



## Expanding Boundaries: Systems Thinking for the Built Environment

### ANALYSIS OF THE MATERIAL-RELATED DESIGN DECISION PROCESS IN FLEMISH ARCHITECTURAL PRACTICE

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#### Abstract

Architects are the key actors in the building design process and as such responsible for many important design decisions, of which a large share influences the final sustainability level of the building. Up to now, little attention has been paid to their handling of (sustainable) material use, since no related regulation exists yet (in contrast to energy performance regulations). Some countries like the Netherlands are preparing for future legal requirements on the environmental impact of buildings, by imposing a mandatory calculation of the environmental impact of new buildings. Also the Flemish/Belgian authorities are developing a tool to incorporate environmental impact calculations in the building design process.

In anticipation of these upcoming legal requirements for sustainable material use, the design process of 14 real life design projects has been unravelled with a specific focus on the material choices during the design process. A process scheme of the material choices along the different design phases has been developed. Semi structured interviews with the architects gave input to fine tune the process scheme. This paper presents the lessons learned from this analysis in view of tool development for and feedback on the environmental performance of building design directed to the architect.

#### Keywords:

Case studies; Material selection; Architectural design; Building environmental impact

## 1 INTRODUCTION

Architects are key actors in building design, from concept to elaborated design, especially in Flanders (Belgium), where private client hood for individual dwelling construction or refurbishment is common practice and in most cases, involvement of an architect is required [1]. Consequently, many important design decisions by architects strongly influence the final sustainability level of the building design.

For now, (Flemish) architects still mainly relate sustainability to a good energy performance, due to the coming into force of the Energy Performance of Buildings Directive (EPBD) since 2006 [2] and its recast in 2010 aiming for nearly zero energy buildings by 2021 [3]. However, according to the Europe 2020 Initiative, Flagship 4 "Roadmap to a Resource Efficient Europe" [4], the material efficiency of building constructions will be tackled in the future by application of a

lifecycle approach assessment on buildings and materials.

The way (Flemish) architects deal with EPBD requirements in the design process was already investigated by Weytjens and Verbeeck [5]. However, up until now, little is known about the way architects handle material selection whilst designing, especially not with regard to sustainable material selection since no legal requirements are imposed yet. Some countries are already anticipating future (legal) targets on the environmental impact of buildings, e.g. the Netherlands, where a mandatory calculation of the environmental impact of new buildings and the materials used in these buildings is imposed (for now without a benchmark to comply with) [6]. However, it is still to be awaited if and how this calculation will influence architectural practice.

In Belgium, the regional governments are undertaking similar initiatives for the development

of a tool to calculate the environmental impact of building design projects (without the date for implementation set yet) [7]. In order to be able to develop an environmental impact assessment tool that is architect oriented and design supportive, the role and approach of the architect in material selection during the design process is investigated. Specifically, the timing of material decisions in the design process and the level of specification of these decisions (by the architect) are studied by means of a retrospective case study analysis. This will serve as input to define the most crucial points in the design process on which usable and appropriate feedback on the environmental impact should and could be provided to the architect.

Section 2 presents the research methods used. In section 3 an overview of the architect's profile and project characteristics is given, followed by a presentation of material decisions during the design process per design phase. Section 4 discusses these findings in the perspective of future tool development and in section 5, conclusions and further research steps are described.

## 2 METHODS

To investigate the architectural design process, with regard to the material selection process, the design information of 14 Flemish architectural design processes has been unravelled in a retrospective case study analysis.

By January 2015, nine architects provided design documentation of 14 new construction dwellings (constructed between 2009 and 2013). The sample consists of six semidetached and eight detached dwellings. Ten are traditional cavity wall constructions and four are timber frame construction.

A process mapping method was used for the analysis of the design documentation in order to identify moments for material decisions and levels of specification of these decisions [8-10].

For the process mapping of the design process, the design documentation was first structured into the four most prevalent phases of the design and construction process in Flanders: i) pre-design, ii) design phase with conceptual design, preliminary design and detailed design, iii) building permit phase and iv) execution phase, consisting of a tendering and construction phase. The post construction phase is not taken into account in this research.

Since material-related decisions are made on a more detailed level than the level of the building shape, this shape has been subdivided into six building layers in line with the research by Brand [11] (Fig. 1): i) building structure (load bearing function), ii) building skin (visible, exterior), iii) building shell (mostly thermal function, but also

waterproofing and/or airtightness), iv) building systems (technical equipment), v) interior space (finishing materials) and vi) room separations (interior walls). Brand [11] focused on the differences in life span of the layers, whereas here this subdivision will be used to present differences in timing and level of specification of material decisions for the different layers.

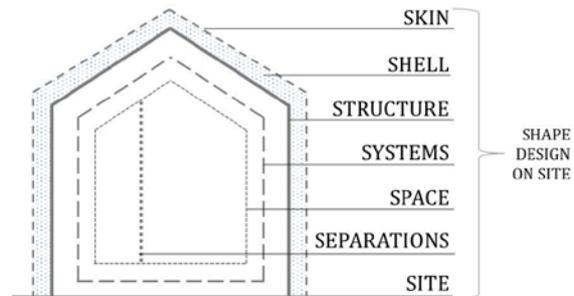


Fig. 1: Representation of the building layers considered in this research, based on [11].

In addition, also the degree of specification of material decisions is considered. Three levels of specification are used: i) level of material category, consisting of very general information e.g. brick or wood for the façade, ii) level of product type, containing more specific product characteristics such as thickness, colour, texture, heat resistance, etc. and iii) level at which a specific brand or producer of the material/product is chosen.

Finally, findings from the design documentation were crosschecked with the nine architects in semi structured interviews, with questions on their general design approach and their material selection strategy. Due to the small number of cases, the analysis cannot be considered representative for the entire building sector, but can nevertheless give insights into the material related design decision process of the Flemish architects.

## 3 RESULTS

Fig. 2 presents the most prominent findings from the analysis regarding the moments for material decisions and their level of specification in the design process. Decisions are qualitatively structured per design phase and subdivided per building layer (according to Fig. 1) and per level of specification. A thickening of the arrow indicates that the gross of the architects is concerned with that level of decision making at that moment, a dotted arrow indicates that only few architects are. The building layer's "structure" and "separations" are considered together here, as most architects (8/9) use similar materials for outer building structure and interior separation walls.

### 3.1 Predesign phase

As can be seen in Fig. 2, the main focus during the predesign phase is to align the preferences, targets and work methods of architect and client and to check the budget and regulation limitations. Most material decisions are not yet addressed in detail. The choice of construction type (structure and separations in Fig. 2) is discussed for the first time. For other building layers (skin, shell, systems and space in Fig. 2), clients may already express some preferences in the design brief (e.g. façade material), but these materials are not fixed yet in this phase.

### 3.2 Design phase

In the design phase, specifications to a material and/or product type level become available for all

building layers. Especially the carcass materials (structure and separations, skin and shell in Fig. 2) are specified to a product type level by the end of the design phase. At this point, all known material information such as types, sizes and quantities are implemented in an intermediate cost estimate. In some cases, even a brand name (e.g. for insulation) is provided, mostly based on the architect's previous experience with these materials. For building systems and interior finishing materials (systems and space in Fig. 2), detailed specifications are not available yet. Only general assumptions are taken into account in the design and the cost estimate.

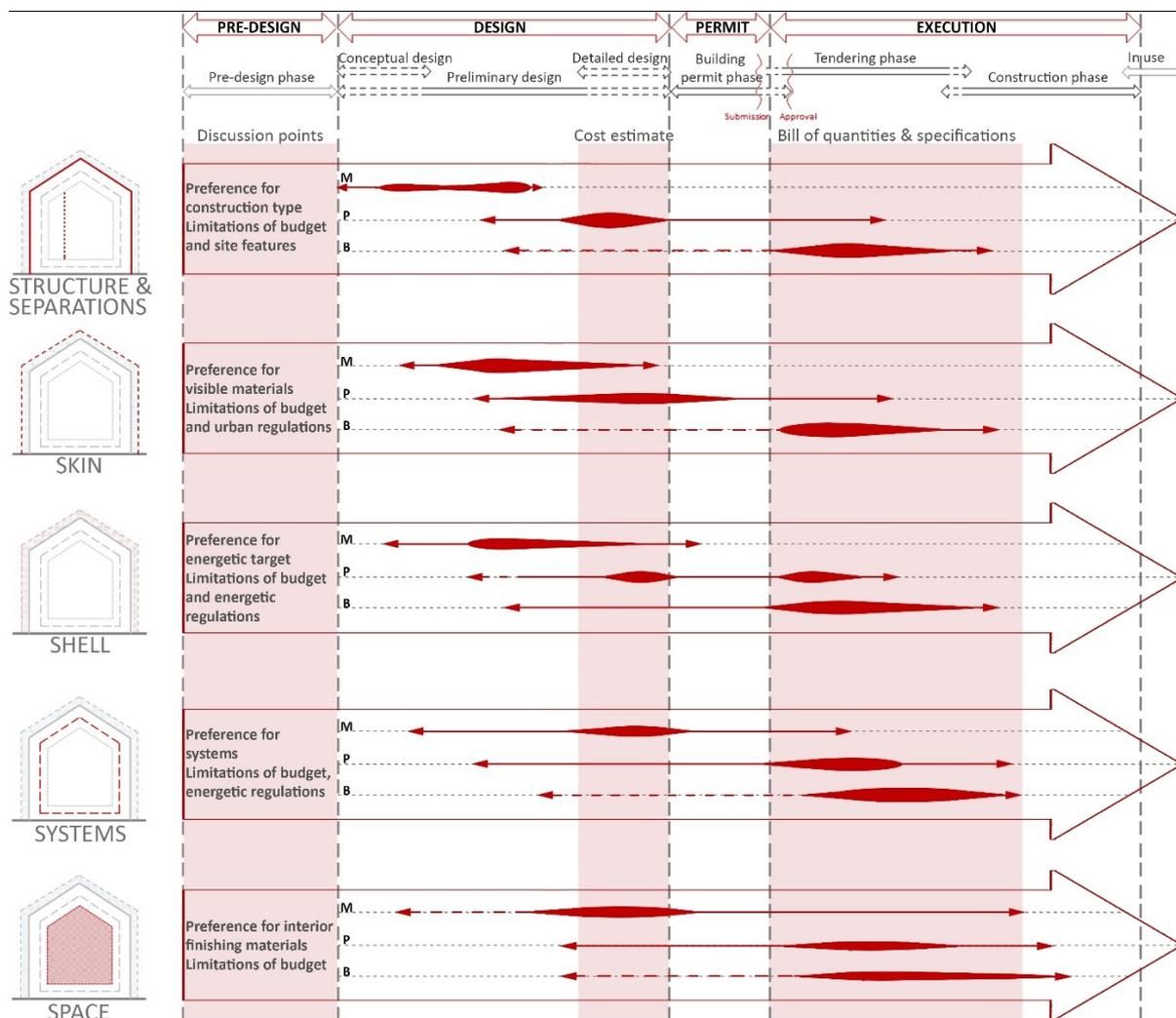


Fig. 2: Material related design decisions for the six building layers on the level of the material category (M), product type (P) and brand or producer (B). Thick arrows represent the gross of the architects, a dotted arrow represents few architects.

### 3.3 Building permit phase

During the building permit phase, materials for the building skin (skin in Fig. 2) must be fixed to a product type level, since these materials have to be in line with the urban planning regulations.

Therefore, this phase is quite crucial for the determination of the building appearance. Architects describe the material type and colour of all visible materials, e.g. the façade, pitched roof, exterior carpentry, and other visible elements. Usually no specification to a brand or

producer level is implemented yet, since colours and even material types (only in exceptional cases) may still change.

### 3.4 Execution phase

During tendering and construction, materials are specified to a brand or producer level in the bill(s) of quantity and/or specification files. In a first instance, tendering files for carcass construction (structure and separations, shell and skin in Fig. 2) are developed. During construction, further detailing of the materials for carcass construction on site may take place (e.g. choice of sills), but the main focus is on specification of building systems (usually starting from a standard package suggested by the architect) and interior finishing materials (systems and space in Fig. 2): specific system types and brands are discussed and specific interior finishing materials (especially flooring materials) are chosen.

Over all, a substantial difference is observed between the actors involved in the specification of visible versus invisible materials. Visible materials (e.g. skin and interior space materials) are generally specified to a very profound level by architect and client, leaving little room for alterations by other actors in the design process. For nonvisible materials (e.g. structure or shell materials), recommendations of the structural engineer and energy expert are taken into account. In addition, contractors and installers may also suggest other materials or products to work with on the construction site [12]. Therefore, the exact contributions of other parties in the design and material decision process is still being investigated in more detail.

## 4 DISCUSSION

As discussed in paragraph 1, this research is conducted to contribute to the development of an architect oriented environmental impact assessment tool, usable from early design on. As the research only includes 14 design cases, the results may not be generalized. However, they do provide valuable information on the material selection process in Flemish dwelling design.

Three possible moments in the design process where an environmental impact assessment calculation of building design could take place

have been identified from the overview of the current practice on material decisions (Fig. 2) and are presented in Fig. 3.

A first intermediate impact calculation can take place in early design stages, after the first meeting with the client and at the beginning of the concept formation. This first assessment is quite valuable, since early design decisions have significant influence on further design development [13]. The format for this calculation could be a very preliminary and intuitive impact calculation based on general design parameters on the building geometry (such as floor area, number of floor levels, typology) and the building materials (intended construction type, façade material preferences, ...). Since information is still rudimentary at this point, this preliminary calculation could result in an impact indication (e.g. a range, order of magnitude) that can serve as a guidance for further design development. In addition, feedback on the architect's preliminary design decisions per building layer and advice on how to improve the impact of their design (by making alterations to the design, picking alternative materials, etc.) could be provided. This impact indication could be linked to early design drawings of the building geometry e.g. in Sketch-Up. Since this indication will mainly be based on assumptions, appropriate default values to replace missing data (material quantities, details on materials/products) should still be investigated in more detail.

A second intermediate impact calculation can take place after the price estimate in detailed design. At this stage, more concrete information of structure, shell and skin materials is available, which can be embedded in an environmental impact assessment with generic LCA data of materials or products. This information would enable the architect to perform intermediate environmental impact assessments of building design options and implement changes if necessary, prior to building permit submission.

A third and final impact calculation can only take place after construction, as some material specifications only occur on site. This calculation can be made starting from the actual materials used on site (starting from brand or producer

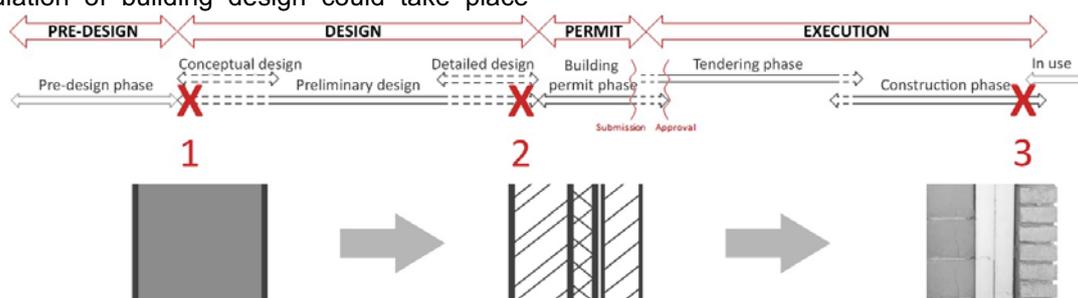


Fig. 3 Three moments for possible environmental impact calculation in the design process and the type of material related design information available at those moments (example for a wall).

specific LCA data, e.g. EPD), based on the available post intervention file or invoices of the purchased materials.

The first two calculations should provide architects with intermediate feedback on their material choices, since they are central actors in the design process and are still able to alter the design at these moments of the design process (if necessary). The final assessment will most likely be outsourced to a specialist (cfr. energy performance calculations), as the architect is usually not involved to the very end of a project. Therefore, it should be investigated to what extent there is a data overlap between energy performance calculation and environmental impact assessment, so that both calculations may be outsourced to the same person.

Furthermore, three out of nine interviewed architects indicate that, after a while, they would adapt their work method to the assessment criteria. This would enable them to skip the first two assessments and go straight to a final (outsourced) assessment (cfr. energy performance calculations). This indicates that the tool could induce a learning process, which is definitely necessary, since previous research [14] already indicated that the (Flemish) architects' knowledge on sustainability and sustainable material use is quite limited. Also, according to one of the interviewed architects, most architects are quite set in their habits. By providing correct and reliable information on the environmental impact of materials in a usable format, they might be triggered to change their custom pattern of decision making. In this context, such a preliminary environmental impact indication can play an important design supportive role.

Further research to investigate the role of other actors (e.g. client, contractor) and possible drivers (e.g. aesthetics, budget) involved in material selection is being conducted. In addition, the environmental impact of the different layers and how to deal with the missing or rudimentary data in the calculations will be investigated. All findings will be implemented in an environmental impact assessment tool that is adapted to the architects' work method and usable from early design on.

## 5 CONCLUSIONS

In this paper, a retrospective case-study analysis (14 cases) and semi structured interviews with nine architects are used to identify the moments and level of specificity of material decisions in the design process.

In early stages, material related information is vague and implicitly taken into account in the shape design. From detailed design on, more concrete material and product information on the building materials becomes available (e.g. in the

cost estimate). The materials for carcass construction (structure and separations, skin and shell) are specified earlier than those for the building's interior (systems and space). During tendering and construction, final material specifications to a brand or producer level occur.

In the context of the development of an architect-oriented environmental assessment tool, three moments for possible environmental impact assessment during building design are identified, being i) after predesign, ii) in detailed design and iii) post construction. Since the first two moments are part of the design process, the architect will most likely be confronted with these impact calculations. Especially the first impact calculation could provide valuable information for further design development.

However, further research is needed on actors and drivers behind material decisions and on the environmental impact of the layers. All findings will be implemented in an architect oriented and design supportive environmental impact assessment tool.

## 6 ACKNOWLEDGMENTS

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