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The strengths, weaknesses, opportunities and threats of Open and Transformable Building related to its financial feasibility

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PAPER ABSTRACT
With the current focus of construction and design on sustainability, Open Building is challenged to reinforce its sustainable character. In this light, Transformable Building is an interesting focus. As it adopts from Open Building its adaptability, it enables the reuse of building components and their resource efficient management. In search for a wider implementation of Transformable Building in practice, its financial feasibility is frequently questioned: designers and contractors fear a higher investment cost to enable disassembly and reuse. However, together with the ecological savings also savings in the life cycle cost of transformable buildings are expected. Unfortunately, insight in those financial effects is limited today. As a first step towards understanding Transformability's costs and savings, a specific literature study has been conducted. By reviewing six publications closely related to Open and Transformable Building over 200 relevant arguments have been collected and organised in a SWOT matrix. In the presented paper, the collected arguments are summarised in 14 hypotheses, each stating a strength, weakness, opportunity or threat of Transformable Building related to its financial feasibility. Those statements are discussed one by one and completed with observations of emerging theories, insights or recent cases in Belgian practice, policy or research. In conclusion, these hypotheses bring designers and investors a preliminary overview of the financial potential of Transformable Building, they can guide researchers and advisors towards focused assessments and they offer a new perspective on Open Building now it is challenged for its share in sustainable building.

KEYWORDS
Design for change, Life Cycle Costing, Financial feasibility, Sustainable building

AUTHOR BIOGRAPHY
Waldo Galle graduated as Master of Science in architectural engineering (Ghent University, 2011) and currently conducts fundamental research on Transformable Building, funded by the Research Foundation Flanders (FWO). In his PhD research he focuses on the dynamic nature of transformable buildings and aims at developing a transformation-integrated life cycle costing method.

Frank De Troyer graduated as Master of Science in architectural engineering (KU Leuven, 1975) and is associate professor at the research group ASRO of the KU Leuven, Belgium. His main expertise entails modelling of building costs, open system building and open industrialisation, as well as structuring information for the construction sector including product specifications and prices.

Niels De Temmerman graduated as Master of Science in architectural engineering (Vrije Universiteit Brussel, 2002) and is professor at the Research Lab for Architectural Engineering of the Vrije Universiteit Brussel, Belgium and chairs the TRANSFORM research team. His main expertise includes the design and analysis of transformable structures including deployable and kit-of-parts systems for architectural applications.
1. Sustainability, a challenge and opportunity for Open Building

Since its emergence, the Open Building movement aims for revitalising housing industrialisation. For that reason it questions the relationships between the profession of architecture and the housing industries and puts emphasis on the users’ needs (Hoogstraten et al. 2000). Today, the context has changed and besides the necessity of an integrated design and construction process, housing industries faces additional challenges. The invasive refurbishments or replacements that are necessary to fulfil our changing needs keep triggering enormous waste streams and consume progressively more resources even though they become increasingly scarce (European Environment Agency 2012).

As Open Building has emerged gradually from user agency and the understanding that our built environment is in constant transition, it has the capacity to fulfil changing needs qualitatively (Kendall & Teicher 2000). Moreover, Open Building enables the efficient life cycle management of building elements and materials: when the design and technical development of Open Building anticipates future alterations, i.e. Transformable Building, it can maximise the sustainability of buildings through time (De Temmerman et al. 2012). Open Building can reduce buildings’ environmental impact if for example infill elements can be demounted and reused or efficiently sorted and recycled (Paduart 2012).

![Fig. 1. With the renovation of Sterrenveld apartments, user agency and technical adaptability are enabled by a generic load bearing structure, demountable terraces (left) and lightweight infill (right). © Quirynen Jacobs](image)

As an example, a Belgian projects that closely resembles Open Building is the refurbishment of the Sterrenveld high-rise apartment building. The building, located in the town of Wezembeek-Oppem, was refurbished in 2007 by the architectural office Quirynen Jacobs. They enabled user agency and technical adaptability at three levels: reorganising the plan lay-out creates generic spaces that can be shared and exchanged, winter gardens with demountable curtain walls allow expansion or deconstruction and reuse (Fig. 1 left) and light-weight dividing walls enable less invasive alterations (Fig. 1 right) (Debacker et al. 2015).

<table>
<thead>
<tr>
<th>one or more advantages of Transformable Building (54 p., 100%)</th>
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<tbody>
<tr>
<td>increased investment cost (24 p., 44%)</td>
</tr>
<tr>
<td>increased design restrictions (9 p., 17%)</td>
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<tr>
<td>insufficient knowledge (8 p., 15%)</td>
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![Fig. 2. A stakeholder survey asking after the opportunities and obstacles for Transformable Building learns that although all interviewees expect advantages when anticipating alterations, many fear higher investment costs.](image)

Despite the functional adaptability and environmental life-cycle savings associated with Transformable Building, Vandenbroucke et al. (2013) detected the significance of its financial feasibility during a qualitative stakeholder survey. In that survey designers and contractors mention frequently an increased investment cost to enable future disassembly and reuse as an important obstacle for the sector wide implementation of Transformable Building (Fig. 2). Unfortunately, insight in its financial feasibility is limited as the numbers point out.
In a first step towards understanding the financial effects of Transformable Building it is necessary to formulate hypotheses. Therefore, we conducted a specific literature study reviewing six publications. Each of them tackles the financial aspects of transformable buildings from a particular perspective. They include policy making (Hemans & Damen 1997), theory (Durmisevic 2006), practice (Crone et al. 2007; Pollution Prevention Program Office 2008) and research (Paduart 2012; van den Thillart 2002). From this review, over 200 arguments have been collected and organised in a SWOT matrix, distinguishing internal (strengths and weaknesses) from external (opportunities and threats) and helpful (strengths and opportunities) from harmful (weaknesses and threats) arguments.

| extended service life and reduced life-cycle costs | increased investment and life cycle costs per year risks in technology and process innovation peoples’ resistance for reuse |
| creation of added value technically feasible | STRENGTHS |
| OPPORTUNITIES | WEAKNESSES |
| people’s constantly changing needs | short-sighted market valuation |
| integrated sustainability evaluation and policy inert sector structure and scale |
| solid sector structure and scale strongly intervening government |
| co-innovation persistence of change |

Fig. 3. After the explorative literature review, over 200 arguments are summarised in 14 hypotheses that state a possible financial strength, weakness, opportunity or threat of Transformable Building.

Finally, the collected and categorised arguments were summarised in 14 hypotheses. Each of these hypotheses states a strength, weakness, opportunity or threat related to the financial feasibility of transformable buildings (Fig. 3). In this paper each hypothesis is discussed and completed with references to ongoing discussions in practice, policy and research. Although this is a non-comprehensive review, it takes a broad perspective and therefore fits its purpose.

### 2. SWOT Analysis, 14 hypotheses on the financial feasibility of Transformable Building

#### 2.1. Strengths

**2.1.1. Extended service life and reduced life-cycle costs**

In contrast to conventional construction practice, the adaptability of transformable buildings will extend their service life and facilitate the reuse of the elements they are composed of.

At building level, refurbishments are less invasive, resulting in reduced material and redevelopment costs. Moreover, it is likely that home owners and building managers will take advantage of this adaptability and optimise the building’s performance, balancing operational costs and desired needs (Crone et al. 2007 pp. 11, 26). Furthermore, although little prove exists, Hemans and Damen (1997 p. 9) expect reduced maintenance and repairation costs since demountable elements simplify regular inspections and interventions.

At building element level, Transformable Building enables the purposeful disassembly of components. Subsequently, these components can be sold, repaired and reused. Taking into account the growing interest in second hand markets, the residual value of building elements could generate earnings (Pollution Prevention Program Office 2008 p. 2). And if not reused the option to disassemble the building can result in purer and thus cheaper waste flows (Crone et al. 2007 p. 118).

These arguments touch many dimensions, from initial design to end-of-life stages, from material to building level and form direct to indirect cost. This indicates that numerous stakeholders could profit from Transformable Building. Therefore, different perspectives should be considered when assessing its feasibility.
2.1.2. Creation of added value

In their report Herman and Damen (1997 pp. 39, 81, 84) expect that the extended service life and reduced life-cycle costs of a transformable building will be reflected in its market value. Although market valuation studies have hardly been conducted, also other authors state that the ‘added value’ of Open Building can persuade owners and investors. However, two types of arguments can be distinguished.

The first group of arguments associates the added value of Transformable Building with the potential of adapting it during its service life. For who understands that our lifestyle and housing pattern is constantly changing (see 2.3.1.) transformability will prevent inefficient use of the building and thus be an added value. The second group of arguments focuses on the added value that is created during the first stages of a building’s life cycle. Throughout the generally long design and construction process, building in a transformable way allows future users and investors to postpone a decision or change their mind in reaction to a changing context or need and again be an added value.

Both motives are further supported by the economical principle of open market valuation: the more needs a building can fulfil, the more people will be interested to rent or buy it, the greater the opportunity to ask more money for it, and the higher its value will be. From the moment they become experienced and aware of their potential, investors could become increasingly interested in Transformable Building.

2.1.3. Experiments have shown the approach’s technical feasibility

In the selected publications, multiple prototypes and cases are presented. They show that it is technically, organisationally and conceptually feasible to realise transformable buildings. Moreover, it is noted that this technology is not necessarily high-tech.

Unfortunately, techniques such as reversible connections are not generally known, confirming the findings by Vandenbroucke et al. (2013) (Fig. 2). Additionally, the IFD case studies (Crone et al. 2007) show that Transformable Building does not solve everything. They rely amongst other concepts on prefabrication, industrialisation and mass customisation for a cost optimal production and construction process. Furthermore, it is frequently stated that a well-thought planning, monitoring and marketing of the cases could have resulted in a higher economic viability.

In addition to these reservations, experiments also bring an interesting advice: set reasonable targets. Indeed, when no future alterations are expected, it might be disadvantageous to build in a transformable way as life cycle analyses already have shown (Vandenbroucke et al. 2015; Galle et al. 2015).

2.2. Weaknesses

2.2.1. Increased investment and life cycle costs

In contrast to the mentioned strengths, an expected increased investment together with the limited insight in the long term financial effects of Transformable Building hampers the large scale implementation of this sustainable building strategy. Indeed, some negative effects should be considered.

As Transformable Building is no common practice yet, several publications associate additional costs to the development process of alternative building elements or technical detailing. Additionally, during the building’s future refurbishments demounting and reinstalling building elements are expected to increase strongly the share of labour in the overall life cycle costs (Paduart 2012 pp. 257, 279, 282). Unfortunately, labour is very expensive and might undo the savings of reusing components. A recent study confirmed that the price evolution of both labour and materials, as well as technical efficiency of construction will be determinative for the feasibility of Transformable Building (Debacker et al. 2015).

Moreover, also transport, storage and equipment costs should be carefully controlled. Therefore, it might be interesting to review - in the light of new technologies such as Building Information Modelling and Additive Manufacturing - the experience with prefabrication, mass customisation and open system building acquired during the early years of Open Building (Sarja 2003)
2.2.2. Risks in technology and process innovation

Like Transformable Building, all innovation comes with uncertainties. Unfortunately, those uncertainties might be reflected in additional costs charged by the product developer to the client.

New concepts cannot reach a broad market from the start and could fail from becoming profitable. Together with the expected higher initial development costs, this risk is an important obstacle for the widespread introduction of transformable buildings and demountable building elements in practice. Innovative Belgian constructors like Skilpod (2015), NewCraft (2015) and Llexx (2015) require large investments but are uncertain about their market share because of the high price they need to ask to compensate development costs. In these early product stages they rely on clients looking for externalities like the long term asset’s (market or rental) value and high adaptability.

Finally, if Open and Transformable Building is associated with industrialisation or prefabrication in order to reduce initial investment costs, they are also subject of a longer production chain. The longer the chain, the higher the risks and associated fail costs (van den Thillart 2002 p. 27).

2.2.3. Resistance to reuse

In addition to those product and process related weaknesses there is another feeble point of Transformable Building: as one of its main strengths it the facilitation of the reuse of buildings, building elements and materials, there has to be a willingness to reuse them. Unfortunately, a general resistance of clients and contractors to use second hand materials is stated by most authors. Three factors play a crucial role.

First, so called soft factors make that reclaimed building materials are perceived as low value and low quality alternatives. This is confirmed by the Belgian architectural office ROTOR who in reaction created the website Opalis (ROTOR 2015) where they collect information on reclaimed components.

Second, there is a lack of knowledge, sheared experience and legal grounds about reclaimed materials. So although some authors note that salvaged materials offer lower cost options, others state that product warranties, quality control systems and sustainable supply chain models will be essential.

Finally, the discontinuous supply of second hand materials is acknowledged as an important barrier for reuse in practice. However, it is expected that building materials mounted with reversible connections and shaped in a generic or even modular way will increasingly feed the reuse market.

2.3. Opportunities

2.3.1. People’s needs are constantly changing

In the selected literature, several arguments refer to one of the main premises of Open and Transformable Building: our increasingly faster changing life styles and patterns. This is an opportunity at two levels.

First, arguments are formulated at the level of the individual users. A transformable house is certainly useful for people that prefer to stay within their social habitat rather than moving to another dwelling that fits their requirements. To them Transformable Building offers affordable refurbish opportunities.

Second, changing needs and standards are also noted at the scale of the society. For example the aging of our population and shrinkage of families set new requirement for our building stock. Consequently, also new users, building owners and governments can profit from a building stock that is easily adaptable.

Moreover, considering that the real estate market characterised by demand-side substitution, i.e. people are open to added value, profit eager companies are pushed towards quality and differentiation. Transformable Building could be an interesting opportunity for them too.

2.3.2. Integrated sustainability evaluation and policy

Another important premise of Transformable Building is the environmental life cycle savings it can bring. However, in literature only three arguments could be found that relate the financials to sustainable building.

First, although an important reduction of waste can be realised, material prices and waste treatment costs are
rarely an incentive for reuse. Hemans and Damen (1997 p. 68) state that to introduce demountable building generally, an important raise of waste treatment cost and material prices would be necessary.

Second, in the Life Cycle Construction Resource Guide (Pollution Prevention Program Office 2008 p. 43) an increased interest from architects and designers in local second hand material stores is attributed to the growing popularity of the LEED and Built Green certification programs.

The last argument is another American example: in the Life Cycle Construction Resource Guide (p. 8) it is written that “property owners can realize tax deductions that include the value of the building and its materials if they are donated to a non-profit organization”. This and similar measures are opportunities to raise the awareness about the environmental life cycle savings Open and Transformable Building can bring.

2.3.3. Solid sector structure and scale

Although some authors state that the construction sector is reluctant to change, others say that it has the proper structure and scale for gradually introducing Transformability.

The construction sector, including design, production and construction, is a stable sector with large experience and a continuous turnover. It typically exists of a lot of individual entities of different size. Consequently, at the scale of the whole sector, individual initiatives can fail without disruption of the construction market.

In addition, the growing refurbishment and renovation practice is a large opportunity for Transformable Building. Not only because refurbishments are illustrative for our changing needs, but also because it is the largest construction activity today, it has the potential to introduce new concepts and products.

In Belgium, policy is well aware of this and launched in 2014 a call for living lab with innovative energy renovation concepts for dwellings. Amongst the 10 project that were awarded funding, 2 concepts take modular building and lifelong living as one of their goals (Kennisplatform Renovatie 2015).

2.3.4. Co-innovation

As several risks and eventual higher costs are associated with the reuse of building components, new business models should be developed. The concept of a circular economy with a growing importance of product-service systems could be a viable framework for the life cycle of transformable buildings and elements. In addition, we detected through our literature review also three other innovations that could be an opportunity for Transformable Building or vice versa.

Innovation in tendering and procurement is cited as a necessity to allow long-term investments. Therefore, Hemans and Damen (1997 p. 15) state that alternative tendering like turnkey, design and build and management contracting should be stimulated.

Also innovation in investing strategies, management and ownership is needed conclude Crone et al. (2007 p. 76) from the Dutch IFD pilot projects. Open building can facilitate new concepts like renting a support while buying an infill or buying a support and renting an infill.

Additionally, Hemans and Damen (1997 p. 38) state that innovation in policy should stimulate sustainable choices and reduce risk for construction companies for example through the participation of local governments or governmental corporations in innovative projects.

2.4. Threats

2.3.1. Short-sighted market valuation

Although some authors state that transformable buildings could be highly valuated on an open market (see 2.1.2.), property markets are more complex than we might guess. Three aspects are not (yet) in accordance with Transformable Building.

First, in the Dutch IFD report (Crone et al. 2007 p. 12) it is written that Transformable Building can make a difference in quality. However, from interviews with a construction sector representative we understand that economically and financially there is little space nor incentive for individual constructors to focus on innovation with long term benefits (Ramaekers 2013).
Additionally, most of the building owners and investors are not interested in the way their building is realised say Hemans and Damen (1997 p. 87). The result and price are more important to them. Therefore, Transformable Building has to focus more on its potential to provide Open Buildings as a result.

Moreover, although Transformable Building has the potential to appeal to a broad user base, other aspects like location and surrounding facilities are still the basic determinants for an asset’s market value warn Hemans and Damen (1997 p. 4).

2.3.2. Inert sector structure and scale

The current construction sector’s structure is regularly sited as a threat for the implementation of Transformable Building. The arguments that were found in the literature are mostly anecdotic and seldom based on objective observations. Nevertheless, three issues feed this perception.

First, it is stated that the construction sector is a conservative, closed, protectionist and cost oriented industry. Hemans and Damen (1997 p. 19) write for example that the industry’s representatives tend to slow down innovative front runners to keep the ‘peloton’ together.

Second, Hemans and Damen (1997 p. 80) note that conventional construction methods have been optimised over such a long period that it is hard to realise significant financial saving with alternative methods like Transformable Building. This has also been confirmed by Debacker (2015) and Paduart (2013).

Third, in the life cycle construction resource guide (Pollution Prevention Program Office 2008 p. 21) it is stated that a few specialised retail yards are not sufficient to establish a market for second hand materials and therefore it should be expanded with numerous small projects and contractor firms.

2.3.3. Strongly intervening government

Although we found earlier that governments can have an important role in supporting sustainable innovation, we know from the IFD projects in the Netherlands that a intensely intervening government might be a threat for the breakthrough of transformable buildings as well. Two specific situations illustrate this insightfully.

Hemans and Damen (1997) state powerfully that a forced cooperation between stakeholders or a top-down coordination brings no success in the long run. The IFD projects showed for example that obtaining a patent was no longer possible after a publicly development project. Moreover, commercial price setting was restricted because actual costs had been openly discussed.

Simultaneously, at market level, strong interventions of governments through subsidies or regulatory pressure tends to unbalance the cost-quality proportion says van den Thillart (2002). Consequently, the product or system is marketed with a quality consumers are not willing to pay at the actual price. This lack of open market operation could be a threat for the long term viability of the innovative product.

2.3.4. Persistence of change

Finally, Hemans and Damen (1997 p. 69) note that change might be more persistent than we can imagine. Therefore it is important to emphasise that Transformable and Open Building by extension is no translation of future expectations, but wants to enables qualitatively and efficiently future alterations. The final thought that there is no certainty about how buildings, the construction sector or technological insights will evolve, implies however that additional initial environmental burdens and financial costs should be minimised.

3. Conclusion, discussion and further research

After reviewing six publications that are closely related to Open and Transformable Building over 200 relevant arguments have been collected and are summarised in 14 hypotheses. Each of them states a strength, weakness, opportunity or threat of Transformable Building related to its financial feasibility. These hypotheses are a first step towards a better understanding the financial effects of Transformable Building. They offer designers and investors a preliminary overview of Transformability’s financial opportunities and risks and guide researchers and advisors towards more focused assessments. Those focused assessments are necessary to clarify the contradictions amongst the 14 hypotheses. Three contradictions we consider particularly important to increase the financial feasibility of Transformable Building.

First, the extended service life and lower costs in use of Transformable Building has to be confronted with the
expected higher investment and life cycle costs. Although Transformable Building enables less invasive refurbishments and the reuse of building elements and materials, those savings will have to stand out against the increased development costs and the overall share of labour due to demounting and reinstalling elements. Although the first steps towards these assessments have already been taken (Debacker et al. 2015; Galle et al. 2015; Paduart et al. 2013), more accurate and comprehensive Life Cycle Costing methods (LCC) will have to be developed and more precise cost data will have to be collected to reflect the financial effects of reversible connections, the reuse of generic building components and their residual value.

Second, there is a contradiction between those authors that state that governments should play a supporting role for sustainable innovation and those that state that governments can hamper the successful commercialisation of new products. In literature it is remembered from experiments that forced cooperation or a publicly development process could harm the long term viability of innovation. Nevertheless, it is also suggested that through alternative governmental participation (e.g. living labs or public-private partnerships) sustainable investments can be promoted or development risks can be reduced. Therefore, more research on the effects of government participation should be conducted.

Third, although it is stated that it is technically, organisationally and conceptually feasible to realise transformable buildings, their development is associate with high costs for designing alternative building elements and reversible connections. Therefore, it is interesting to study which advantage existing production strategies like prefabrication, mass customisation and open systems building could provide as well as the gains that could be generated by new technologies like Building Information Modelling or additive manufacturing. Applying those concepts could move Transformable Building from technically feasible to economically viable.

Although these contradictions and perspectives for further research are only based on the hypotheses we summarised from a specific and incomprehensive literature review, they feed the discussion about the future of Open Building and its sustainable focus Transformable Building.

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