THE DYNAMIC DESIGN MATRIX
a major review of the Flemish design principles for closed material loops

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ABSTRACT

Design choices, extending the service life of buildings and fostering closed material loops, can be a key instrument for the transition towards a circular economy. After all, the best waste, is waste that will never exist. For this reason, the Flanders' Public Waste Agency OVAM published in 2013 a set of 23 design principles for increasing the generality, adaptability and thus circularity of buildings and their components. These principles were developed in de context of a design consultancy program (Paduart et al., 2013), and are illustrated in fact-sheets by exemplary techniques and applications (Debacker et al., 2015). Organised in a matrix, all principles together, address three scale levels and three design aspects.

Since 2013, the set of design principles has been guiding consultancy programs but was also used as an evaluation framework during explorative master theses, strategic research projects, and construction system reviews by members of the TRANSFORM research team of the Vrije Universiteit Brussel. Occasionally they have been adopted in construction practice. Although successful in creating awareness about the long-term consequences of design choices among architects and engineers, that hands-on experience revealed a series of complexities characterising the matrix at the table. Moreover, it could be observed that every consultancy program and design evaluation reinterpreted the principles and adapted the set to their specific context and goal. Although the freedom to make those interpretations might be a strength of the matrix, it also challenges its robustness and relevance. In concrete terms, it is difficult to compare the outcomes of different evaluations and therefore limits the matrix's role in the transition towards a circular economy.

Based on all experience, the extended abstract below tackles different types of complexity. To each of these complexities, possible risks and drawbacks are related, among which the clearness of the principles, the comprehensiveness of a resulting qualitative evaluation, and its relevance for extending the service life of buildings and closing material loops. Following these findings, a major revision of the matrix of principles is recommended. It is suggested that a revision should include a refined definition of every scale level, design aspect and individual principle, but also additional principles such as the location, facilities and accessibility of buildings, and the the purity, safety and renewability of materials. Further it comes with a series of guidelines about how this matrix can be used to create awareness or as a design review framework.

KEYWORDS

Design for Change, Design for Reuse, Adaptability, Generality

1. INTRODUCTION TO THE DYNAMIC DESIGN MATRIX

Following several doctoral studies (Henrotay, 2008; Debacker, 2009; Paduart, 2012), Paduart et al. (2013) proposed the first qualitative assessment matrix for Design for Change. They did that in the context of the Design for Change research project on the occasion of the redevelopment of the Mahatma Gandhi neighbourhood in the Belgian city of Mechelen. With that matrix, the researchers wanted to facilitate the review of the adaptability, versatility and reuse potential of alternative design proposals, while identifying the conditions for those alternatives' successful implementation.

The proposed matrix collects 23 design principles (Table 1). By considering three scale levels, the matrix fosters an inclusive evaluation. The first level takes into account building elements such as walls, technical services and

joinery. Because future refurbishments require the alteration of elements, their characteristics determine the feasibility of their future reuse. The second level considers buildings, regardless their type or size. Every building's structural layout and proportions are decisive for its versatility, whereas the way its components (i.e. the building elements) are assembled, determines how easily it can be altered. The third level is the neighbourhood level. Because this level addresses the most slowly changing scale, anticipating changes is crucial. Therefore, multipurpose assets are promoted and the possibility to remove them completely is encouraged. In addition to these levels, the comprehensiveness of the set of principles is aspired by tackling three distinct aspects. These aspects include the components of each level, their interface and their composition.

Table 1. A breakdown by scale (elements, buildings, neighbourhoods) and aspect (components, interfaces, composition) offers a inclusive matrix on Design for Change (Paduart et al., 2013; translation Deprins, 2015).

	Components	**Interfaces**	**Composition**
Elements	Durability Compatibility Reused	Simplicity Reversibility Speed	Pace-layered Independence Prefabrication
Buildings	Demountability Extensibility Reusability	Accessibility	Versatility
Neighbourhoods	Retrofitted Dimensioned Removable	Clear Adaptable	Multipurpose Diverse, Unified Densificable

To assist in the use of the matrix, each principle is discussed and illustrated on separate factsheets (Debacker et al., 2015). These sheets are made available online by Flanders' Public Waste Agency OVAM and provide designers, developers and policymakers with a brief description of the aim and importance of each principle. Further, they allow stakeholders to get acquainted with existing design alternatives and the key questions that should be verified to assess other design options. As an example, the following principles are cited:

Are the elements' interfaces reversible? Reversible connections can be undone without damaging the components they connect. This is a necessary condition for the components' future reuse and facilitates their eventual recycling. Often, special attention is required for air and vapour tightness.

Are the elements' components compatible? Compatible components are designed in accordance to dimensional or other standards to guarantee their interchangeability and increase their potential for future resell. Additionally, they facilitate the replacement of existing components within a building to keep it up-to-date.

Are the elements properly pace-layered? Pace-layering is the principle of organising building elements in physically separated layers according to their estimated service life. If this is done properly, layers with a shorter service life are easier to reach, increasing the efficiency of future refurbishments.

Are the elements' components durable? The materials' resistance to everyday wear and tear or the damage of repeated disassembly determine the viability of their reuse. Therefore, components with a longer service life are preferred. This is closely connected to people's appreciation and valuation of materials.

All 23 principles have been adopted to evaluate the adaptability and versatility of buildings and design proposals during several case studies. They have been tested in the context of conventional renovation and new construction projects (Debacker et al., 2015), during post construction evaluations (Deprins, 2015) as well as to assess temporary urban interventions (Selleslag, 2016). Although these case studies demonstrated the principles' usefulness to advice designers about the adaptability and versatility of design proposals further refinement, validation and benchmarking of the principles is identified as indispensable (Galle, 2016).

On the initiative of OVAM, the matrix was already extended with a 24th principle: health. This principle was one of the results of a study into the indoor air quality of buildings (Ceraa et al., 2016). The following observations show however that further refinement remains necessary.

2. OBSERVATIONS AND IDENTIFIED COMPLEXITIES

2.1. Observations

To facilitate the review of the adaptability, versatility and reuse potential of alternative building design proposals, and implement the idea of Design for Change from the initial design phases, the matrix of 23 principles discussed above was published in 2013. Being descriptive by nature, it was open for different uses. And, so happened. Since that time, the set of design principles has been guiding design consultancy programs, was used as an evaluation framework during explorative master theses, strategic research projects, and construction system evaluations by members of the TRANSFORM research team of the Vrije Universiteit Brussel. Moreover, occasionally they have been adopted in construction practice.

Although successful in creating awareness about the long-term consequences of design choices among architects and engineers (Debacker et al., 2015), that same hands-on experience revealed a series of complexities characterising the matrix at the table. A thorough review of the matrix is thus necessary to make sure contradiction and confusion are avoided during its further application. Therefore, this extended abstract presents first an overview of 12 studies and practices that already applied the matrix, their methodological findings and their conclusions relevant for the matrix's further development.

2.1.1. In master research

The four master theses discussed in this extended abstract, explored deliberately the limits of the matrix of design principles proposed by Paduart et al. (2013) Therefore, they used it in divergent contexts. The theses were conducted at the Department of Architectural Engineering of the Vrije Universiteit Brussel under the supervision of prof. De Temmerman and advised by the TRANSFORM research team.

1. Deprins (2015) tested in her thesis "Analysing the transformability degree in Design for Change" if the proposed matrix could be transformed into an assessment method. To facilitate the comparison of the adaptability and reuse potential of alternative design choices and identify points for improvement, she proposed Dynamic Design Profiles. Based on the matrix, or Dynamic Design Matrix as she calls it, each profile is a visual representation of the extent to which the considered alternative adheres to each of the series of principles. By grading according to a discrete scale, varying from "not" over "partially" to "fully implemented", the resulting profile allows a visual comparison. After the evaluation of 2 existing buildings, her main reservations are the lack of benchmark for each principle and the apparent redundancy of al principles.

2. Selleslag (2016) made in her thesis "The Dynamic Design Matrix as a tool for the analysis and design of temporary uses" a similar exploration. Focusing on temporary interventions, i.e. architectural constructions in an urban context with an intentionally short service life, the adaptability and reusability of the used components becomes even more important. Nevertheless, because temporary interventions differ from conventional buildings in the material selection, construction methods, and the pace of change, it was necessary to adapt the structure of the matrix and define a relevant interpretation of each principle. The proposed adaptations of the Dynamic Design Matrix arose from 13 case studies in which temporary interventions were analysed.

3. Grandry (2017) took a different focus. In her thesis "Reversible Design: Development of a prefabricated external wall system for transformable buildings" the 23 design principles of Paduart et al. (2013), the design guidelines by Crowther (2005) and the concepts of Durmisevic (2006) served as a broad base for evaluating the adaptability and reuse potential of conventional and innovative façade panels. For convenience sake, Grandry had to identify first those guidelines, concepts and principles that were relevant to a building's façade, and then regrouped them in seven points of attention. Those points related to the material selection, the relations between building components, the adopted connection methods, the organisation of work on site, the systematisation in the facade, the use of standardized components and the provision of related documentation.

4. Wahid (2017) challenged the matrix once again in his thesis “Exploring adaptability and generality in Antwerp’s residential typologies”. While the design principles were originally developed for introducing the notion of circularity from the initial design phases, his research aimed at assessing the adaptability and generality of historical building types. Characterised by a limited number of design variants, all conventionally non-reversible, some principles did not reveal any insight. Other aspects, that explained why building types as Town Houses and Bel-étage dwellings are so often refurbished and efficiently transformed, were therefore added to the explorative assessment. Those include a quantitative evaluation of the generality of the plan lay-out (Herthogs et al., 2013) and a qualitative scenario planning exercise (Galle, 2016).

2.1.2. In practice and policy consultancy

1. In the policy preparation study on Design for Change (Debacker et al., 2015) 4 inspiring projects have been discussed on the bases of the principles collected in the matrix*:* the residential complex “Sterrenveld”, the apartment building “Grundbau und Siedler”, the hospital “AZ Groeninge” and the modular building system “LLEXX”. These analyses showed how the principles are implemented today, their added value and limitations. At the building level, both adaptable and multi-use projects exist. Principles such as “pace-layering” and “generality” are already often adopted. At building element level, sometimes prefabricated and demountable construction systems are applied enabling the future reuse of building elements or their components.

2. In the same study an experimental consultancy programme on two construction projects was initiated and successfully completed (Debacker et al., 2015): the renovation of the social housing apartment building on the Hoogbouwplein in Zelzate by KPW Architects, and the construction of a new school wing the Vlindertuin in Mechelen by AREAL Architects. For each programme, the researchers made a qualitative review of the subsequent design proposals and performed also quantitative lifecycle analyses. During this consultancy, the qualitative assessment was a catalyst for a future oriented design process as, thanks to this approach, the architects became increasingly aware of the long-term consequences of their initial choices.

3. For the occasion of Open Bedrijvendag, a national initiative on which dozens of Belgian companies and public actors welcome all people, Flanders’ waste agency OVAM assigned constructors Hahbo and Skilpod to display two pavilions that are an example of sustainable, adaptable and circular design. Both temporary structures could be visited on the brownfield site Alesa, located in Schoten near the city of Antwerp. To encourage both constructors to refine the proposed construction system, OVAM ordered a detailed evaluation with specific attention for those systems’ potential to be part of a circular business model (Galle et al., 2016). Departing from a selection of 12 of 23 applicable design principles, concrete strengths and weaknesses were revealed. Based on these findings and the related guidance, constructors could improve their products and business models.

4. In the context of the RetrofitXL research platform created by the Brussels regional government, an innovative “DynamicWall” was developed as a sustainable alternative for conventional space and unit dividing wall systems (Paduart et al., 2015). Proceeding from the design principles at element level, the system focused on the adaptability of the design and the reusability of its components. As a result, all such walls can be easily assembled and disassembled in analogy to do-it-yourself construction kits like flat-pack furniture. Prototypes were successfully tested on horizontal impacts and their acoustical performance under laboratory conditions to verify the walls’ actual applicability, which was also demonstrated in an architect’s apartment in Brussels.

2.1.3. In design and construction practices

1. To enhance the international importance of Brussels, the Beliris investment agency funds construction projects in various fields. On the table is the realisation of a new Learning and Innovation Center on the crossing of the Université Libre de Bruxelles and the Vrije Universiteit Brussel (Galle & De Temmerman, 2014). With the ambition to realise a sustainable landmark, consultants of different fields have been hired by Beliris. In their consultancy, Galle and De Temmerman developed project ambitions and design brief sections tackling “integral accessibility”, “effective resource management” and “long-term utility” by adopting the principles of the matrix. To be able to eventually evaluate the received design proposals, also concrete requirements and principles were selected in collaboration with the team of investors, governments and facility managers.

2. By the end of 2017, the facility management office of the Flemish government published its GRO manual, a guide for sustainable design, tendering, construction and management of public buildings (Facilitair Bedrijf, 2017). In this manual the 23 design principles have been adopted in two checklists. Designers and contractors are requested to demonstrate they fulfill at least 50%, or if possible 75% or 90% of the principles in the checklist for “Maintenance and repair” (33 principles) and the checklist for “Cleaning-conscious design” (55 principles). In contrast to the matrix proposed by Paduart et al. (2013) it is however not clear to which scale level or building parts each principle applies. Moreover, allowing only a “fulfills” or “fulfills not” score, the robustness of these checklists’ outcomes can be questioned by the lack of benchmarks.

3. During the 2018 Pixii expert day on circular construction the VK Engineering company presented its review of a series of 13 construction products, evaluating each product’s “level of circularity” (Ost, 2018). That series includes load bearing walls, floors and beam systems, as well as non-bearing partition walls, façade systems and interior finishing. The review starts from the original principles at element level only. By scoring each product green, orange or red for each of those 9 principles, while some of them are judged as not relevant, the aim is to provide insight in the potential and risks associated to each product in regard of a built environment of closed material loops. During his evaluation, Ost nevertheless identified that these principles include no guarantee that the product will actually be reused at the end of its first service life.

4. Finally, under development, when writing this extended abstract, is a catalogue of reversible building solutions at sector organisation VIBE commissioned by OVAM (Vandenbroucke, 2018). To support of practitioners, in the design of adaptable and circular design, this catalogue collects a variety of design options for wall and floor structures, partitioning and finishing systems, and thermal insulation layers (building further on Vandenbroucke, 2016). By reviewing each option for the 9 design principles at element level, insight is given into their reuse potential. With this objective, the design principle “reused” was left out the review, and the principle “manageable” was added for evaluating the practical feasibility of disassembly by hand or using simple tools.

2.2. Complexities

Following the above overview of studies and practices that already applied the matrix, issues of redundancy, consequentially and conditionality, as well as of possible misinterpretation are identified. To each of these complexities, possible risks and drawbacks are related, among which the clearness of the principles, the comprehensiveness of a resulting qualitative evaluation, and its relevance for extending eventually the service life of buildings and closing material loops.

2.2.1. Need for reinterpretation for every context and project

Throughout the discussed studies and practices, a need to reinterpret the matrix and each principle for every other context or project can be identified. On the one hand, the relevance of principles and the possibility to review them, as some require detailed information on materials, technical solutions and building utilities, was stated as a difficulty (Selleslag, 2016; Wahid, 2017). On the other hand, evaluating 23 principles proved to be a lot of work, while several principles are strongly related and reveal exactly the same insight (Deprins, 2015; Selleslag, 2016). Consequently, the user-friendliness could be increased if the number of principles can be limited and its implementation as a design guidance and review framework would be facilitated by strategic guidelines about how to use the matrix in different contexts and projects.

2.2.2. Risks and drawback of the comprehensibility

Only if the principles are easily understandable, they will be used in a consistent way and trigger correct design insights. In that respect, the expertise of the assessor is identified as crucial factor for the matrix its implementation. One needs to know how to use it and have enough knowledge and insight in the service life of buildings and the interaction amongst a building’s components (Deprins, 2015). Moreover, the examples illustrating the principles in the separate factsheets (Debacker et al., 2015) should be straightforward, but not restrictive or normative. After all, the building design and construction sector is still in a transition towards circularity, during which new technical solutions are constantly developed (e.g. DynamicWall) and the economic and legal context is gradually adapting (e.g. European Circular Economy package). In this context, an ad-hoc

selection and interpretation of the principles might lead to a chaotic sprawl of matrix variants, undermining the approach its power in creating awareness about the long-term consequences of initial design choices.

2.2.3. Consistency and comparability of project reviews

Within a tendency to objectify the level of adaptability, reuse potential or circularity and being able to compare empirically alternative design options, it was tested if it is feasible to use the matrix of design principles as an assessment and comparison method. From those tests can be concluded that indeed alternatives can be compared relative one to another, principle by principle, but that by the lack of minimum and maximum values and further benchmarks, the scoring of alternatives on a continuous scale and a weighting of all principles was unachievable so far (Deprins, 2015; Selleslag, 2016). Rather, the matrix can be used as a base to build up a project review (Debacker et al., 2015; Galle et al., 2016), consultancy program (Galle & De Temmerman, 2014; Debacker et al., 2015) or system development (Paduart et al., 2015). Altogether, the qualitive nature of the design principles was acknowledged as a strength of the matrix (Grandry, 2017), while comparative profiles or scores are perceived as unreliable due to a lack, and difficulty to develop, benchmarks and objective scoring principles (Deprins, 2015; Selleslag, 2016).

2.2.4. Relevance for extending the service life of buildings and closing material loops

The original objective of the matrix is to let architects and contractors implement a circular building, by, through these principles, close the material loops and extend the service life of the building and its element. Nevertheless, there is no guarantee. Building project that followed carefully similar principles, and were thus easily demountable, have been demolished in a conventional way, and their components were simply wasted. That, due to financial or temporal pressure to the site its redevelopment. Therefore, it is more correct to say that the design principles of the matrix increase the potential of buildings and their components to have an extended service life and increased utility, and follow closed material loops compared to conventional solutions. Further, it was identified that the matrix does not explain how it contributes to each of these potentials, though a clear relation to ‘adaptability’, ‘moveable’ or ‘generality’ was suggested as a way to clarify that (Selleslag, 2016).

2.3. Remarks per principle

A detailed discussion of the complexities related to each individual principle is out of the scope of the present extended abstract.

3. CONCLUSIONS

3.1. Points of improvement

The ultimate goal is to make designers and less familiar stakeholders aware of the long-term consequences of their initial choices and empower them with design principles that support the transition towards a circular and thus conceivably more sustainable and future-proof built environment. With that objective in mind, which is shared by Flanders’ Public Waste Agency OVAM, five points of improvement of the matrix of design principles proposed by Paduart et al. (2013) are concluded on the basis of the observed cases and studies, and the consequently identified complexities.

1. Further guidance on how to use the matrix is indispensable. Its implementation as a design tool and review framework would be facilitated by strategic guidelines about how to use the matrix in different contexts and projects. Therefore, a review of the matrix should include a clear definition and clarification of every scale level, design aspect and individual principle. Three guidelines on how to use the matrix are already proposed below.

2. More design principles are necessary. Previous cases and studies have shown the relevance, for the same circularity objectives, of principles like documentation facilitating future building and material management, but also the location, facilities and accessibility of buildings, the affordability and mobility of elements, and the purity, safety and renewability of materials. Nevertheless, the matrix its user-friendliness should be maintained or even increased. If that would not be possible by reducing number of principles (as some have shown redundancy), it should be achieved by proper guidance and a clear structure.

3. The matrix's structure should remain clear. In the observed cases and studies, the 24th principle on health was not often considered. Partially, that is due to the fact it was added only later. Also, to the fact it does not fit one of the 3 levels and 3 aspects in the matrix might play a role. The consistent integration of additional design principles in the matrix is therefore put forward as a point of attention.

4. The impact of the principles on the social, economic and environmental aspects of buildings must be clarified. After all, not only specialised architects but all users of the matrix should also be able to understand the relevance and importance of each design principle. Therefore, Grandry (2017) suggested to discuss and order all design principles by their potential contribution to achieve increasingly sustainable, feasible and material efficient end-of-life scenarios, for example their facilitation of reuse, remanufacturing and recycling.

5. It will be worthwhile to discuss and share more cases, as they will provide more insights in how the design principles can be translated into practical design choices, and which possibilities for improvement already exist. Moreover, the more different cases, options and perspectives are presented, the more valuable this matrix will become as a design framework.

3.2. Strategic guidelines

As a first attempt to guide architectural designers, engineers, product developers, tenders and contractors, as series of three guidelines is proposed. They proceed directly from the observations made in the context of the cases and studies cited above, and therefore need further validation.

1. The matrix and its design principles are qualitative by nature. Alternative design choices can be compared relative one to another, principle by principle, but by the lack of benchmarks and objective metrics, the scoring of alternatives on a continuous scale is of little relevance. Rather, the matrix has already demonstrated its value when adopted as a framework from the beginning of the design process, regardless that process takes a classical programming, research by design, or co-creation approach.

2. The final design solution will not be black or white, neither red, orange or green, but rather a compromise considering the whole of principles and the design's context. Being part of an ongoing transition, the optimal solution might not be the ideal one. What is important, is that design choices are made based on the awareness of their long-term consequences. Understanding that the future is uncertain, it seems in the interest of all stakeholders to retain those options that are the most resilient or robust.

3. Although it is not always possible to review all principles, it is important to avoid cherry picking of individual principles, but to communicate clearly about which scale levels and aspects have been considered, and which not. In those situations where it is possible to evaluate only at element level, the assessors and reader should be aware and made conscious of the fact that choices at other levels might jeopardise their conclusions. Such reservations should therefore be stated as a point of attention.

3.3. Further research

To share the existing expertise with the Flemish design principles for closed material loops (cf. 5th point of improvement), and develop it further, more research is necessary. Moreover, also to validate the observations made from the limited number of cases and studies above, broader expert consultancy is indispensable. Therefore, at the WASCO2018 conference, where this extended abstract is presented as a state-of-affairs, a workshop is organised during which participants will be invited to share their insights.

At the same time, the need for an increasingly holistic approach to building design, as it was identified when extending the 23 first principles with the principle health, is addressed in the European Horizon 2020 research project 'Buildings As Material Banks' (IBGE, VUB, ..., 2015). Concretely, the assessment approach and method Circular Building Assessment is being developed. Circular Building Assessment fosters better informed decision-making about 'circular' alternatives. The discussed matrix and principles served as one of the starting points.

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AKNOWLEDGEMENT

The authors wish to thank all master theses students for their valuable contributions. This research is made possible thanks to the operational program for the implementation of the European Regional Development Fund ERDF in the Brussels-Capital Region, the European Commission Horizon 2020 research and innovation program, and the Research Foundation – Flanders FWO.