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*Design to Thrive*

## **Towards a Holistic approach to Low Energy-Building Design: Introducing Metrics for Evaluation of Spatial Quality**

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**Abstract:** Building renovation is a complex task involving many stakeholders with different agendas. Therefore, various methodologies for assessing the impact of renovation initiatives on stakeholder agendas have been proposed. However, recent research questions contemporary practice in this matter and points out that the developed methodologies tend to favor technical (quantitative) values over more qualitative values, such as the potential to improve the perceived spatial quality in a manner that builds on the existing qualities and reflects contemporary social and cultural values. This paper discusses how to introduce metrics for more qualitative value creation in renovation processes. The hypothesis is that metrics for e.g. spatial quality can be established and used for decision-support in the early phases of renovation projects. The paper focuses on how to translate qualitative values related to human comfort and spatial perception into metrics, which can be operationalised for design information and performance evaluation. Examples of metrics related to façade properties are put forward and form the basis for a discussion about the relevance of including and quantifying such metrics as an integral part of a holistic approach to low energy-building design.

**Keywords:** Building Performance Evaluation, Architectural transformation, Refurbishment, Energy renovation, Spatial Quality

### **Introduction**

The building sector accounts for up to 40 % of the total energy consumption in the EU. Considering that the vast majority of the existing building mass will still in operation in 2050, it is evident that there is a significant energy saving potential in renovations rather than focusing solely on building energy efficient new buildings (Government, 2014b). A significant proportion of this potential lies in existing private households, which accounted for approx. 25% of the total energy consumption in the EU in 2011 (European Commission, 2016). In Denmark, there are approx. 566.000 social housing units, which constitute 20 % of different types of ownerships (Statistics Denmark, 2016). The vast majority of these were built before the energy saving requirements in the national building regulations were tightened in the late 1970's. As such, there is a significant potential for reducing the overall energy consumption in the building sector by addressing this particular building typology (Government, 2014a, p. 56). The dwellings of the future already exist, so to speak, and we have been entrusted the task of updating them in a way, which complies with today's energy standards while at the same time respecting their cultural and social significance.

This is, however, easier said than done. Renovation projects commonly involve a number of stakeholders, with each their own perspective. As such, they make up highly

complex, or “messy”, systems (Churchman, 1967). As a response, later years have seen the development of different methodologies for evaluating the performance of the building prior to renovation and after completion. In this study, we focus on performance evaluation in the pre-renovation phase. To be more precise, we focus our attention on the concept development phase in which design freedom is still relatively high, but the knowledge about the project in its entirety is limited (figure 1). Despite this paradox, we are often obliged to make design decisions, which have high consequences for the overall outcome of the renovation. As such, building performance evaluation could be a tool for decision support at a crucial stage in the process and a way to make sense of the complex system it composes. By this, we do not intend to replace the creative process, but to provide inputs, which can inform the decision-making processes.

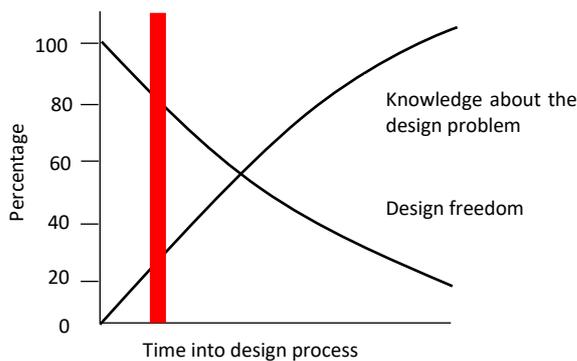


Figure 1. This paper focuses on the conceptual design phase (illustrated with the red bar) in which design freedom is still high, but the knowledge about the project in its entirety is limited. In this phase, the design decisions may have high consequences for the performance of the completed project. Based on (Ullman, 2009, p. 19).

However, one could pose the question: by which criteria should the performance of e.g. a renovated dwelling be evaluated?

Stylsvig Madsen and Beim (2015) carried out a comparative study of eight evaluation methodologies with relevance for the Danish building renovation industry and found that the majority of the methodologies had an apparent emphasis on technical, quantifiable values. They then advocated for a need to include qualitative socio-cultural values in future evaluations in order to secure a holistic approach (Stylsvig Madsen and Beim, 2015, p. 39). This is supported by the Norwegian researchers Acre and Wyckmans, who state that “...the inattention to the potential of nontechnical dimensions such as spatial quality, by stakeholders involved in the energy renovation of dwellings, constitutes a lost opportunity to increase occupants’ receptiveness to energy renovation.” (Acre and Wyckmans, 2015, p. 12). Acre and Wyckmans (2015) as well as Hvejsel et al (2015) argue that the transformation towards a more energy-efficient building mass often involves radical changes to the existing built environment, which affect the perceived spatial quality (Acre and Wyckmans, 2014) (Stylsvig Madsen and Beim, 2015) (Hvejsel et al., 2015). But how do we proceed from here? How do we articulate these changes to spatial quality as part of a holistic approach to building performance evaluation and decision support in the early stages of a design process?

In the popular science publication “Arkitektur Energi Renovering” (Architecture, Energy Renovation), the authors proposed a “hands on” renovation guide for practicing consultants (Marsh et al., 2013). The guide is divided into three typologies: single-family houses, multi-storey dwellings and offices, and provides simple tools, suggestions for strategies and cases. In addition to energy optimization and indoor climate guidelines, the guide also articulates more “soft” renovation themes such as “Bedre rumlighed” (“improved spatiality”) but only to a limited extent. The theme “spatial quality” therefore still appears to be less explicitly

articulated than its more quantifiable counterparts such as energy performance (Marsh et al., 2013, p. 5) (Hvejsel et al., 2015, p. 37).

In this paper, we take the above-mentioned publications as our point of departure and begin to elaborate on how to further articulate the notion of spatial quality. The study reviews existing literature on the subject, including an analysis on how different architectural theoreticians have communicated their views - spanning from more loosely defined themes, over “rules of thumb” to metrics, which are more readily applicable for performance evaluation. We follow up on this by suggesting that metrics for articulating spatial quality can be established and subsequently made operational for design information and performance evaluation in the early design stages. Based on the literature review and a case study, the paper discusses the relevance of doing so in practice, and what we gain or lose when pursuing this approach.

## **Methods**

### ***Narrative literature review***

When aiming to evaluate spatial quality, we could study the users’ affective appraisal of the spaces in question, i.e. how the users experience the spaces they inhabit and how they describe that experience. Another way is to focus on identification of parameters (metrics) through existing literature (Acre & Wyckmans, 2014) (Olesen, 2014). In this study, we use the latter approach. Based on a literature study of four architectural theorist’s perspective on spatial quality, we aim to articulate examples of “metrics” within the topic of “spatial quality” and discuss if and how they can be operationalised for inclusion in building performance simulation tools.

Exploring the notion of spatial quality has been a theme of many a scholar and practitioner. This paper does not encompass an exhaustive account of the term “spatial quality” but rather aims to articulate what lies behind this term, focusing on its qualitative aspects. The selection process for including architectural theoreticians has been to include a span of definitions, ranging from more loosely defined spatial themes (e.g. Juhani Pallasmaa and Pierre von Meiss), over “rules of thumb” by e.g. Jan Gehl, to researchers with a quantitative approach as part of a qualitative evaluation system. We have only included literature with relevance for the dwelling scale and its immediate surroundings. Based on the literature review, the paper discusses the relevance of including and quantifying metrics related to spatial quality as an integral part of a holistic approach to low energy-building design and evaluating these through computer simulation.

In the paper “Towards a Holistic Approach to Low-Energy Building Design: Consequences of Metrics for Evaluation of Spatial Quality on Design” by Purup et al (2017), the examples of identified metrics from the present paper are included in computer simulations of design proposals for the renovation of a housing complex in Aarhus Denmark.

## **Analysis**

### ***Expanding the notion of spatial quality***

In table 1, we present an overview of parameters put forward by four architectural theoreticians in relation to “spatial quality”. To the right is an indication of the architects’ approach, ranging from a more intuitive qualitative approach to metrics intended for quantitative evaluation.

Table 1. Spatial quality in the eyes of architectural theorists.

	Focus	Parameters	Approach (spanning from an intuitive qualitative approach to metrics intended for quantitative evaluation)	Method of inquiry
<b>Acre &amp; Wyckmans</b> (Acre and Wyckmans, 2014)	Renovation of dwellings	<ul style="list-style-type: none"> <li>Views</li> <li>Internal spatiality and spatial arrangements</li> <li>Transition between private and public spaces</li> <li>Perceived human and built densities</li> </ul>		Litterature review
<b>Jan Gehl</b> (Gehl, 2003)	Outdoor spaces and transition spaces	<ul style="list-style-type: none"> <li>To gather – or scatter</li> <li>To integrate – or segregate</li> <li>To invite - or reject</li> <li>To open up – or enclose</li> </ul>		Field studies Literature review
<b>Pierre von Meiss</b> (von Meiss, 1990)	Architecure in general	<ul style="list-style-type: none"> <li>Depth of space</li> <li>Density of space</li> <li>Openings</li> <li>Spatial juxtaposition and interpenetration</li> <li>Geometry of plan, sections and spaces</li> <li>Light and shade</li> <li>Floor, wall and ceiling (enclosure, demarcation, texture)</li> </ul>		Case studies Literature review
<b>Juhani Pallasmaa</b> (Pallasmaa, 1996)	Architecure in general	<ul style="list-style-type: none"> <li>Multi-sensory experience</li> <li>Shadow</li> <li>Acoustics</li> <li>Scent</li> <li>Taste</li> <li>Bodily identification</li> </ul>		Case studies Literature review

Table 1 illustrates the somewhat ambiguous notion of “spatial quality”. It also suggests that there are differences in the approaches of the included theoreticians. Meiss points out the “strings” of the instrument of architecture, which can be put into use, but refrains from establishing rules for how to play on it. Gehl puts forward “rules of thumb” based on observations from literature studies (Gehl, 2003). Acre and Wyckmans use references such as Gehl to establish a set of more generally applicable and quantifiable “rules”, which can ultimately be applied in an evaluation scheme, in which one can assess the consequences of renovation initiatives (Acre and Wyckmans, 2015). This, in turn, contrasts the more phenomenological, sensuous approach proposed by e.g. Pallasmaa (Pallasmaa, 1996).

### ***Exemplifying metrics for evaluation of spatial quality***

In the previous section, we have briefly outlined how four architectural theorists have communicated their views on the term “spatial quality”. We see that the represented theorists offer different types of “decision support” for the design process. In this section, we examine if we can further develop the themes towards more quantifiable metrics, which can

be made operational for building performance evaluation through computer simulation. The objective is to translate “spatial quality” themes of a more qualitative character into metrics. More specifically, we focus on the four following issues related to spatial quality: Thermal comfort, Daylight conditions, View quality, and Privacy. The four issues (especially the two latter) are included as examples of how one could potentially include themes, which are traditionally treated more qualitatively as part of an argumentative design process. In the paper *“Towards a Holistic Approach to Low-Energy Building Design: Consequences of Metrics for Evaluation of Spatial Quality on Design”* by Purup et al (2017) the examples of metrics proposed in the present paper are further developed and included in simulations of design proposals for a renovation case. In the present paper, we shall limit ourselves to discussing the process of translating themes into examples of metrics applicable for computer simulation.

### *Thermal comfort*

Looking into comfort parameters in residential buildings, Frontczak et al (2011) found that 35 % of the 645 respondents answered, that temperature contributes to their comfort. Only light and sun was more influential (46%). In another survey among 1990 randomly chosen house owners in Furesø Kommune, Denmark, thermal comfort was mentioned as the third most important motivation for renovation (Knudsen, 2014). These studies indicate that thermal comfort is an important quality in housing. However, studies rarely correlate user answers to thermal measurements that can be transformed into metrics; even the well-known PMV-metric is not suitable for evaluation of thermal comfort in homes (Becker and Paciuk, 2008). A recent study of student houses in Aarhus, Denmark, seeks to correlate user votes and thermal measurements (Petersen et al, 2016), and find a slight correlation to the SCAT-model which relates the comfortable indoor temperatures to the outdoor temperature while assuming that occupants have adaptive behavior in terms of clothing level and opening of windows for cooling (Nicol and Humphreys, 2010). This evaluation model is also used in other research on thermal comfort in housing (Brotas and Nicol, 2016), and suggested as evaluation model for Danish residential (Petersen et al, 2014). Despite the lacking research-based evidence, the SCAT-model may be suitable for evaluation of thermal comfort in houses, and is proposed as a metric by the authors of this paper.

### *Daylight*

The importance of daylight to human well-being is widely recognized, e.g. by Volf (2013). As opposed to e.g. View quality and Privacy, the idea of quantifying “daylight quality” for the purpose of performance evaluation is not a novelty. In Denmark, the Building Regulations require a minimum glazed area corresponding to minimum 10 % of the interior floor area or a documented daylight factor of minimum 2 % in half of the room (Byggecentrum, 2016). Acre and Wyckmans suggest using daylight factor and sky view factor as a means to evaluate the daylight performance (Acre et al., 2015). Nabil and Mardaljevic (2006) proposed that UDI (Useful daylight Illuminance) should substitute the DF as a way to say more about the quality of the daylight. UDI can be defined as the percentage of the year when daylight illuminance on the work plane falls within a range from 100-2000 lux. Below 100 lux, artificial lighting is needed and above 2000 lux the illuminance level is likely to cause discomfort (Nabil and Mardaljevic, 2006). From a phenomenological perspective, such quantifications do not say much about the actual perceived quality of daylight (or shadow). Meiss argues that the changing character of light during the day contributes to a *“change in atmosphere’ which denotes a qualitative change in which quantity of light is of only secondary importance”* (von

Meiss, 1990, p. 121). Since it is the purpose of this study to propose metrics for quantification, we propose the UDI as a way to proceed. However, the brief elaboration of the theme illustrates that it is essential to only use UDI as one of perhaps many indicators in a qualitative assessment of daylight conditions.

*View quality and degree of privacy through windows*

It is well recognized that the possibility to look out and observe nature and orient oneself in relation to time and place is important for human wellbeing (Hauge, 2013, p. 5) (VELUX, 2013, P. 8). On the other hand, the window also comprises a “social boundary” which makes it possible to remain private (Hauge, 2013, p. 47). In table 2, we revisit and expand the notions put forward by the architectural theorists listed in table 1 to discuss their different approaches to articulating ‘views’ and ‘privacy’ as themes within the architectural theoretical domain.

Table 2. Selected statements about views and privacy put forward by architectural theorists.

	<b>Example of statements related to view quality</b>	<b>Example of statement related to degree of privacy</b>
Acre and Wyckmans	<p><i>“Spatial quality assesment for views:</i></p> <p><i>2. Quality of the view (composition of the view)</i></p> <p><i>a) Distance of the view (depth) is &gt;6 m (yes or no question)</i></p> <p><i>b) Width of the view through window(s) is &gt; 28_ (yes or no question).</i></p> <p><i>c) Presence of layers of proximity (sky, landscape and ground) (yes or no question)” (Acre and Wyckmans, 2015, p. 15)</i></p>	<p><i>“(C) Distance and degree of sight protection (visual privacy and protection of the private domain)</i></p> <p><i>1. View of arriving visitors and entrance, and entry-lock (hall) to the dwelling</i></p> <p><i>a) Possibility to see arriving visitors (yes or no question)</i></p> <p><i>b) Possibility to see arriving visitors without being seen (yes or no question)” (Acre and Wyckmans, 2015, p. 15)</i></p>
Gehl	<p><i>“Many details of the building, the outdoor areas and the entrance, can influence the use of the outdoor spaces”...“The bench by the entrance, sheltered from the rain and wind and with a nice view to the access road, is a modest, yet obvious way to support the life between the houses.” (Gehl, 2003, p. 179)</i></p>	<p><i>“The houses were placed 3-4 m from the pavement, far enough to secure a certain level of privacy in the area in front of the house – to keep the activities at an arm’s length.” (Gehl, 2003, p. 181)</i></p>
von Meiss	<p><i>“The degree of enclosure does not only depend on the quantity and the size of the openings. When we wish to create a space which tends to open to the exterior, we are trying to make it less explicit”...“The larger theese openings become the more they designate an absence of wall.” (von Meiss, 1990, p. 107f)</i></p>	<p><i>“The space of the window is a potential priviliged place in the room. Its transparency, the direct light and sun which enters it, invite and encourage particular activities: to sit near the window and follow the comings and goings outside without beeing seen.” (von Meiss, 1990, p. 152)</i></p>
Pallasmaa	<p><i>“In our time, light has turned into a mere quantitative matter and the window has lost its significance as a mediator between two worlds, between enclosed and open, interiority and exteriority, private and public, shadow and light. Having lost its ontological meaning, the window has turned into a mere absence of the wall.” (Pallasmaa, 1996, p. 47)</i></p>	

We see from table 2 that the included theoretical statements span from discussions about the window from an ontological and phenomenological perspective (Pallasmaa, 1996)

(von Meiss, 1990) to more concrete guidelines for how to practically deal with this threshold (Gehl, 2003) and an actual “check list” provided by Acre and Wyckmans (Acre and Wyckmans, 2015). In testing metrics for application in computational simulation, we lean on the latter approach. Acre and Wyckmans suggest an approach to view quality through windows based on “yes/no” questions. This offers a means to compare different alternatives in a similar way, yet the metrics must be further elaborated for implementation in computer simulation. For evaluation of view quality through windows, we suggest establishing an expression “View-out quality” that takes into account the extent of the potential view to the exterior through the proposed windows and a weighing of the elements that constitute the view. For evaluation of “Degree of privacy”, we suggest an expression based on the complementary percentage of the view potential and a weighing of areas in the exterior, which represent a risk of views to the interior. In the proposed examples of metrics, we focus on the performance in the interior space. As such, we do not address the view quality or degree of privacy in relation to private outdoor spaces (Gehl, 2003) (Acre and Wyckmans, 2015). For further elaboration of the proposed metrics, see Purup et al (2017).

### **Discussion and conclusion**

In the previous chapter, we have listed examples of metrics for “View-out quality” and “Degree of privacy” related to alteration of the building envelope. In this section we engage in a brief discussion about the relevance of including metrics for evaluation of spatial quality in building performance evaluation through simulation. In relation to renovation of existing social housing, we see a potential in the use of the metrics to articulate the more “soft” values alongside the “hard” values in a more equal manner, which can ultimately lead to different design choices compared to design decision based on “hard” values only. For an experienced architect, it may not be surprising that one solution may offer a better view than another does. However, when graphically displaying the quantitative outcomes of the simulations related to e.g. daylight and view alongside the results related to energy consumption, we may be more inclined to accept design solutions in interdisciplinary design teams, which have slightly reduced performance in terms of energy consumptions, but performs significantly better in terms of daylight and view quality. However, we do not see this approach as a replacement of the creative argumentative process. The architect must still evaluate the results relative to the expected activities within the space and with a specific user group in mind. Seen from a phenomenological perspective, in this study represented by e.g. Pallasmaa (1996), the spatial experience cannot be understood separately through quantification of single components, but must be understood as a totality, as it is experienced by a subject through bodily encounters (Pallasmaa, 1996). An example, where the quantitative metrics on “View-out quality” and “Degree of privacy” may be insufficient for a holistic performance evaluation is that they do not account for aspects such as “ambience” (von Meiss, 1990, p. 121), “material encounters” (Pallasmaa, 1996) (Rasmussen, 1966) or the ability for people to personalize the windowsill with “knick-knack” (Hauge, 2013, p. 8) when e.g. exploring façade solutions scenarios. What we are merely suggesting is that quantifying some of the qualities related to spatial quality may establish a shared language for equal evaluation of both “soft” and “hard” metrics in the early stage of the renovation process.

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