Multiple design approaches to transformable building: construction typologies

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ABSTRACT: Considering the increasing dynamism of our society, contemporary building practice is characterised by a widening gap between the functional and technical lifespan of most assets. Consequently, designers are challenged to apply strategies that anticipate change and avoid abandonment or early demolition. Life cycle analysis has proven that transformability has the potential to be a more sustainable strategy to build than those that are currently used. Nevertheless, several unresolved design questions and a higher purchase cost prevent the widespread implementation of such transformable structures. In response, a broad literature study and two case studies gave rise to the design strategy ‘partiality transformable building’. This paper discusses several construction types for partially transformable building and a systematic study identified the types’ potential to anticipate change in multiple ways.

1 INTRODUCTION

1.1 The challenge to anticipate change

Continuously improving construction techniques greatly increase the quality of buildings and lengthen their potential, technical lifespan. However, most technical services, the building’s skin and space plan elements do not reach that age but are altered earlier. Traditionally, dwellings with an intended lifespan of 60 years begin already to change within three years after completion and are entirely refurbished at the age of 25 (Tros et al. 1999). Those refurbishments are driven by social as well as demographic evolutions such as changing family structures and an unprecedented aging. Moreover, it is expected that these evolutions will accelerate even further. As a result, the building’s actual, functional lifespan still shortens(Schwehr & Plagaro Cowee 2011).

Traditional buildings that are constructed in a static way remain vacant, are thoroughly refurbished or even demolished when they no longer meet the owners’ needs. That can be illustrated with current vacancy rates of office buildings reaching 11.5 per cent in Brussels and iconic demolitions, e.g. Pruitt-Igoe in 1972 (Woodford & Kuljanin 2012). Thereby all energy, material and financial resources are lost. The inert characteristics of traditional buildings become even more problematic when they are linked to acknowledged ecological and socio-economic consequences such as the serious depletion of the earth’s mineral and fossil energy resources and the enormous waste flows construction industry introduces(European Environment Agency 2012). All these consequences considered one understands that resources should be well spent and designers are challenged to apply strategies that anticipate change.
1.2 Strategies and concepts surmounting the gap

In reaction to the gap between the technical and functional lifespan of traditional buildings, architects H. Hendrickx and H. Vanwallegehem proposed the design strategy ‘transformable building’ (De Wilde & Hendrickx 2002). In order to build in a transformable way, two key concepts are generally maintained: a ‘generative dimensioning system’ constitutes together with ‘design for disassembly’ a set of exchangeable and demountable components of which transformable buildings are composed.

Transformable buildings can be easily altered and foster the reuse and recycling of entire constructions, single components and their materials (Durmisic 2006). As a result, the problematic material and waste flows are countered. The two key concepts considered, transformable buildings and their components can be given a new function, prolonging their functional lifespan until it reaches their technical one. As a result, the gap between functional and technical lifespan can be surmounted (Debacker et al. 2007).

1.3 Questioning the ultimate solution

Characterised by both demountable and exchangeable components, Kit-of-parts are frequently proposed as the ultimate approach to transformable building (De Temmerman et al. 2012). Kit-of-part systems are a special form of prefabrication because of their clean and controlled building process, their potential to be assembled automatically and their capacity to be assembled and dismantled repeatedly. Unlike the majority of prefabricated components that are permanently connected at the time of construction, kit-of-part systems encourage the construction of transformable buildings and a life cycle management of their components (Howe et al. 1999).

Kit-of-parts have been a recurring theme in historical studies and pilot projects (figure 1). Particularly within the context of an open industrialisation, the High-Tech movement, Metabolism and Dutch Structuralism designers aspired after reconfigurable systems in order to reconcile the mere standardisation of construction components with individual needs. Although examples such as the recyclable XX-office by architect Jouke Post (1999, Delft) and the reusable low-tech-high-performance ABT-office building by Hubert-Hencket architects (2001, Delft) illustrate the potential of kit-of-part systems, they simultaneously reveal a plethora of unresolved questions such as the suitable construction sequence, the need for overcapacity and the size of a basic unit (Leupen et al. 2005). In addition, a higher purchase cost prevents the widespread implementation of compatible components and demountable systems for transformable building (Durmisic 2006).

Figure 1. The XX-office by architect Jouke Post (left) and the ABT-office building by Hubert-Hencket architects (right) are two Dutch projects that successfully illustrate the potential of kit-of-part systems, but simultaneously reveal a plethora of unresolved design questions. Photos by the architectural offices.
2 LITERATURE AND CASE STUDIES

2.1 Introducing additional time-dependent design aspects

In response to the design-related questions concerning kit-of-parts, a broad literature study on time and change in design has been elaborated. In addition to transformability’s two key concepts, a 'generative dimensioning system' and 'design for disassembly', numerous other time-dependent issues were found (figure 2)(Galle 2011). That might not be surprising since also social and cultural concerns play an important role within the architectural design.

For this broad research, literature from different fields was consulted. Publications of various types, including papers, technical reports, essays and project discussions, by multiple groups of authors, including governmental organisations, researchers, designers and censors were explored. The collected time-dependent issues were grouped in four aspects that could be clearly distinguished through all consulted discussions on time and change in design. They imply significant consequences for a building’s potential to deal with changing demands or its resistance against them. Together they form a framework for the analysis of multiple approaches to the design strategy ‘transformable building’

First, it is essential that components are not damaged during use, disassembly, handling or transport. Therefore ‘durability’ plays an important role. Second, ‘versatility’ can be introduced prior to transformability. Simply by their generic qualities, such as a straightforward accessibility, bright illumination or generous space plan buildings can respond to multiple requirements and house many functions. Third, ‘building management’ through an accurate monitoring of the users’ needs and an according allocation guaranties an efficient use of the available facilities. Finally, in addition to the technical requirements of users or standards, a building’s functional lifespan is also determined by the ‘sociocultural value’ that is addressed to it(Galle 2011).

![Figure 2. Two key concepts of transformable building are completed with four time-dependent design aspects after a broad literature study, constituting a framework for the analysis of multiple approaches to the design strategy ‘transformable building’](image)

2.2 Validation of the time-depended design aspects

In order to explore the usefulness of the elaborated framework, aimed at analysing or designing transformable buildings, two case studies have been elaborated: (figure 3)the Hypotecaire Beleggingskas (HBK) bank office originally designed by architect Willy Van Der Meeren (1923-2003) and the Medical faculty housing (La Mémé) designed by architect Lucien Kroll.
(born 1927)(Galle & De Temmerman 2013). For both cases, the framework of key concepts and additional change-related design aspects allowed a comprehensive analysis of the projects’ design concepts and process and indicated their capacity to deal with change as well as their shortcomings.

However, these case studies also revealed that the relation between specific design concepts and the more general design aspects of the presented framework is not unambiguous. In both cases, multiple design approaches were found that take position within the idea of change and transformability, and different aspects of the analytical framework are thus compiled in diverse design concepts.

Consequently, the case studies showed that, it would be hard for a designer to balance the aspects of the framework since there is no one-to-one relation between the analytical framework and the architectural design of transformable buildings. Moreover, each architectural assignment has its unique context.

Furthermore, the case studies illustrated that however the aspects are acknowledged in literature and designers are aware of their advantaged during the redesign of buildings, they are rarely reconsidered and implemented in practice.

![Figure 3. The analysis of the HBK bank office (left) and La Mémé (right) illustrated the applicability of the time-depended design aspects that were derived from literature. Photos by the first author.](image)

2.3 Proposing a comprehensive design strategy

After the findings of the two case studies, the design strategy ‘partially transformable building’ is proposed. Partially transformable building has the intention to be a more feasible implementation of transformability than kit-of-parts. Like the HBK bank office and La Mémé faculty housing, partially transformable buildings combine static and transformable building parts. Transformable building parts can be altered without difficulty and cope with changing users’ needs and standards. Their components can be easily dismantled and efficiently reused or recycled, anticipating problematic resource depletion and waste flows. The building parts most evident to be transformable are the building’s stuff and space plan. Those are the most vulnerable for fashion and have the shortest lifespan. However, also technical services, the buildings’ skin and load bearing structure can be designed in a transformable way, enabling change in the long term.

In complement, static building parts can be introduced. They guaranty a financial feasibility, reliable technical quality and are commonly available. Their inability to be altered should however be countered through the introduction of durability, versatility and a well-taught management. The building part that is the most evident to be static is traditionally the load bearing structure(Galle & De Temmerman 2013).
3 PARTIALLY TRANSFORMABLE CONSTRUCTION TYPES

3.1 Layering, generic space and the frame

In order to provide the design strategy ‘partially transformable building’ of useful implementation possibilities, four alternatives to kit-of-part systems are studied in the final part of this paper. The proposed construction types are derived from professor Leupen’s thesis ‘Frame and Generic Space, a study into the changeable dwelling proceeding form the permanent’ (Leupen 2006).

Leupen recombines five ‘Functional layers’ (Structure, Skin, Services, Space plan and Access) and presents an overview of no less than thirty-two construction types. Those types are of great interest since they proceed from a traditional, inert frame and facilitate a transformable infill and thus fit the idea of partially transformable building. The types that are used in the rest of this paper are those wherein only one layer constitutes the permanent frame and the others can be altered easily (figure 4).

A critical adaptation of those construction types will offer guidance for designers and will further introduce partially transformable construction types in the research on transformability. Each type is studied in multiple ways, including the preconditions of the permanent layer and the relationship between the permanent and transformable layers. This study does however not emphasise the conceptual and spatial qualities that are already insightfully illustrated by Leupen, rather it focuses on technical and functional as well as social and cultural aspects.

Figure 4. In contrast to kit-of-part systems (a.), the proposed construction types for partially transformable building combine a static frame and a transformable infill. The discussed types are the Base-building type (b.), the Structural wall type (c.), the Façade type (d.) and the Structural service core type (e.).

3.2 The Base-building type

The Base-building type proceeds from its permanent, load bearing structure. A structure conceived as a grid of columns offers spatial versatility in two directions. In contrast, a sequence of cross walls sets limits the maximum space width. Both permanent frames have fixed ceiling heights, but those could include multiple stories or have openings providing versatility in the third dimension. Considering overall stability and structural stiffness, additional cores or wind bracings are indispensable. Bearing those constraints in mind from design stage already is thus crucial for the building’s appropriate versatility and related longevity.

The Base-building construction type is widespread in contemporary high-rise office buildings and multi-story dwelling blocks. Materials that are generally used for the load bearing structure are concrete and brickwork. They are preferred because of their high compression strength, low cost and common availability. Unfortunately, few construction techniques allow the realisation
of a demountable and reusable load bearing structure. However, an inert load bearing structure might be very durable. Its technical lifespan can reach up to several hundreds of years. Additionally, a Base-building can provide a reliable sound- and fireproof compartmentalisation.

A Base-building’s versatile floor plan facilitates a transformable infill. Given that only the structure is permanent, space plan, skin as well as technical services can be composed out of demountable and compatible systems. The structure’s dimensions implement a possible generative dimensioning of those systems. Consequently, the combination of permanent and transformable building layers requires well thought engineering and well managed exploitation of both frame and infill.

3.3 The Structural wall type

Similar to the Base-building, the Structural wall construction type emerges from its intransformatible but durable load bearing structure. According to the Structural wall type, that structure is conceived as two or more parallel cross walls. Buttress walls can guarantee overall stability. Since there are no floors, the distance between the walls becomes all-decisive. That distance is determined by both functional and economic preconditions. The Structural walls offer a rigid seclusion of multiple compartments and corresponding versatility: the floor area is extendable in depth and height, whether repetition of the type is eligible perpendicularly to the walls. Consequently, this type is the most suitable for terraced houses.

Similar to the Base-building the building’s skin, space plan, services and access can be built in a transformable way. Since the structure is strongly compartmentalised and generally no additional partition walls are needed, technical requirements are low. Consequently, the Structural wall type demands little management and enhances customisation and subsequently the user’s appreciation. When multiple dwellings should be integrated between two walls, infill can be conceptualised as independent sub-structures according to a box-in-box layout. Apart from local planning regulations, it is the total building depth that determines its functional versatility taking into account daylight penetration, ventilation and accessibility. Traditional urban terraced houses perfectly illustrate the advances of this construction type (Pfeifer & Brauneck 2009).

3.4 The Façade type

Traditionally, a building’s skin has a shorter lifespan than its load bearing structure. The Façade type proceeding from it might thus be surprising. Although Leupen limits the permanent part to the building’s front face, the entire skin could form a permanent enclosure. The lack of structural elements characterising the Façade type, provides a versatile space behind it or within the volume it encloses. Therefore, the skin should be self-supporting by for example truss structures. Leupen also states that the Façade type is limited to low-rise buildings. However, multi-story ‘skins’ are already realised, e.g. the four-story Crystalic ‘greenhouse’ office building in the Dutch city Leeuwarden.

Unlike the Base-building or Structural wall type, the Façade offers a collective or semi-public space that lacks compartmentalisation. Consequently, the building’s transformable infill should be designed as sub-structures, preferably transformable. Suitable innovative property concepts might resemble leasing or rental contracts known from contemporary co-working offices.

To meet the occupant’s needs, lightweight kit-of-parts systems can constitute space plan and services. Sub-structures can be suspended or stand independent from the skin, including their own access routes or alternatively offering space for sheared circulation. Due to the semi-public character of the inner space of the Façade and the temporariness of transformable sub-structures, management after construction becomes however essentially important for this type.

The Façade intermediates between public space, collective regulations and private interests. As a result, this typology owns the potential to gain cultural value and take advantage of the appreciation that is addressed to it. By the same token, the Façade screens the transformable building parts form public space and local planning regulations, overcoming one acknowledged obstacle for the implementation of transformable building in practice. For the same reason, this typology might be very useful to buildings whose façade already acquired cultural value.
3.5 *Structural service core type*

The fourth construction type is the Structural service core type. It proceeds from a base that is empty except from connections to the mains. Since these preconditions are the same in contemporary practice, it illustrates the opportunities of a traditional building to become transformable.

Although services have a technical lifespan of about 20 years and pipes and ducts have no load bearing capacity, their clustering in a vertical service core has the potential to constitute the frame for a transformable fit-out. In low-rise buildings, the service core is confined to a technical cell with enclosing walls and a platform. In the construction of multi-story buildings, services cores offer the overall stability. When they are made out of durable materials, they will offer a permanent but versatile frame and free the building from complicated technical services.

Similar to the Façade type, no compartmentalisation proceeds from the permanent part of the Structural service core type. This sets high requirements to the building’s demountable structure, space plan and skin, but offers three dimensions of versatility and ‘endless’ extendibility. Consequently, the need for a well thought maintenance and management strategy is for this type as important as for the Base-building and Façade construction types.

A transformable load-bearing structure made of multi-purpose components can be assembled around the core. Thereafter it can be completed with floors, walls, and other layers. According to the Structural service core type, it is up to designer to create or select the most appropriate systems of compatible and demountable components, their hierarchy, scale, materialisation etcetera. Concluding, the Structural service core type stands the closest to the kit-of-part systems of all partially transformable construction types, enabling transformations that can be driven by technical, functional as well as economic and cultural change.

4 **CONCLUSION**

Given that the design strategy of transformability proved to be a sustainable approach to our built environment, regularly kit-of-parts systems are proposed because of their demountability and the compatibility of their constitutive components. Nevertheless, a broad literature study, searching for alternative approaches to deal with change within architectural design, detected multiple time-dependent aspects in addition to the key concepts of transformable building. Additionally, two case studies gave rise to the concept of partially transformable building.

The reappraisal of existing, but divergent partially transformable construction types resulted in a ‘range’ of such greater of lesser transformable types. The Base-building and the Structural wall, characterised by an inert building structure, the Façade, characterised by an inert building skin and the Structural service core type, proceeding from the technical services, were identified to have an important potential to anticipate change. Moreover, those types take into account the durability of the load bearing structure, the cultural value of the building’s envelope, the effortless maintenance of a compartmentalised frame and the versatility of an open space plan. In those partially transformable buildings, the advantages of both traditional and transformable concepts are combined in a feasible way. For that reason, those partially transformable construction typologies should be considered in addition to kit-of-part systems when designing and researching our built environment.

**ACKNOWLEDGMENT**

This fundamental research is funded by the Research Foundation Flanders - FWO and hosted by the Research Lab for Architectural Engineering (æ-lab) at the Vrije Universiteit Brussel.

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