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Conference Paper

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Publication date:

2015

Permanent link:

<https://doi.org/10.3929/ethz-a-010578376>

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Open Building as the basis for Circular Economy Buildings

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During 25 years of experience following Remko Zuidema's TU Delft Architecture education, the author worked as principal, manager and engineer on off-shore modules, housing, education, healthcare and office projects from private companies, and as general manager on infrastructure at the municipality of Amsterdam. Conflicts between end-users' interests in comparison with the owner's decisions are well known. As former local politician, strategic consultant, founder and chairman of the BRIQS foundation on sustainable societal systems in the built environment, the author is directly involved in tuning natural resources, materials, products, building's lifecycles of the building fabric to the end-user's and investor's demands.

KEYWORDS:

Open Building, Circular Economy, Circular Buildings, Real Estate Ownership, Governance

Abstract

The concept of Circular Economy introduces material and product after-use value as an increasingly important factor and a new economic factor of Open Building principles implementation in the Netherlands, Europe and possibly beyond. So-far the investor, end-user and municipality were economically the deciding value driven partners of Real Estate, with the first being dominant decisive. Previous and expected future commodity price rises due to increasing demands and shortening supply of materials and products introduce value creating options in buildings on the long run. Recent project assessments approved by accountancy and banking officers in The Netherlands show a present value of materials and products at around a one years lease price of the project office space.

Due to the recent challenges of financial institutions, the power of public and private investors, developers and corporations has shifted towards more bottom-up end-user initiated Real Estate development. Open Building principles are effective as the basic connection between circularity and economy in those developments because it fundamentally incorporates the end-users interests. Recent implementation of Open Building principles in national legislation in Japan and South Korea show an easier access to materials and products by partial disassembly due to separation of service systems from construction and façade elements. This can become a large factor in the protection remaining value of used items in buildings. Further industrialization of the building approach in The Netherlands – especially in the Fit-Out – should create a further end-of-life value rise due to a more controlled high quality implementation approach.

In the near future further research on transparent ownership distribution between end-users and investors, ownership sharing with or distribution to suppliers of building parts and the further development of BIM solutions to easily trace materials and products in buildings are needed to extricate and enjoy the benefits of Circular Buildings.

1. Effects of mindset changes of end-users, investors and local communities on Real Estate and construction.

1.1. Resource overstretch and the response in economic thinking

More and more consumers all over the world are using a decreasing amount of easily available resources and in doing so are overstretching the known capacity limitations of the earth¹; originally in availability of natural

resources and now also increasingly in terms of humane climate. Circular material use is based on the basic findings written down in publications of the Cradle to Cradleⁱⁱ and Circular Economyⁱⁱⁱ founders. Within a Circular Economy, we describe the economic benefits of closing material or product cycles leaving no waste existing. Reuse, but even a step further. Waste as a raw material for a new product, repair and remanufacturing as a basis for a next (economic) life. The smaller the circle, the easier it is to get it balanced. Circular Economy therefore offers (also) particular employment and innovation opportunities at local and regional level. Within transactions these opportunities are identified by a generally broader look at the overall costs and benefits; longevity, maintenance, resale value and social costs and benefits. In a circular system in which all kinds of economic stakeholders can be involved around you, more prosperity for the environment, for people and for the economy can emerge. Furthermore, recent developments in Japan illustrate^{iv} the importance of Open Building principles to change the rules of the housing market towards new business model implementation that support circularity by directly connecting the decision makers with the knowledge, responsibility and scale of the industry.

1.2. Governance responses in development

New concepts of governance are required to handle the transition from the current large overcapacity of buildings for offices, shops, churches and healthcare into a new strategy needed to meet the growing demand for non-standard homes. Focus on the large existing building stock by government and market actually makes the much smaller volume of new construction in Europe the exception. This introduces Open Building in governance as a solution to more tailor-made tuning between users and investors in existing and new buildings. Adding the distinction between the Base Building and Fit-Out to the existing options of land and furniture owning or leasing.

In procurement new selection principles arise, based on the different short-term and long-term goals set by both private and public commissioners. These new principles consists of fairness, circularity, footprint, product performance and transparency^v, being judged continuously and also seen as key value propositions for both end-users and investors. These five items are all taken into account, not just focusing on the second most obvious.

1.3. Open Building providing distinction between short-term end-user and long-term investor clients

As the objective is to create more sustainable building, the economy is the preferred driver focusing on the two big decision-making variables of the economy: scarcity and prosperity as defined by em. prof. Heertje^{vi}. The actual most sustainable and economic way of commissioning sustainable project is mostly done by directly connected investors and end-users.

Open Building provides distinction between the short-term end-user client and the long-term investor client with principally different expectations, requirements and business models. In traditional Real Estate business models often the end-user is represented by the developer, a public housing corporation or a project manager. But the many earlier projects on Open Building and the wide range of participating industrial companies - as documented in the comprehensive book on Residential Buildings^{vii} - already anticipate the huge and growing differentiation between goals as society, which only proves to become increasingly more diverse and demanding. Defining the interface between the Open Building of Public, Investor and End-User stakeholders as described in the Open Design^{viii} book shows the possibilities and challenges to be tackled.

The real value of natural resources and the inclusion of environmental costs in products and services fundamentally change the game to repair, reuse/refurbish, remanufacture and recycle. Thus influencing the factors driving towards the 'weakest link' component, fashion, economic and financial/legal obsolescence by mitigation in various ways. In general, the risks and price expectations of the present make – use – waste models are therefore growing fast. And this will be making business models based on a more industrial controlled circular way of production and service providing more appreciated from a point of view of risk aversion.

1.4 Open Building as related to materials and products

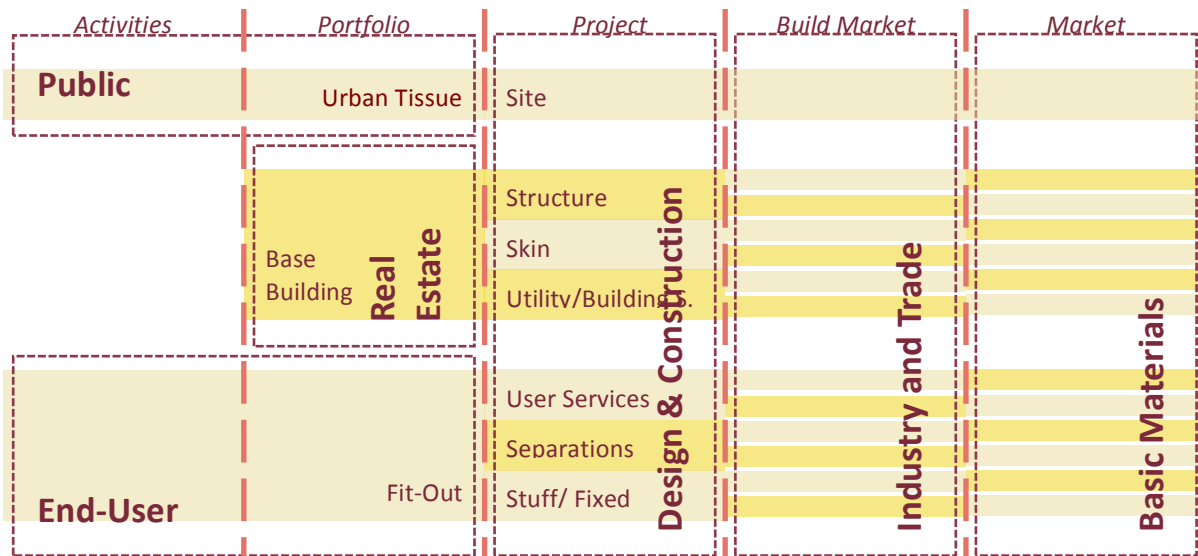


Fig. 1. The 5 business areas – placed horizontally – of the building world leading to Open Building based distinctive separation of stakeholders in buildings

A proposed change from a sole focus on transactions of products by construction and production companies towards the performance services - including the products – can be implemented in buildings by introducing the 6S principles of building layers by Steward Brand^x. But this relationship between the competence of stakeholders in open building and the physical location of a component of the 6S principles in a building, is not one-on-one. Thus in Figure 1 (next page) you see the Utility/ Building Services and User Services as fundamentally separated in the project based “Design & Construction” segment, in contrast to one item of Services as defined by Brand. But there are a few known examples of more elements and products changing side. This is one of the research conclusions of the paper published at the TU Delft on ‘Materials and Circular Buildings’ (Geldermans et al., 2015)^x with participation of the author.

This technical and organizational approach, however, still lacks the essential direct contact of producer/ supplier of goods and services with the actual beneficial client. As a service company this becomes the legal risk and the key quality of the company in delivering the assumed value on which payments are based. As the awareness amongst the European population on issues of health, wellbeing and productivity in work and home are increasing and are gaining momentum, new approaches in letting, renting or owning Real Estate are looked after. Open Building is known to give occupants the right of decision on the indoor space that directly influences these issues. This gives more room to adaptation of buildings by construction, production or service companies implementing the ever-faster changing and more diverse requirements of end-users, both in being companies or individuals.

2. Multiple strategies to Circular Economy introduction

2.1. Cost transparency

The incorporation of TCO¹ and TCU² into performance commissioning and new financial frameworks spark a demand for new approaches. Open Building makes it transparent to distinguish the owner / investor interests

¹ TCO stands for Total Costs of Ownership, a term regularly used in defining the costs of owning the object in lifetime. In case of buildings potentially a more than a lifetime experience, with the end of life of the total building in mind.

² TCU stands for Total Costs of Using, a term regularly used in defining the costs of using the object in lifetime of use, mostly end-of-lease or rental term.

from the end-user – personal / or company – needs and preferences. Both interests can be holistically met in design, construction, maintenance, gradual transformation, demolition and re-use of built assets. This leads to the view that Open Building is a logical approach towards incorporation of the circular economy and as a preferred way to meet these new demands. Therefore, from the point of view of users, investors and governments the incorporation of Open Building based rules in basic building codes, property principles, tender procurement and environmental principles provide accelerating freedom of implementation. As seen in Figure 1 the different building parts logically fall into the designated fit-out of the end-user, the base building of the investor, or into the public domain.



Fig. 2. The 5 Real Estate business agreements in Open Building as seen from the end-user

2.2. Effects on the five business areas

Integrating the building supplier needs bridges the right three areas into one responsibility. The focus on energy of the last decade is slowly shifting towards materials as the awareness on reducing availability and growing market prices expands. The so-called Split Incentive – different colliding interests – like the energy bill being paid by the end-user while the owner of the building has the costs of creating a building which is energy-low, neutral or even energy-producing. And providing the inability to raise the rent, has blocked most energy-saving investments in the rental market. And, therefore, deserves to be avoided to create an effective market; not one repaired in complexity.

Traditional home ownership consists of all four levels shown in Figure 2, although in large cities in the Netherlands land ownership – for more than a century – also remained with the municipality, thus creating land lease by the municipality. Existing private land lease with home ownership is fast disappearing because of the failure to be allowed bank funding by new owners. Urgent fundamental problems for homeowners having mortgages higher than the actual building value are currently addressed by transferring ground ownership to the municipality by funding for the actual foundation reconstruction of the property, retaining its value and loan surety. The base building and fit-out separation in terms of ownership may assist in getting the requested freedom of self-interest of end-users of apartment buildings in combination with needed energy-saving renovations of condominiums. Thus alleviating the present paralyzing conflicts of interests between the various apartment owners, due to the specific location of an apartment in the building and the related actual energy use and costs.

The use of healthy and/or bio-based materials will increase indoor air quality, including traceable, transparent and predictable ownership responsibilities thereof. It is expected that it will create a longer life span of the urban fabric in general, and the base building in particular, than what is created today. The appearance of material passports - to track and trace material flows and changing buildings into material banks for the future development of things - create new value propositions. New business models based on the Circular Economy – as defined by the Ellen MacArthur Foundation – principles have shifted from product to service and are solely based on the value of use, instead of primarily the user's ownership.

2.3 New taxation strategy

The transition to more resilience in the abundant availability of labor and the growing constraints on natural resources all point a new light on taxation in the Netherlands and other EU countries. With this planned tax shift – named Ex'tax^{xi} – from around 60% taxation of labor costs downwards, especially in the first income tax levels, towards the under 0.3% average tax on basic natural resources, both labor and building materials change the present business cost structure fundamentally. What will be especially important in both construction and buildings in the Netherlands is the change from largely new build to large-scale renovation towards energy saving in the upcoming decades. As new buildings are highly material intensive, renovation is highly labor intensive. The national goal of the Netherlands of making all homes net-energy free to be completed round the year 2050 already needs doubling the present number of yearly renovated homes.

2.4. Business models for Investors and End-Users combined

The 5 different situations in Figure 2 offer a total of 8 different existing business models for investors and end-users combined, all with value in the present market in the Netherlands. Fully furnished homes almost resemble hotels, long-stay and services like Airbnb and have all 4 levels in Figure 2 rented out. Having your own furniture is the standard rental situation appearing to be the most common on the world. Letting the Fit-Out can go two ways: at present mostly by the home owner, but in the future also by the Fit-Out lease company providing a full service environment out of the Circular Economy. Industrial production and ICT will enable more knowledge on actual performances, compared to the present melting pot of products and materials. And as a consequence the guided use will make performances of climate, light and other services available.

It is essential for industrialization to systemize and upscale the Fit-Out industry that the Open Building implementation will be worked out in laws providing the legal framework. Although the present building regulation system (in 1992 introduced in the Netherlands) are largely based on the Open Building principles, the present situation as a result of over 20 years of implementing political alterations, is considered malformed by the national parliament itself, who has requested a proposal for a new, fresh building code system. One of the preferred actions is to remove all building permit restraints on the Fit-Out elements while introducing general guaranties and certificates, making the Fit-Out requirements come close to existing furniture ones.

Fit-Out specific business models can be applied anywhere in the world and can create new opportunities globally, providing physical transport is limited and not heavily regulated. Developing countries have huge building opportunities but lack much of the industrial power to create cities based on industrial customization of buildings. Thus the effective use of materials and the creation of a market for the continuous reuse of products and material flows is an export product to any country not yet adopting this opportunity. As we have seen in other areas - like the automobile, television and computer markets - this could lead to accessibility for the still deprived part of the world population, while taking into account the impact energy and material use has on the living environment and recovery rate of the planet. Mostly, these tools start in the developed countries and are rapidly being adopted by the rest of the world.

3. Transition to Circular Economy with Open Building strategy

3.1. Transition overview

Due to growing concerns about material availability, fueled by reducing ore quality^{xii}, growing earth depletion^{xiii} and growing use by more people^{xiv}, getting older than ever^{xv} and into a higher standard of living^{xvi} prices will go up and periods of unavailability are likely. And these five elements enhance each other in this process, as well as each other's influence. Due to the basic key factors in economics of scarcity and prosperity^{xvii}, the turn in the long term material value drop happened around the year 2000, and despite a number of crises, hiccups continued to rise to new cost levels. Therefore the materials are becoming of value after use if properly recovered, treated and placed in products and buildings. In Figure 3 that transition of this economy is presented from linear in the past – and in most places in the world today – to the present model in the Netherlands, towards the proposed ideal model of the future where biological materials are returning to nature for reuse and the technical materials are reused, thus avoiding mining etc. of virgin materials.

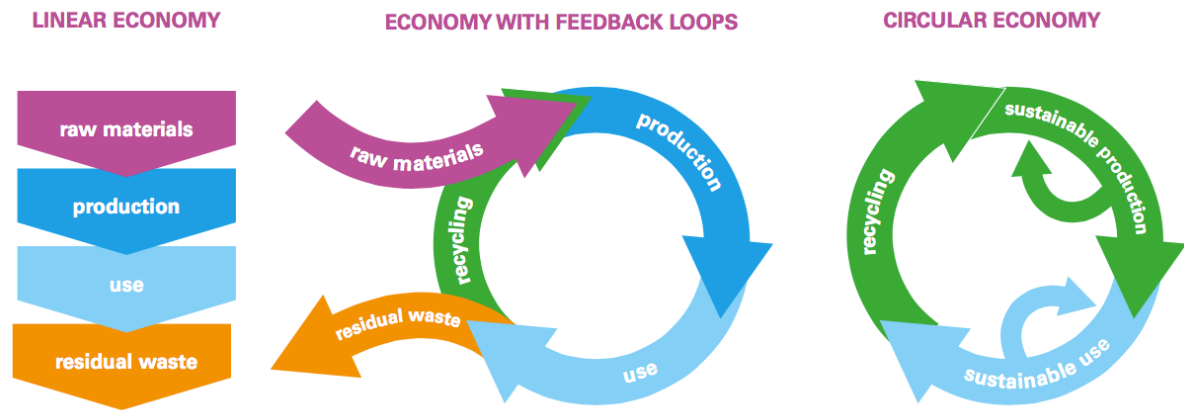


Fig. 3. The transition from linear to circular business models in the general economy^{xviii}

3.2. Linear business model introduction of business as usual

When seeing the traditional business model as shown in Figure 3, the lack of systemization of the total building process can be recognized as being linear from cradle to grave. Together with the inability to respond to material change or future value, we see a split incentive between the business models of developers, consultants and construction companies based on transactions on the one hand, and the business models of investors, government and end-users based on value growth on the other hand. This total mixture of interests blocks interests that are wider than the project scope, and avoids quality growth of any teams within any of the five economic groups mentioned in figure 1. Quality growth connecting these five economic groups has become totally out of range, except for based or gradual societal conformity. The challenges of the growing end-user demands and real-estate investor demands are even overturned by the increasingly fast-growing material value and even shortages in hiccups being is on the rise. Therefore, the linear model is losing the value creating abilities required by the clients – government, real-estate investors and end-users – leading to value losses, empty buildings and lost materials.

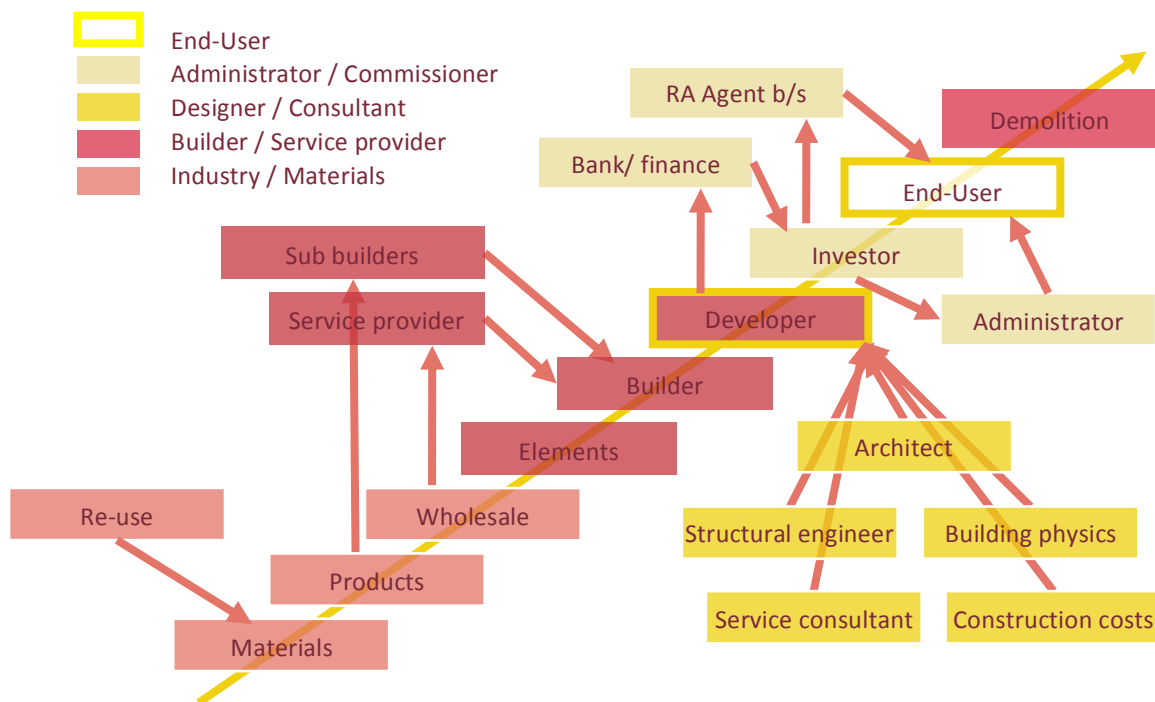


Fig. 4. The Linear business models in present traditional building world

3.2. Circular business model options introduction

In the Circular Economy these business models can be divided into:

- Models being user specific or just avoiding production;
- Models on sustainable & social integration;
- Models based on reduced damage or destruction of products or materials.

In the first group we see that, while part of the industry is focusing on large-scale production in centralized locations, the opposite is happening at the same time in a series of one. In this case we know the 3D print from actual demand generation and collective crowd based decision-making taking the lead. The actual connection of the Fit-Out of a building to the internet will enable it user demanded activation and control to become better available, also in non WIFI or GSM connectivity. The replacement of actual products by ones working virtually will be more disruptive, based for instance on a single app purchase or a service subscription.

In the second group of contract or direct services we find the already familiar repair services, sharing platforms, pay for actual use, waste reduction and pay-as-you-go services. Those are relatively short-lived transaction obligations from suppliers to clients. What has been added is that the basic characteristics of these business models now include reduction of waste and need of resources, large social and organizational impact into functionality for the end-user. Keeping the integral product focus and ownership responsibilities with the (service) provider.

Contracts based on the actual production of goods and services in the third group are relying on self-organizing communities of individuals, or up-cycling or recycling and repurpose, are based on cascades of use, each with its own price and quality levels. Other contract services are more based on the full actual use of the product, or - in this case - the home or fit-out. Contracts and payments are based on actual performance, for instance. Forms that have come to market include the forms of take-back organization, or refurbishments and next life guaranties with resell opportunities on products with long endurance compared to the use period.

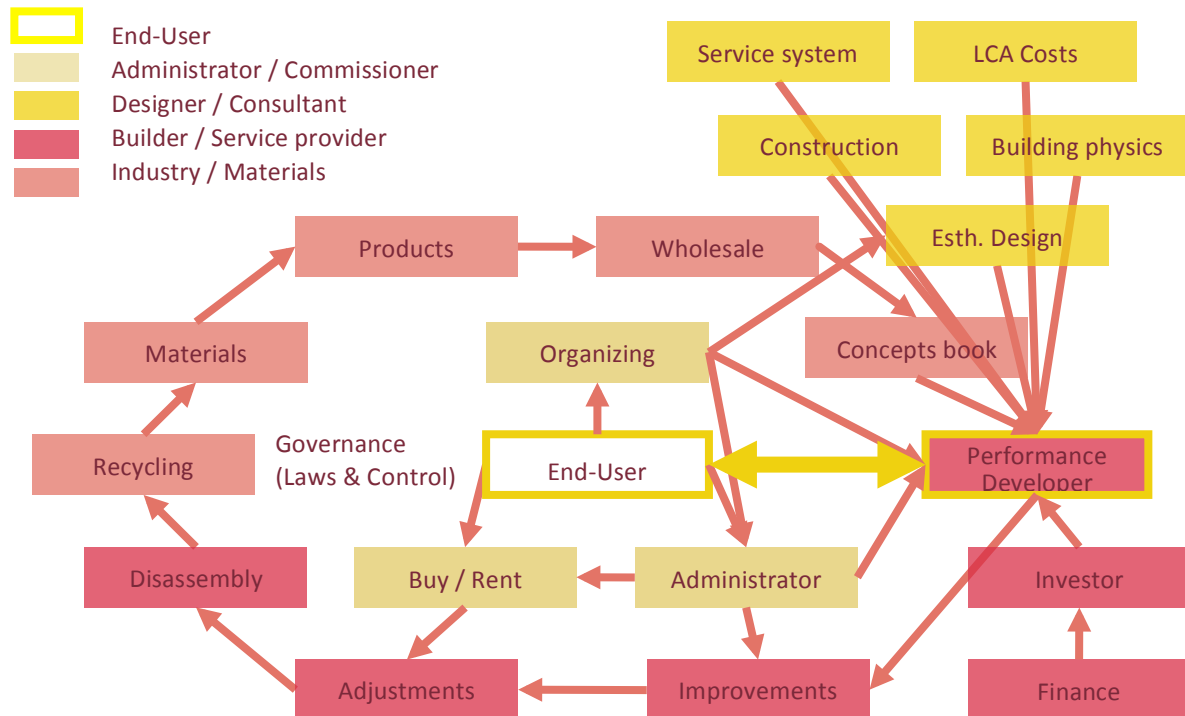


Fig. 5. The Circular business models on a single Open Building level in the future building world

All of the models can eventually – following Figure 5 – be developed towards circular sourcing including cradle-to-cradle principles when clearly solving or vastly reducing social or ecological issues.

At the moment a completely new Real Estate market is emerging based on industrialization towards low energy, high-quality materials and adaptability to specific end-user requests. A clear example is the Park20|20

area development in the town of Hoofddorp The Netherlands where the material value is currently set at approximately a year of the offices lease income, approved by accountancy and banking officers. Those new models are based on the actual decision maker being the client, and have a deeply integrated material and product manufacturer involvement. The clients can be investors with B2B³ interest or end-users with clearly more B2C⁴ interests. At the same time we see those businesses using C2C⁵ for their exchange of Fit-Out or furniture parts and manufacturers providing replacement parts of service through C2B⁶ contracts by local repair cafés and individual craftsmen in avoiding rising travel costs and inconsistent workflows responsibilities.

4. Propositions with Open Building principles for Circular Economy implementation

Ownership of Real Estate is now challenging the implementation of Circular Economy principles in the built environment. Real Estate loans are one of the three traditional investment forms, together with stocks and bonds. The definition on what is exactly defined as Real Estate and what is considered not-Real Estate as the collateral of these bank loans lack currently an EU definition. Now the major EU banks within the Eurozone countries have been brought under the supervision of the European Central Bank on January 1st of 2015, this seems to be odd and not without risk. Therefore I believe research is quickly needed to get a clear view on the differences within the present legal systems of the different EU countries to explore risks or opportunities . BRIQS foundation initiated a research proposal that was granted partial funding by the NWO⁷ in the Netherlands in 2013, providing sufficient additional private funds will become available, to fund this research. At the moment private funding is still awaited to receive support to be able to start this comparative research.

4.1. Legal issues in different counties

Commercial ownership follows the available options of legal ownership in the Netherlands. New building elements added to a rental property now by the End-User of third parties are, by default, owned by the building owner today. For instance while leasing a kitchen by the tenant from a kitchen supplier, the Dutch law will consider by default the kitchen to be legally owned by the building owner when mounted on site. Thus making most service contracts within Real Estate impossible. A PV-system or sun-heating system placed on top of a building will by default be owned by the building owner, unless legal ownership divisions have passed notary and are published at the national cadaster with all costs included. Commercial ownership is restricted by legal ownership.

How different the situation is in the bordering country of Belgium. Legal ownership automatically follows commercial ownership in Belgium, as implemented in 1824 by king William I of the Netherlands. In Belgium, the adding of new elements in a rental home will by law still be owned by the tenant of the building and can later be removed. Only after the rent is terminated, or after 50 years of rent and then only with financial compensation the building owner becomes legal owner of these elements. So placed and rented elements from third parties by the tenant will not be transferred into ownership by the owner of the building by default and without compensation, as is the case in the Netherlands. Only after the tenant terminated the lease contract what remains in the building transfers in ownership.

In most countries, the ownership of building materials, products and components are by law transferred to the owner of the ground or building and that transfer is irreversible. But Preliminary research already reveals that France provides the legal opportunity to reclaim this ownership after demolition if so registered in public legal registration papers. Germany in turn seems to have the option to share ownership with partners of the

³ Business to Business (B2B) is commerce transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

⁴ Business to Consumer (B2C) basically encompasses the process of selling consumer goods and/or services to customers through multiple channels of distribution to earn a profit.

⁵ Consumer to Consumer (C2C) is direct exchange between consumers as in neighbor exchange on physical or digital market platforms.

⁶ Consumer to Business (C2B) is mostly seen as help by handyman or pensioners with 'golden hands' to help out repairing and simple modifying in their neighborhood.

⁷ NWO The Netherlands Organization for Scientific Research (NWO) funds top researchers, steers the course of Dutch science by means of research programs and by managing the national knowledge infrastructure

building, leaving the building as a legal entity intact but with registered multi ownership based on parts brought in ownership before. More research can help to publish the various interesting situations in EU countries to clarify the influence of options in societies. As Real Estate also functions as collateral for loans of banks, pension and other financial institutions, the introduction of law changes in ownership will preferably be based on proven concepts of nearby countries.

4.2. Issues on parameters and ICT

Workshops bringing together teachers, researchers and students of three Dutch universities, three Dutch colleges and frontrunner businesses created room for BRIQS foundation to work on clarifying the most dominant actual parameters of circular building and buildings. As mentioned before in this article, the research on Materials & Circular Construction at TU Delft (Geldermans et al., 2015)^{xix} has recently been published, stating categories of indicators being oversizing, dimensioning, connections and connectivity. The connection towards adaptivity provides research input to accelerate towards tools needed for measurements and to include tools in assessments systems. The value proposition for both clients of a building – end-user and investor – are in essence so different to each other that transparent measurements are essential. Thus connecting the more situational dimensioning and performance to the more intrinsic values of material quality, sustainability, health and reusability.

The introduction of material tracing parameters in BIM (Building Information Models) as a building tool ought to be provided, making the essential information accessible during the building lifetime. As the building lifetime exceeds average time of its building (products) companies and individual ownership, a new partner is needed for storage to be secure of retrieving the information at that stage. As far as we see, only the municipalities can cope with these long terms in comparison with the present storage of building (construction) drawings. Standardization of the used formats, however, will be important in order to allow reading those digital BIM files within the required timeframe. This is a new unprecedented phenomenon in the building history that can unleash huge international industrialization bringing prices down, enhancing quality especially in the Fit-Out market in the EU.

5. Conclusion and reflection

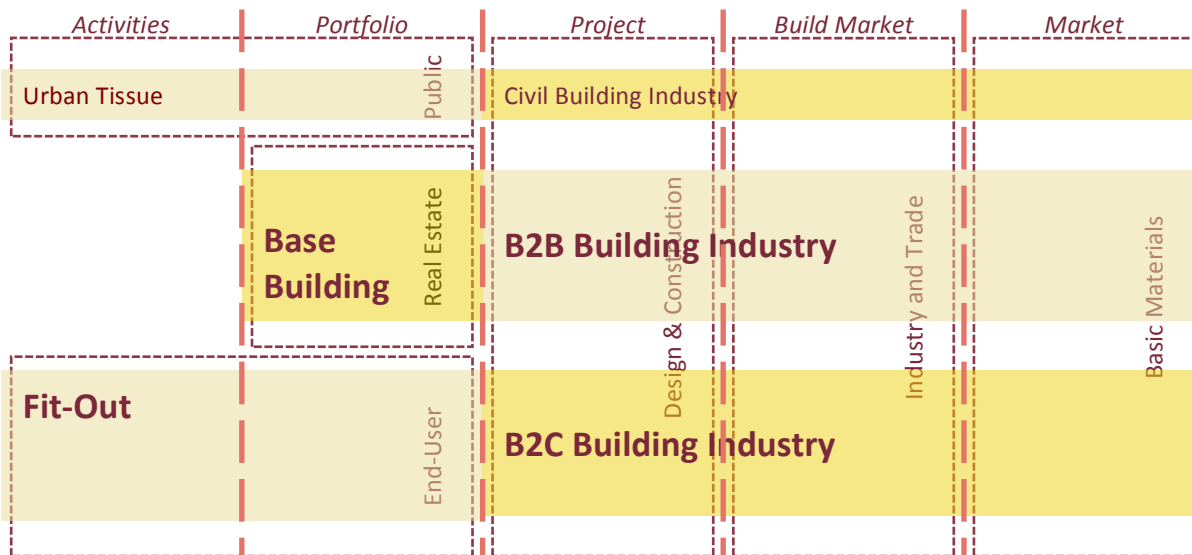


Fig. 6. The four leading value focused business areas in the new building world in Circular Buildings

By putting the social process of making choices first by empowering people to use the Open Building principles, it provides the first step in identifying the different client value propositions by the building world. But by entering a new business model based on material value for the building industry a new and potentially disruptive business model is starting to arise. Therefore, creating circular business models catering for the right and specific client needs, deserve extra interest and focus.

As the clients follow the economic interests created by the building industry on the basis of scarcity and prosperity factors, the key value creators for clients must to be explored. Figure 6 identifies the sets of partners that are identified in new economic partnerships. Both key economic factors – scarcity and prosperity – eventually lead to a more environmental approach towards preserving climate and natural resources, based on the earth capacity to reprocess.

Then three issues need to be resolved:

1. New Real Estate ownership options implementation enabling affordable transparent ownership separation between end-users and investors;
2. Joint ownership and ownership revival after demolition need an assessment of legal options to be implemented;
3. Upscaling and standardizing circularity methods by measurement/assessment in buildings and introduction into BIM through material tracing.

Specific research on those areas is targeted by the BRIQS foundation, welcoming all assistance and cooperation in order to accelerate the building world into this new and promising era.

References and documentation

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ⁱ <http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries.html>

(accessed September 21, 2015);

ⁱⁱ Michael Braungart and William McDonough (cradletocradle.com), *Cradle to Cradle*, North Point Press, 2002;

ⁱⁱⁱ Ellen McArthur (ellenmacarthurfoundation.org), *Towards the Circular Economy Vol. 1, 2 and 3*, McKinsey & Company, 2012, 2013, 2014;

^{iv} Kazunobu Minami, <http://www.minami.arc.shibaura-it.ac.jp/research/article/pdf/10.pdf> (accessed September 21, 2015);

^v

https://www.waag.org/sites/waag/files/public/media/publicaties/ritframework_finalreport_metabolic_29.01.2015.pdf (accessed September 21, 2015);

^{vi} Arnold Heertje “Echte economie - Een verhandeling over schaarste en welvaart en over het geloof in leermeesters en leren” (Real economy - A discourse on scarcity and prosperity and the belief in teachers and studying) published 1977;

^{vii} Kendall, Stephen H., and Jonathan Teicher. *Residential open building*. Routledge, 2000;

^{viii} Van der Werf, Frans. *Open ontwerpen*. Uitgeverij 010, 1993;

^{ix} Stewart Brand, *6 S's from How Buildings Learn*, Viking Press, 1994;

^x Bob Geldermans et.al., *Materialen & Circulair Bouwen (Materials and Circular Construction)*, TU Delft 2015 including the author Remko Zuidema as co-writer;

^{xi} Femke Groothuis, Ex'tax (ex-tax.com), Deloitte, EY, KPMG/Meijburg & PwC, “New Era, New Plan”, 2014;

^{xii} International Council on Mining & Metals <https://www.icmm.com/document/4441> (accessed September 21, 2015);

^{xiii} Stockholm Resilience Centre Stockholm University

<http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html> (accessed September 21, 2015);

^{xiv} OurWorldInData of The Institute for New Economic Thinking at the Oxford Martin School Oxford University <http://ourworldindata.org/data/population-growth-vital-statistics/world-population-growth> (accessed September 21, 2015);

^{xv} National Institute on Aging NIH US Department of Health and Human Services

<https://www.nia.nih.gov/research/dbsr/world-population-aging> (accessed September 21, 2015);

^{xvi} OurWorldInData of The Institute for New Economic Thinking at the Oxford Martin School Oxford University Max Roser (2015) – ‘World Poverty’ <http://ourworldindata.org/data/growth-and-distribution-of-prosperity/world-poverty> (accessed September 21, 2015);

^{xvii} See reference vi above;

^{xviii} Council for Environment and Infrastructure (Rli) <http://en.rli.nl/publications/2015/advice/circular-economy-from-wish-to-practice> (accessed September 21, 2015);

^{xix} See reference x above.