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LETTER

Environmental assessments in the built environment: crucial yet underdeveloped

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Abstract

Environmental assessments have been developed with increasing emphasis since the wide-scale emergence of environmental concerns in the 1970s. However, after decades there is still plenty of room left for development. These assessments are also rapidly becoming more and more crucial as we seem to be reaching the boundaries of the carrying capacity of our planet. Assessments of the emissions from the built environment and especially of the interactions between human communities and emissions are in a very central role in the quest to solve the great problem of sustainable living. Policy-makers and professionals in various fields urgently need reliable data on the current conditions and realistic future projections, as well as robust and scientifically defensible models for decision making. This recognition was the main motivation to call for this Focus Issue, and the published contributions truly highlight the same point. This editorial provides brief summaries and discussions on the 16 articles of the Focus Issue, depicting the several interesting perspectives they offer to advance the state of the art. Now we encourage academics, practitioners, government, industry, individual consumers, and other decision makers to utilize the available findings and develop the domain of environmental assessment of the built environment further. Indeed, we hope that this Focus Issue is merely a kernel of a significantly large future body of literature.

1. Introduction

Creating sustainable human settlements will be one of the grand challenges in the coming decades (Rees and Wackernagel 1996, Glaeser 2011, Seto *et al* 2014). On a global scale we overuse our planet's renewable capacity (WWF 2014), and we seem to have –already crossed the planetary boundaries regarding several impact categories and in others the limits are getting closer (Rockström *et al* 2009). It is vital to investigate what would make cities sustainable in order to fulfil our ever increasing needs and find opportunities to live, work, urbanize in a more environmentally affordable way.

However, we currently seem to be much more capable of measuring and describing the problems than finding solutions. For example, the confidence in anthropogenic greenhouse gases (GHGs) causing the climate change is very high (Cook *et al* 2013), and in that urban areas cause the majority of the emissions (Seto *et al* 2014), but very different views exist regarding the relationship between the urban structure and GHG emissions. Traditionally higher density has been connected to lower emissions (e.g. Kenworthy 2006, Brown *et al* 2009, Glaeser and Kahn 2010) and thus it has become the dominant urban development target around the developed countries. Notwithstanding, an increasing number of studies have indicated that density might not be a sufficient indicator for GHGs (Jones and Kammen 2013, Minx *et al* 2013, Baur *et al* 2014), and that higher density might even drive higher emissions (Heinonen *et al* 2011, Wiedenhofer *et al* 2013). Regarding many other impact categories the situation is very similar. Higher density is tied to reduced private driving, which decreases the particulate matter emissions, but the intake fractions have been shown to increase at the same time, potentially more than enough to compensate the reductions in the emissions (Apte *et al* 2012). Furthermore, balancing the assessments between the emissions occurring now and those taking place in the future is an issue where two different, but widely used and accepted, assessment approaches can lead to very different outcomes and policy implications (e.g. Schwietzke *et al* 2011, Säynäjoki *et al* 2012).

Assessments of the emissions and especially of the interactions between human communities and emissions are thus in a very central role in the quest to solve the problem of sustainable living. This, combined with all the contradictions and shortcomings in the current environmental assessment practices, gave motivation for this focus issue, and led us to invite especially papers based on empirical and quantitative data. At the closure of the issue we cannot say that the sustainability problem would be solved, far from that as recent evidence shows (Seto *et al* 2014, WWF 2014), but the collection of published papers certainly forms an interesting combination of perspectives on the big issues and advances the state of the art by one step.

Altogether 15 research papers and one perspective were accepted for this focus issue during 2012–2014. The issues concerned in the papers vary from indoor air quality and urban heat island (UHI) mitigation to (more) sustainable transportation, urban densification, carbon footprinting and several others. In the next sections we shortly summarize the perspectives offered by these studies and the suggestions they give to advance the quest for sustainable living. In the final section, we discuss the overall take-away messages and the existing and emerging future research needs.

2. Perspectives on and improvements to environmental assessments in the built environment

2.1. Improving transportation assessments

Reducing private driving and increasing the share of public transport has established a strong position in the environmental sustainability strategies from country to local community levels. The issue rose to a significant role in this Focus Issue as well, especially from the perspective of how infrastructure should be taken into account in environmental burden assessments. In two letters the authors stress that despite the strong position of transportation in general, the impacts of the transportation infrastructure development have been undermined in this branch of research (Chester *et al* 2013, Thorne *et al* 2014). Eckelman (2013) discusses in his perspective further the issues presented by Chester *et al.* Strongly related to the previous, Gosse and Clarens (2013) discuss utility and the currently weak position of systems thinking in the optimization of urban roadway design, arguing that success in the efforts to reduce the traffic-related costs and emissions require systems thinking over the whole life cycle.

Chester *et al* (2013) point out that the infrastructure impacts can be significant and variable across different impact categories in comparison to the use phase emissions, with decades-long payback times at worst. They notice that the assessment results are highly sensitive to the assumed modal shifts as the result of investing into improving public transit systems. While assessing the life-cycle emissions, Chester *et al* separate the locally occurring from those caused elsewhere. In his perspective, Eckelman discusses how in transportation decision-making one problem is the spreading of environmental burdens far outside the local community responsible for the transportation infrastructure. He stresses the importance of separating the local emissions and those occurring elsewhere in future assessments, as done by Chester *et al.* He also gives credit to Chester *et al* for using consequential life-cycle assessment (LCA) to demonstrate the temporal perspective of the caused environmental burdens and the potential future gains, and raises the issue as an important direction of assessment development.

Thorne *et al* (2014) approach the infrastructure issue from a different perspective. They demonstrate the applicability of a regional advance mitigation planning (RAMP) framework in assessing the ecosystem impacts of infrastructure development. Using the San Francisco Bay Area in California as a case, they show how a regional integrated assessment of multiple projects brings advantages when compared to traditional project-by-project assessments. An integrated assessment framework like RAMP could enable such planning which would prevent infrastructure development from cutting the habitat reserves into a myriad of insufficiently small land pieces. Additional interest should evoke the thought that combined mitigation solutions might reduce the required land acquisitions and thus the transaction costs.

Gosse and Clarens apply LCA on the infrastructure system level to analyze how a modal shift to bicycling affects the costs and emissions of transportation. Continuing in similar vein to the previously-described letters, the authors stress the importance of a system-wide scope and life-cycle perspective in assessing the environmental burdens from transportation. They show that turning parking space into bike lanes can reduce time and environmental burdens, and require only minimal investments, if done so that increased bicycling does not delay traffic. According to the authors this might also.

While the three papers are very different in nature, their common quality is that they all stress the importance of comprehensive assessments with wider scopes than traditionally adopted. An analogous consequence is that the assessments become very complex and include a lot of uncertainty. However, it is easy to justify a conclusion that more and more comprehensive assessments are mandatory to assist the policy-making processes in finding the best-available options.

2.2. Understanding the negative health impacts of the built environment

Nazaroff (2013) presents an overview on how climate change will or might affect indoor air quality and related health impacts. He argues that while the health consequences of different indoor and outdoor emissions have been studied relatively extensively, little attention has been paid so far to the effect of climate change on these. He concludes that the impact of climate change is very complex and that the net impact is difficult to assess. On one hand, there are certain benefits that the presumed shift away from fossil fuels in both power generation and in transportation will bring to indoor air quality. On the other, the endeavor for higher building energy efficiency might show in decreased ventilation levels and cause the concentrations of indoor-sourced emissions to increase. In addition, climate change itself will lead to changes in the existence and harmfulness of certain natural causes of negative health impacts, such as windblown dust.

From the assessment perspective, Nazaroff's paper raises again the problem of high complexity of comprehensive assessments in the context of the built environment. A very high level of uncertainty has to be accepted especially when looking into the future, with changes both in the natural environment and in the built environment affecting the assessments concurrently. Nazaroff also mentions the interesting yet not always recognized paradox of the built environment, namely that even if emissions decrease, human exposures might still increase. Apte *et al* (2012) give a good example of this by depicting how particulate matter exposures are higher in denser cities around the globe than in less urbanized areas, despite the well-documented decrease in transportation trip generation that typically comes with higher density.

2.3. UHI measurement and mitigation

Li *et al* (2013) approached UHI measurement and mitigation from the perspective of pavement materials, showing how higher permeability could offer a feasible way to significantly mitigate the surface and near-surface temperatures in urban settlements. They also show how permeable pavements can help in stormwater management. Li *et al* also argue that in the future assessments should reach wider life-cycle scopes. The direct impacts can already be measured with reasonable reliability, but life-cycle impacts of new technologies and materials are less known.

In their two-part contribution to this focus issue, Dan Li *et al* concentrate on another contribution to UHI mitigation, that of green and cool roofs. In the first part, Li and Bou-Zeid (2014) validate the simulation method and demonstrate how it reduces the temperature biases in comparison to several earlier simulation methods due to its ability to accommodate the variation in the intra-urban facets and the main hydrological processes. In the second part, Li *et al* (2014) employ the method in a simulation of the impacts of green and cool roof mitigation strategies on UHI in the Baltimore–Washington metropolitan area. They depict how both mitigation strategies show linear mitigation ability in optimal conditions (moisture/albedo). They suggest that the employed assessment method adds an important piece to UHI simulation via city-scale simulation, with sensitivity to heterogeneity in the intra-city canopies.

The UHI effect provides an example of a man-made environmental impact of which we have been aware for decades, but which still needs important development steps in environmental assessment and simulation techniques. The articles from Li *et al* (2013), Li and Bou-Zeid (2014) and Li *et al* (2014) are just such steps. However, both also stress the importance of further development needs in this area.

2.4. Analyzing GHG emissions caused by different types of human settlements

As many as four letters in this Focus Issue are devoted to discussing GHG and to a lesser extent other emissions that human settlements cause by their users' and residents' consumption of goods and services. Heinonen *et al* (2013a, 2013b) assessed the carbon footprints of the residents of different types of human settlements in Finland and elaborate their analysis with time-use data to understand better the differences in the daily lives behind the varying carbon footprints. Minx *et al* (2013) look at the carbon footprints in the UK analyzing the impacts of the settlement type and several other variables. Goldstein *et al* (2013) enhance traditional urban metabolism (UM) analysis with LCA to form an UM approach capable of quantifying global environmental burdens. To nicely complement these four approaches, Ramaswami and Chavez (2013) present an analysis how different metrics should be used to understand the different perspectives of the energy and carbon intensities of cities.

Heinonen *et al* find in the first part of their study (2013a) that carbon footprints increase rather steadily with the income level from the least to the most urbanized, highest density areas in Finland. They analyze the lifestyles to understand the mechanisms behind the results, and with evidence from both monetary consumption data and time-use data they present a concept of parallel consumption as one explanation: how the reduced living spaces in the more urbanized areas are actually a trade-off with service spaces in near proximity, and how space consumption spreads outside the home even while homes are equipped to provide many of the searched services.

In the second part Heinonen *et al* restrict their analyses to the middle-income population and look at additional variables of housing type and motorization. The results depict interestingly how little impact these variables have on the overall carbon footprints when the same disposable income is given for each resident.

With the same income, the apartment buildings are crowded with very small households and the economies-of-scale effect equalizes the carbon footprints. Regarding motorization, the cost of owning and operating a vehicle is so high that the non-motorized can spend significantly more on other consumption and thus reduce the positive impact of not driving.

Minx *et al* (2013) look at GHG emissions from two perspectives: from the more traditional territorially restricted and from consumption based. They show how the vast majority of the human settlements in the United Kingdom are importers of GHGs. In the territorial (scope 2) analysis, the level of urbanization seems to play a role in that GHG emissions increase towards the less urbanized areas, but when the consumption-based perspective is taken, the differences disappear almost completely. They also conclude, similarly to Heinonen *et al* that density is a poor indicator for carbon footprints, and that the emissions are much more strongly driven by socio-economic characteristics than density of a certain area.

There are several well-known problems related to carbon footprinting. In this Focus Issue, two author groups approach the issue using two different assessment methods or data sets, thus being able to analyze additional perspectives, especially the lifestyle differences explaining the findings. Both groups also call for more contributions, looking particularly at the lifestyles from various perspectives and advancing the assessments that way.

Goldstein *et al* (2013) on their part approach the issue from the opposite direction, utilizing LCA to enhance the traditional UM analysis. They call the approach UM-LCA and describe it as a third-generation UM framework. They show how the earlier-generation UM frameworks end up underestimating the actual environmental burdens due to their inability to properly capture the life-cycle impacts caused by a certain settlement. Their work aims clearly to enhance the UM methods, but as stated by the authors, the framework they propose is not ready, but is rather a first step in the right direction. They also propose an important further step, maybe the fourth-generation UM framework, in suggesting to bind the UM-LCA into the planetary boundaries approach presented some years ago by Rockström *et al* (2009).

As a kind of umbrella for all the above approaches, Ramaswami and Chavez (2013) discuss the best metric to describe the GHG or energy efficiency of a certain human settlement. They suggest that we should not even try to use a single metric, but actually understand the utility of different approaches and use them in the right way and in the right context. The regional energy and carbon intensity should be measured as an intensity relative to the gross domestic product, whereas the consumption-based assessment should use a per-capita basis. Their work could provide valuable guidance for policy makers seeking GHG mitigation strategies and grappling with highly variable assessment results coming from different sources.

2.5. Densification prospects and consequences

While the letters from Heinonen *et al* and Minx *et al* in this Focus Issue question the utility of densification as a vehicle to GHG mitigation, it remains a paradigm in urban planning policies in the developed countries due to the demonstrated connection to reducing private driving. In their letters, Brecheisen and Theis (2013) and Shmidt-Thomé *et al* (2013) concentrate on the issue of densification.

Schmidt-Thomé *et al* look at the prospects for densification using SoftGIS data collected from Finland. Their hypothesis is that densification is a highly context-sensitive issue and thus perceived very differently in different locations. Giving some policy advice, the authors find that the residents tend to ex ante prefer the same degree of density in the future as they experience at the time of the interview. However, regarding large new residential development projects, the study found no correlation between the density of a development and the interest shown towards it. The authors conclude that densification development should be place-sensitive to understand the perceptions of the residents and target developments where they are received well.

From the perspective of this Focus Issue, Schmidt-Thomé *et al* suggest that context-sensitivity should be given more emphasis in planning and the type of Soft-GIS approach they employ could be the tool. Infill developments are not always perceived very well by the residents of a certain area, but by understanding the perceptions, better infill policies could be designed.

Schmidt-Thomé *et al* refrain from taking a stand on the environmental sustainability perspective of infill developments, while Brecheisen and Theis study the particular issue from a life-cycle energy requirements perspective. They employ LCA to study the energy requirements of a brownfield redevelopment project from the remediation until 10 years of use. Infill developments often require utilization of brownfield sites, creating a problematic situation since the remediation requirements may be significant. For Brecheisen and Theis the results are promising since the authors report the refurbished building to have reached nearly 50% lower use-phase energy consumption than the average in the area for the same building type, and the use-phase energy still dominates the life-cycle energy requirements after 10 years of use despite significant land removal and remediation requirements. Furthermore, the authors estimate that demolishing and constructing a new building would have tripled the energy requirements of the project.

2.6. Economic incentives

Mitigating the environmental harm caused by humans will require significant amount of capital if we are to achieve sustainable coexistence with nature. Yet it is much more likely that the improvement potentials will realize if there is economic incentive to invest in certain improvements. Cox *et al* (2013) and Gosse and Clarens (2013) approach their topics through the lens of economic and environmental feasibility.

Cox *et al* propose enhanced benchmarking for building energy efficiency, arguing that the current practices easily underestimate the savings potentials due to their weak recognition of future technological development. They find the efficiency improvements to be not just economically feasible, but also to reduce both criteria pollutants and GHG emissions. Furthermore, their analysis shows the benchmarking policies to economically benefit both the private sector and society. Gosse and Clarens' approach, as discussed in section 2.1, is very similar in that they also look for the opportunities to reduce life-cycle costs and show how it leads to reduced environmental burdens as well.

3. Final remarks

Environmental assessments have been developed since the wide-scale emergence of environmental concerns (mostly in rich countries) in the 1970s and even earlier. Still, after decades there is plenty of room left for further development. Environmental assessments are quickly becoming more and more crucial as we seem to be reaching the boundaries of the carrying capacity of our planet. Policy-makers and professionals in various fields urgently need reliable data on the current conditions and realistic future projections, as well as robust and scientifically defensible models for decision making.

This recognition was the main motivation to call for a Focus Issue on environmental assessment of the built environment. We can conclude that the published articles highlight and address the same point. Representing various fields and disciplines, a theme taken up in the majority of the letters is the requirement for further development in the assessment methods, while recognizing that important and crucial steps have been taken to improve environmental assessment techniques and analyses.

Now we hope academics, practitioners, government, industry, individual consumers, and other decision makers will get motivated to utilize the available findings and develop the domain of environmental assessment of the built environment further. Indeed, we hope that this Focus Issue is merely a kernel of a significantly large future body of literature.

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