resources, maximizing the opportunities offered by the site, the building configuration, and its materials and several technical resources and facilities available. The work that has been carried out determined strategies and actions for the renovation, extension and operation that the PEV-G building had to implement in order to minimize its current environmental impacts and achieve the best possible standards of environmental quality considering the life cycle, and the energy efficiency in the operational phase. For this purpose it is intended to influence both the redesign of the building and its operation, as well as the integral management of the congress activity. In this regard, it is expected that the future offer of congresses and exhibitions of the PEV-G will be different from other regional alternatives because of its low ecological and/or carbon footprint (05) performing these operations, according to Vitoria-Gasteiz's role as European Green Capital (06).

The following main environmental indicators have been used and will be used throughout the entire process: the consumption of energy, water and materials and the generation of solid waste and CO_2 emissions in a life cycle of 50 years, focusing especially in the renovation and extension phases and operation, being these the phases with the highest environmental impacts over the life cycle of the building (07). Environmental goals to be met along the process of renovation, extension and building operation objectives have been defined: the building must achieve the highest level of the energy certification (RD 235/2013), at least 70% of the highest level in voluntary certification tools for environmental quality (VERDE-GBCe Tool and the Sustainable Building Guides IHOBE) and compliance with the prescriptive values of energy efficiency standard (PassivHaus, commercial buildings).

The content and sequence of the environmental work can be summarized as follows: a) defining a methodology for environmental renovation and extension of the PEV-G as a reference basis for other similar processes in other public and private buildings, b) the greening of specifications of the general process, competition and tender as well as drafting an environmental manual of building use and maintenance, c) establishing the current level of the environmental impact of the PEV-G and defining strategies and improvement actions to be applied in the renovation, extension and use, assessing their environmental and economic impact, d) determining the level of environmental impact of the building once reopened and compare with the objectives. Defining environmental requirements to be met in the planning stages, construction and commissioning, e) communication actions throughout the environmental consulting f) provide with environmental training the manager of the building, its technicians and users, so they can behave appropriately in the operational phase.

3. Methodology of analysis, improvement, tracking and certification

The methodology that would allow a comprehensive assessment of the environmental impact of buildings is the life cycle analysis (LCA) (08). However, its application in buildings is rare (09), due to its complexity. Addressing these problems and with the intention of creating a simplified methodology, but capable of performing a complete and replicable evaluation in other projects, a simplified LCA, useful for the assessment of trends of environmental impacts - not for highly accurate data – of the PEV-G, was implement. A simplified LCA permits a shorter completion time of the analysis', lower amounts of information to represent the life cycle and, eventually, lower economic costs because much of the work can be carried out with tools and information sources freely available or at least at a low cost (Figure 3).

	Material extraction and manufacturing	**Use and building maintenance**	**Transport, construction and demolition**
Energy (kWh/m^2)	Consumption of renovation and extension, considering the weight. Tools and dB: ITeC or Cype.	Demand, consumption and renewable en. HVAC and lighting. Tools: Enegy+, Ecotect, etc.	Estimates according to available sources (publications, research projects).
CO_2 (kg/m^2)	Consumption of renovation and extension, considering the weight. Tools and dB: ITeC or Cype.	Conversion of energy consumption into emissions according to official information in force	Conversion of energy consumption into emissions according to official information in force
Water (l/pers.)	Not considered	Consumption of network water and reuse by means of a water balance	Not considered
Waste (kg/m^2)	Not considered	Calculation of the production, dump and incinerator waste, statistical sources	Calculation of the production, dump and incinerator waste. Tools and dB: ITeC or Cype.

Figure 3. Table of impacts, life cycle phases and calculation tools

Using this simplified LCA, different constructive, HVAC and building management options, defined by considering the existing building and the preliminary design, were compared. The work developed can be summarized as: 1) collection and study of building information. Plans, building systems, HVAC systems, consumption, use profile, climate, etc., 2) implementation of a computerized listing of its environmental impacts (energy, CO2, water, waste, etc..) through its modeling, 3) determination of impact reduction options for renovation and use, with technical, economic and management assessment, 4) reprocessing computerized listing of the impacts of the proposed optimized building and verification of the compliance with environmental objectives 5) definition of performance (levels of consumption, emissions, etc.., according to comfort and habitability conditions) and prescriptive (minimum quality of construction systems and facilities) requirements to comply. Drafting of the environmental specifications of the project and construction process.

4. Existing building evaluation

Once all available information about the building was collected and analyzed (plans, reports, usage statistics, usage profiles are facilities, visits, interviews with technicians, thermographic evaluation, etc...) the environmental vectors of energy, water, materials and waste of the building were modeled (Figure 5) in order to determine their current levels of impact, contrasting them with the regulatory requirements and benchmarks from other similar buildings and determining the causes of the greatest impact.

	Analysis conducted	Main problems detected
Energy and CO_2	Annual consumption according to sources HVAC and lighting consumption Efficiency of plants Solar control and natural lighting Thermography of envelope	Insufficient insulation and air-tightness, excess solar radiation through skylights, low efficiency and adaptability of HVAC, lack of air energy recovery, natural ventilation is not used, lack of comfort, control difficulties and building management contracting that discourages savings.
Water	Annual consumption of tap water Efficiency of plants Reusing rainwater Reuse of greywater	Inadequate segregation of consumption, lack of savings mechanisms, no greywater nor rainwater is reused and wastewater ends up straight to the sewer.
Materials	Impacts of existing construction Reusability potentials Impacts new construction	Constructive systems that hinder recycling, high-impact materials in some cases and constructive systems that need to be demolished to make when modifications have to be carried out
Waste	Generation renovation Generation in extension (nc)	In current practice there is a high waste generation, difficulties in the selective separation, reuse and recycling, and a high percentage ends up in dumps.

Figure 5: Evaluation of the existing building, analysis and diagnosis

In order to link the calculations of the environmental impacts to the operation of the building according to the actual real situation (last year) and future (prediction), a model that collects usage information and experience of building maintenance and operation was defined. This information includes parameters of the operation of spaces, schedules and days of operation, intensity and simultaneity in the use of spaces, comfort profiles and any other characteristics that could define the performance profiles of PEV-G. This is very important in the evaluation of the existing building, but also in the design of the renovation and extension project.

5. Improvement strategies and quality level to be reached

Several options for reducing environmental impacts have been analyzed, to be incorporated in the proposed renovation and extension of the building. Below (Figure 6), and following the order of the environmental vectors considered, the major opportunities for improvement analyzed for the outline project (10), are presented.

	Analysis conducted	Opportunities
Energy and CO_2	HVAC and lighting consumption Solar control and natural lighting Alternatives for HVAC	Improving insulation and air-tightness of the envelope, solar control in skylights, change to more efficient HVAC and zoning, decreasing comfort requirements in areas of short permanence, energy recovery for fresh air, installing photovoltaic on the roof and cooling by natural ventilation.
Water	Efficiency of plants Reuse of water Natural purification	Savings mechanisms in south wings (renovation) and center (new construction), rainwater reuse, recovery of nutrients from wastewater, natural purification of greywater and natural discharge of treated water.
Materials	Low impact materials Potential for reuse and recycling	Maximum use of existing construction, renewable and recycled materials in renovation (south wing) and new construction (north side), building systems with mechanical joints for future reuse and recycling.
Waste	Decrease generation Potential for reuse and recycling	Minimize generation through the selection of constructive systems, increased selective separation through construction control, on-site reuse of aggregates and recycling of aggregate, metals, wood, plastics, etc…

Figure 6: Opportunities in environmental renovation and extension

Once the implementation of improvement opportunities are known, the following steps are to determine their economic viability, their practical implementation in the project, their influence on the use of the building and the training needed for operators and users.

6. Objectives of the Project, construction and operation

The outline design development and final definition of the construction budget can modify both the actions of environmental impact reduction as well as their effect on the final performance of the building. The legal framework regulating these aspects is the developed administrative and technical project and construction tender specifications. These documents, with the possible modifications carried out in the future, include the environmental protocol for the entire process, the requirements and methodology to be implemented in the verification of environmental objectives as well as the building operation analysis model. The environmental requirements enable the comparison of the existing building with the situation to be achieved once its renovation and extension is fully implemented. These requirements are organized both in performance terms, through quantitative verification (Fig. 7) as well as in prescriptive and methodological terms, to be implemented to the project and construction.

	Parameter	Existing building	Prediction of savings
Energy and CO_2	Demand	211 KWh/m^2 year	52 %
	Consumption HVAC	158 KWh/m^2 year	60 %
	Total consumption	240 KWh/m^2 year	60 %
	Total primary energy	341 KWh/m^2 year	63 %
	Total emissions	79 Kg/m^2 year	60 %
Water	Total consumption	9 l/pers. day	80%
	Reuse	Not existent	Total in non-drinkable uses
Materials	Energy new construction	9.000 MJ/m^2 approx.	50 %
	CO2 new construction t	1.000 Kg/m^2 approx.	50%
	Renovationn energy	No reference	Demonstrably best alternative
	CO2 renovation	No reference	Demonstrably best alternative
Waste	Generation renovation	84 kg/m^2 approx.	20%
	Generation in extension (nc)	No reference	Demonstrably max. reduction
	Non-recyclable	50% approx.	60 % (recycling el 80%)

Figure 7. Comparison of performance between existing and proposed building

Also following prescriptive requirements have been proposed: In energy, 30% reduction of thermal transmittance in building envelope, increased solar protection, condensation control, reduction of air permeability in joints and frames, elimination or reduction of thermal bridges and 40% of on-site produced renewable energy (compared to final electricity consumption), regardless of regulatory requirements (11). As for HVAC systems, higher efficiency in energy production, benefit from the passive criteria developed, free-cooling, flexible comfort conditions in some areas, increased distribution efficiency, reducing auxiliary energy consumption for pumping and ventilation, increased lighting performance in all power levels and regulation according to natural light and contracting a management service depending on the final efficiency.

In water, pressure reducers in the supply, low discharge WC (minimum 2/4 liters) with flow interruption, low flow faucets (3-5 l / min) and opening control, dry urinals, mechanical separation of the liquid and solid fractions in toilets and greywater natural purification and infiltration into the natural soil.

In materials, both for the renovation and for the extension, using a minimum of 20% recycled aggregate in concrete if structural and 100% in non-structural, minimum 90% recycled steel, constructive solutions that allow easy disassembly (dry joint) if the materials being joined do not have the same level of recyclability. In renovation the constructive solution has to be justified by the qualitative comparison of environmental impacts.

As for urban waste, designing spaces and facilities necessary for selective separation of at least the fractions of paper and cardboard, glass, plastic, metal, organic, specials, and other large recyclables, and an internal waste management that allows to adopt the external system of door to door collection.

	Requirements / Weighting	**Additional improvements**
Environmental objectives of design and construction	Good scores in energy certification, VERDE, IHOBE and PassivHaus performance. Performance objectives (quantification of impacts) and prescriptive (physical requirements) in energy, CO2, water, materials and waste	Highest levels in certification Overmatch performance and prescriptive objectives
Design and construction team	Demonstrable environ. & technical competence Proposal to meeting objectives Experience in similar projects with environmental requirements	Experts in additional disciplines Propose higher goals Experience or further recognitions
Builder company	Certification of environmental quality Demonstrable environ. & technical competence	Additional certifications Experts in additional disciplines
Tender score	A third dedicated to environmental aspects, built-in project literature	………..
Environmental assessment team	Demonstrable environ. & technical competence Experience in similar projects Experience developing and managing certification tools	Experts in additional disciplines Superior experience ………..
Project drafting	Environmental study with methodology of determining objectives	Improvements over the minimum objectives
Construction monitoring	Environmental plan with objective validation methodology	Improvements over the minimum objectives
Commissioning	One year of management by the builder, with verification of environmental objectives Warranty on value of contract	Overcoming environmental objectives during the first year of use

Fig. 12 Environmental aspects of the specifications of project and construction tender

7. Conclusions

The methodology based on a simplified LCA, tools and data freely available and the comparison between the baselines (the building itself, regulations, etc..) and the design project has allowed to adequately model the building, both in its present definition as well as proposed, and to establish environmental objectives and verification processes. It was essential to have a team that integrates the municipal officers of urbanism, environment, maintenance and building management together with the environmental consultants, with a common vision about what is sustainability, how to apply it in building and what actions are involved. Environmental impact savings that can be achieved in energy, CO_2, water and waste, according to current technical and economic possibilities, are between 20% and 80%. Preparing a building to operate with low environmental impact is not enough. Also an environmental work plan is necessary, from the decision to invest and develop up to the building operating, it implies specialists, managers and users, through training and information as well as carrying out routine monitoring and improvement. The methodology developed in this work, if adjusted to the characteristics of the buildings, climates and usage profiles, is applicable to many other cases in the city, the Basque Country and the rest of Spain.

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