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An urban hospital base79,2d on the principles of circular economy: the case of Joseph Bracops hospital

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Abstract. The building industry has mainly focused on improving operational energy consumption to minimise the environmental impacts of buildings which are major sources of greenhouse gas emissions (GHG). However, considering the full life cycle of buildings, energy use and GHG emissions occur for reasons that extend beyond the operational phase and involve the embodied impacts of construction and disassembly. Circular building design can provide a holistic approach where the building's whole life cycle is considered in a manner consistent with circular economy principles, minimizing global material consumption, reducing waste and insuring a more circular building material stock. To date, research on the wide-scale adoption of circular design and construction strategies in public projects is still lacking. On this basis, the case study of the new Joseph Bracops hospital in Brussels shows that circular building design principles can be applied in the healthcare sector within the framework of a public tender. The project integrates circular economy principles at different scales (city, site, building, element), optimises different material and energy flows and takes into account different timespans (short and long term). The study also offers insight and guidance for future research into how the urban hospital of tomorrow will be a resilient public venue. Such a venue can enable a more comprehensive approach of health promotion, reflected by the qualitative integration of circular economy principles both with a social and technical focus, connected to the community and capable to mutate over time.

Keywords: hospital building, circularity assessment, healthcare, circular building, Reversible Building Design Protocol

1. Introduction

1.1. The integration of circular principles in public construction projects and tenders

The construction sector is responsible for the largest share of total EU final energy consumption (40%) and greenhouse emissions (36%) [1]. To the date, efforts for reducing the environmental impact of buildings focus mainly on increasing energy efficiency to reduce operational energy demand [2]. This has required vigorous policies [3] which have led to a growing awareness among actors, increasing development of construction products and systems, and the improvement of information and design support tools [2]. However, the sole focus on the operational stage of a building would not suffice to

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reduce its environmental impact [4]. Circular economy (CE) is a new paradigm gaining interest among researchers and practitioners in the building sector, which also focuses on the embodied impacts of buildings. Current literature considers CE as a regenerative system in which a better management of resource input and waste is ensured by slowing, closing, and narrowing material and energy loops [5]. According to Pomponi and Moncaster, (2017) the concept of CE applied to buildings (meso-level) is less developed than the research on a micro-level (building components) or a macro-level (urban agglomerates), highlighting the need for interdisciplinary research which also considers the building as an entity per se.

To date, research on circular building is still fragmented [6]. The knowledge and legal gap concerning the implementation of circular design principles in public tenders is a barrier to a wider implementation of CE and circular building principles in public procurement projects. The European Commission published in 2016 the Green Public Procurement Criteria for Office Building Design, Construction and Management [7]. This guide has a short section on 'recycled content', with a focus on recycled granulates and reuse of materials, and gives guidance on the follow up of these criteria. Unfortunately, it lacks information on broader circular construction principles and on the legal aspects. However, this report is currently under revision with the aim to expand the scope to other types of buildings and to be in line with recent policy developments such as the Level(s) common framework [8], which provides sustainability indicators to measure carbon, materials, water, health, comfort and climate change impacts throughout the building's life cycle. Other EU initiatives such as Interreg ProCirc (2018-2023) [9], Big Buyers Initiative (2019-2020) [10] or Circular Cities Project (2018-2019) [11] investigate circular public procurement through case studies and pilot projects, analysing supply chains, materials, and cities without including a building-scale approach. In Belgium, the Flemish government initiated in 2020 an open research platform, the "Open call Circulair Bouwen", which provides funding for research on circular construction. In this research platform at least 3 research projects focus on public procurement, tendering and legal consequences: "Public tenders in a higher circular gear" [12], "CircuTender" [13], "Insurability of circular construction and circular buildings" [14]. At the time this article was written, all these studies are still ongoing. Very recently, the Brussels Region published a guide, the "Vademecum Circular Construction – directed towards the public building owners for the sustainable and circular management of resources" [15], assessing the current available strategies for incorporating circular economy principles in public procurement.

In the light of these knowledge and legal gaps and latest development in Belgium, the Joseph Bracops hospital in Brussels is presented here as a case study, to contribute to the discussion on the following research topics:

- How can circular principles be applied and assessed in the design of healthcare projects?
- How can circular design be integrated in the frame of a public procurement and which are, to date, the main barriers for such an integration?

1.2. Presentation of the case study: Joseph Bracops hospital

In 2018, the Iris South hospitals network (Hôpitaux Iris Sud – Iris Ziekenhuizen Zuid) launched a design competition to modernize the infrastructure of the Joseph Bracops hospital and provide a structured vision for the long-term redevelopment of the site (masterplan). The original hospital was built at the end of the nineteenth century on the outskirts of Brussels, in the municipality of Anderlecht. For over half a century it remained nearly unchanged as a suburban hospital, while the municipality of Anderlecht was developing around it, with among other things the creation of a public park and a football stadium located next to the hospital. In the last decades, the original hospital infrastructure was progressively replaced by new buildings without a long-term vision or masterplan, resulting in a very heterogeneous infrastructure with increasing functional issues. As of now, the hospital is fully integrated in a mostly residential neighbourhood surrounded by significant and qualitative green spaces. The competition was won by archipelago architects (B), in partnership with NU architectuuratelier (B) and BUUR (B) with a design that focuses on adaptability and circular construction principles.

2. Materials and methods

2.1. Application of circular principles in the design strategy

The new Joseph Bracops hospital has been designed starting from the macro-level (masterplan) to the micro-level (building components and materials), considering the building (meso-level) as an entity capable of evolving over time. Adaptability was one of the main drivers behind all design choices.
First, at the urban scale, the choice was made to favour the densification of the infrastructure to increase green, permeable land surfaces on the site, strengthening relations with the surrounding urban fabric and green spaces.

Second, at the scale of the Master Plan, the fundamental distribution and technical flows of the future infrastructure were established to allow all upcoming buildings to be integrated coherently regardless of the evolution of their programme or architectural features, in a phased reconstruction.
Third, at the scale of the individual buildings, the position of the vertical circulation cores and the choice of a structural system based on a modular grid have been studied so as to leave the plan as flexible as possible, to allow different configurations. Daylight availability was one of the key criteria for designing the building depth and position of the central patio, and technical solutions were favoured to maximize prefabrication and disassembly potential.

2.2. Circular principles assessment: the Reversible Building Design protocol tool

During the competition phase most of the design decisions were taken based on common sense, designers' experience and building simulations. The need was felt to objectify the adaptability and flexibility of the building. In consultation with Brussels Environment (the environment and energy agency of the Brussels Capital Region), the project development was intended as an interesting testcase for evaluating the potential for circular and reversible building design. In this context, the Reversible Building Design (RBD) protocol was applied in collaboration with its main author Dr. Elma Durmisevic of TU Twente University/4D Architects and Brussels Environment. RBD, which provides a multi-criteria analysis, has been developed during the Horizon 2020 research project BAMB2020 to guide the design of buildings and building products towards reversible solutions. RBD integrates time as a factor in the design brief which requires multiple use scenarios for building space and its materials [16]. As the RBD tool is under constant development, its application in the Joseph Bracops hospital was also seen as an opportunity to further refine the tool and to test its applicability in the Belgian/Brussels Region context.

The RBD tool focuses on two main aspects of circular buildings: the ability of a building to adapt to different functions during its lifetime and the ability to extract and exchange materials from the building, in both cases without the need for major reconstruction works, demolition and material loss. During the different design stages, several aspects are assessed (Figure 1). These are grouped under two main indicators of reversibility for a project: the Transformation Capacity (TC) and the Reuse Potential (RP). These are analysed by evaluating the Technical Reversibility (including the technical flexibility of system, product and materials) and the Spatial Reversibility (including the spatial flexibility of the building). During the preliminary design phase, the general dimensions as well as the position of core and load-bearing elements have a direct impact on the Spatial Reversibility, while during the definitive design phase and the technical design phase, the Technical Reversibility is most affected by the choice of materials and technical solutions. Spatial Reversibility has a higher impact than Technical Reversibility because it allows to extend the lifespan of entire buildings or building parts without the need to disassemble, reducing future efforts and energy inputs.

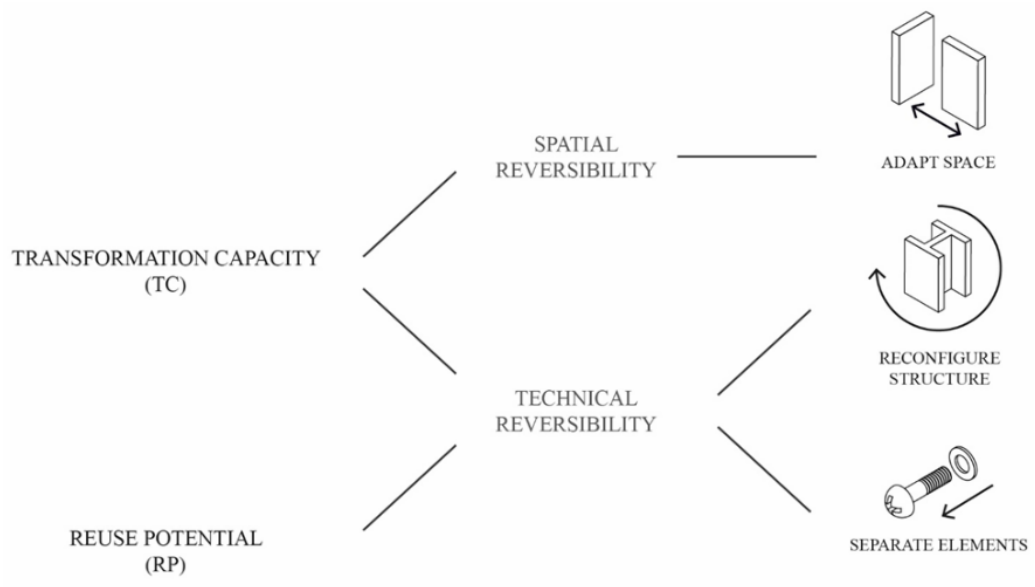


Figure 1. Reversible Building Design protocol scheme.

The TC score focuses on the ability of building space and structure to accommodate different functions without causing major reconstruction works, demolition and material loss. The less effort is needed to transform a building and the greater variety and number of modifications are possible, the higher the transformation potential will be. In this research we focus on the assessment of the TC of the building design. Four indicators determine the TC of the building: 1. capacity of the dimensions; 2. capacity of the positions; 3. disassembly capacity and 4. physical capacity. The project receives a total score based on the average of subscores for each indicator. The subscores are assigned based on sets of subindicators. For instance, the capacity of the 'block dimensions' indicator is evaluated through the type of structure, the unit dimension, the façade modularity and the maximum distance to a communication core. The capacity of core position is estimated through subindicators such as the integration of core elements, position of communication and service cores, distance between central core and distribution etc. The disassembly capacity considers the mutual integration or independence of different building components such as loadbearing elements and installation components. Finally, the physical capacity takes into account aspects such as load-bearing capacity of floors or space for distribution of services.

The Reuse Potential (RP) indicator measures the capacity of an assembly to be disassembled simply, fast and without damage, and thus reused. The assembly can be a small technological system as well as the whole building. It relies on aspects such as the compatibility and independence of its parts, and evaluates criteria such as functional and technical autonomy, modularity, base element position, assembly sequence, connection reversibility, component geometry and life cycle coordination.

2.3. Integration of circular construction materials in a public procurement

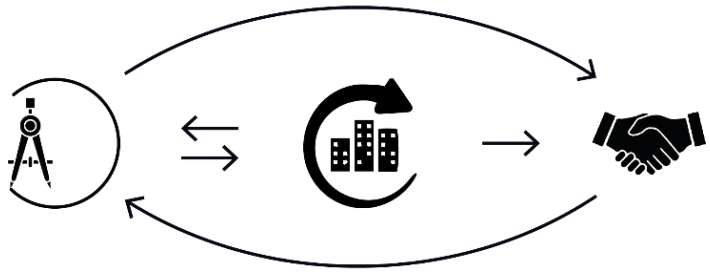
A literature review was carried out before drafting the public procurement tender documents. Databases such as Scopus or Google Scholar and the grey literature have been consulted using keywords such as: circular public procurement; circular building tendering, etc. The literature search included results in English and French. Only results related to the construction sector were selected.

The literature search was carried out to achieve the following goals: 1) find templates for clauses to understand how to prescribe specific technical solutions and 2) set criteria to select and compare offers beyond the economic performance.

Besides the analysis of the existing literature, a training led by Brussels Environment was followed. Its main topic was the integration of circular economy in a public procurement through the presentation of theorical and practical examples.

Finally, a semi-structured interview with a local construction company committed to CE has been organised to understand the major barriers that companies face when responding to a circular public procurement.

Process



Barriers

CIRCULAR DESIGN	RBD TOOL	PUBLIC PROCUREMENT
- Lack of client awareness - Prevalence of business-as-usual materials and construction methods	- Context based tool - Lack of automatization - Experimental tool	- Lack of literature on circular public procurement - Difficulty in determining selection criteria - Lack of construction companies with meaningful references - Financial pressure - Lack of a common framework for the material passport on a national scale.

Figure 2. Process and barriers

3. **Results and discussion**

3.1. Circular principles in the design of the Joseph Bracops hospital

The master plan is based on an open ended 'backbone' consisting of the dedicated medical link between the buildings and their circulation cores, on which different structures can be connected to anticipate the renewal or extension of the programme in later phases (Figure 3a).

The design of the first phase includes the construction of the new entrance of the hospital with a 7.000m² polyclinic building, the reconstruction of the operation rooms and imaging services which are directly connected to the existing wards, a new underground car park, and the demolition of six existing buildings. The rebuilt infrastructure will reach a total of approximately 15.000 m² in the first phase.

The flexibility of the new building is ensured by the modularity of the structure/plan and the standardisation of the components (from the facades to the interior furniture). Moreover, the building has been conceived as a set of layers with a different lifespan to facilitate the replacement of the components of which some will be most likely changed in a 5-to-10-year horizon, which is common in healthcare infrastructure.

The façade is made up of prefabricated wooden frames fixed to the concrete structure, covered by a demountable façade cladding made of small ceramic tiles. This process guarantees a high degree of adaptability in the long-term allowing the building to be easily modified for future use. In early design stages, several types of programmes were implemented as a theoretical exercise to check the feasibility of the adaptation in the medium or long term, such as: student or social housing, care home, etc. (Figure 3b).



Figure 3a. Masterplan scheme Bracops hospital by archipelago architects

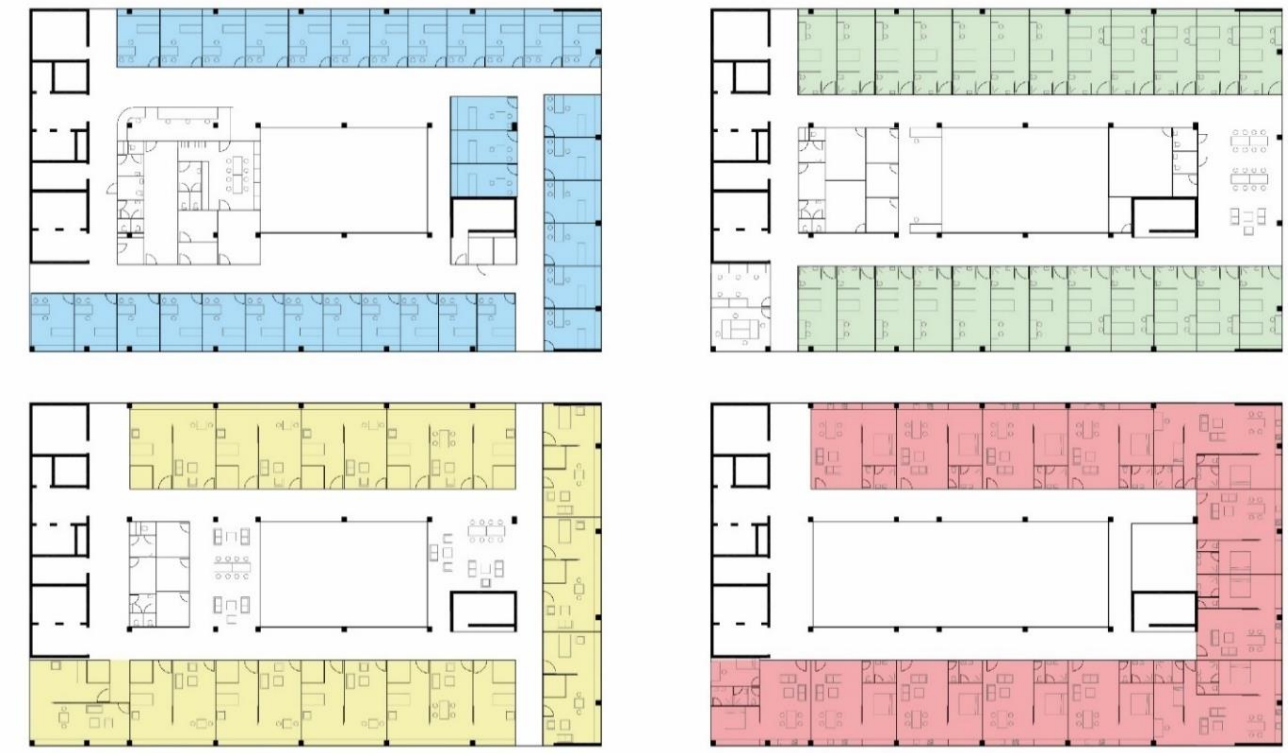


Figure 3b. Spatial reversibility: exploring alternative programmes for future potential use.
Top left: consultation rooms. Top right: care unit. Bottom left: care home. Bottom right: appartements.

All polyclinic floors are designed as "open plans" with a minimum of cores. They are organised according to a very clear zoning principle, which allows to differentiate uses and thus to ensure optimal adaptability of the programme. The choice of demountable partitions facilitates the dismantling of the areas which can be most likely modified in the short term.

The design of furniture also aims at standardizing the elements, which can be easily reconfigured according to changing needs, without generating waste.

Vertical circulation cores are placed in the periphery of the plan as well as sanitary supplies and drains. The pipes are laid out in a technical gutter located in the plinth of furniture placed in the perimeter of the building and the evacuations are taken up vertically along the structural columns to the basement. This configuration is designed to facilitate the dismantling of the partition walls since this is free of any sanitary facilities. The regular layout of the valves, usually centred on the windows, allows the connection and disconnection of sanitary equipment, according to a "plug and play" principle supporting the evolution of the system and the changing needs (Figure 4).

Finally, technical equipment fixed to the ceiling of standard rooms is gathered in a prefabricated suspended box/ceiling island that leaves concrete slabs accessible for thermal inertia and facilitates the reconfiguration of partition walls, if necessary.

All these design choices are consistent with the goals of circular building design such as maximizing the use of available resources, reducing waste production and environmental impacts [17].

Besides, energy and water cycles have been narrowed and closed as much as possible. Energy demand for heating and cooling is mitigated through a carefully designed building skin, with a high insulation level, a well elaborated window-to-wall ratio and external dynamic shading. Daylight harvesting is optimised through iterative simulations on the position and dimensions of the patio and windows. The electric consumption of the ventilation fans and the cooling load are reduced through the integration of natural ventilation in the public spaces and standard rooms. The performance of all these elements has been thoroughly tested and simulated with dynamic models. Combined with solar energy harvesting with photovoltaic panels on the roof, the building reaches a NZEB (Nearly Zero Energy Building) performance.

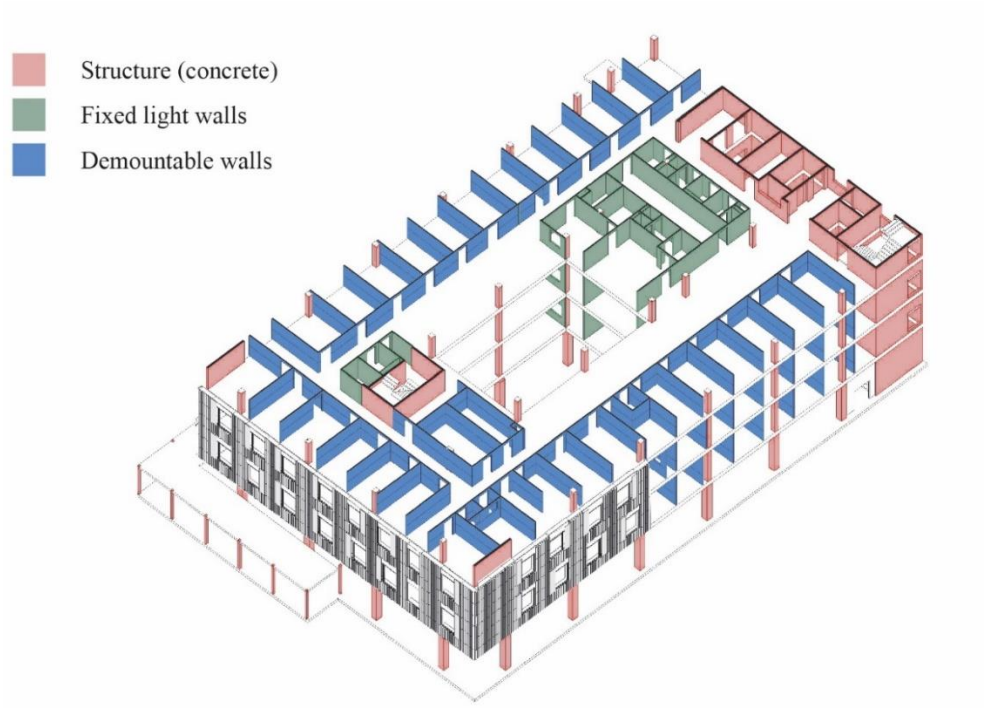


Figure 4. Technical Reversibility – Transformation Capacity. Configurable walls and adaptable façade Bracops hospital.

3.2. Assessment: the total score of the Reversible Building Design (RBD) protocol tool

The design decisions described above were discussed, validated and optimised with the RBD protocol team during three workshop sessions. Stepwise, from the preliminary design phase, the design team has communicated data about the design to the RBD protocol team. During the workshops, feedback on these data was provided and improvements discussed. Afterwards these improvements were assessed with the RBD. In this way the design has been iteratively optimised.

The project received a total score of 0.77 (on a maximum of 0.90), an average score between Spatial and Technical Transformation. According to the RBD protocol total scores in a range between 0.66-0.90 represent transformable and reversible buildings which can change functionality and configuration without demolition.

However, the application of a quantitative tool as the RBD demands the necessary caution and common sense. Not all of the feedback from the RBD could directly be integrated into the design. Sometimes the conclusion of the RBD assessment was counter-intuitive and needed to be interpreted. This was also part of the testing and improvement scheme of the RBD tool itself. Some of this counter-intuitive feedback originate from the Dutch background of the tool, which is in its current version based on the Dutch building practise and building market. A future adaptation towards local context seems relevant, starting with the adaptation of the Transformation Capacity (TC) tool to the context of the Brussels Region. The used workflow seemed cumbersome, as the design data needed to be sent to the RBD team, who processed the data and gave feedback in the workshops. This often resulted in a mismatch between design and assessment process. To be usable in a design practise the tool should be automatised so the assessment can be done in real time. This topic was explored in the BAMB2020 research by the development of the Circular Building Assessment tool, which has been developed to the level of a prototype.

3.3. The public tender criteria and main barriers

There is a limited body of literature on circular public procurement [18] which, according to the European Commission can be defined as “the process by which public authorities purchase works, goods or services that seek to contribute to closed energy and material loops within supply chains, whilst minimizing, and in the best case avoiding, negative environmental impacts and waste creation across their whole life-cycle” [19]. This definition incorporates the former concepts of green and sustainable procurements and raise the level of complexity in public procurement compared to traditional scenarios based on purchase at the lowest up-front price [18].

The integration of circular principles in a public procurement should be facilitated by policies and a global strategy [15]. In the case of the Joseph Bracops hospital, a CE strategy was set up according to three aspects: architecture, site management and data management. ‘Architecture’ includes reversible design and materials selection; ‘site management’ includes the management of construction and demolition waste; ‘data management’ involves all the aspects linked to the BIM management and the material passport. Reversible design, which has been described in paragraph 3.1., must be translated in the procurement prescriptions through the proper selection of materials and construction methods. The main selection principles are: precautionary principle (choice of homogeneous materials, separable composite materials etc.); eco-design principle (choice of healthy, local and renewable materials); and the reversibility principle (choice of reversible components, prefabrication, demountability of materials etc.) [20]. Based on these principles, the first step is to select the materials in the project which have the most important circular and sustainable potential, depending for example on quantities, location or use. For those materials, a search for references must be done. It’s a primary concern that these references should be clear and easy understandable for the client and for the contractor. The contractor needs to know if the product he proposes complies with the demands of the tender. The client and architect in charge need to be able to efficiently assess if the proposed material is compliant. Hence the choice has been made to prescribe type I Environmental Declarations (ISO 14024), e.g. technical sheets, ecolabel criteria, etc. Prescribing certifications or eco-labels can help public procurers to define their requirements regarding durable and circular products. The advantage of the type I Environmental

declaration is the external control and certification of the products, which can assure the client of the envisioned properties of the product. Certifications or labels must be prescribed among a range of possible choices available, and they will help to compare technical solution and/or assessing award criteria. For instance, some specific requirements can consist of the quantity of recycled materials, emissions or pollutant content. Ambitions for circularity and sustainability can be presented in the general introduction of the procurement and then specified article by article. In this case study a document specifying the requirements for materials titled "Sustainable sourcing plan" has been added in annex. However, in the hospital environment, the choice of materials is often guided by business-as-usual criteria which hamper the choice of certain materials, amongst which most bio-based materials, and of certain demountable construction methods. A critical revision of those business-as-usual criteria could facilitate the application of new technical solutions while keeping the hygiene standards.

Site management plays a key role in the generation and disposal of construction and demolition waste. Specific clauses must be included in the tender relating for example to selective waste sorting; recovery of offcuts; the involvement of social economy enterprises which can take care of specific tasks such as the collection of site's waste; implementation of prefabricated systems; industrial symbiosis among companies to recover certain types of waste, etc. These prescriptions must be coordinated with the company managing the logistics and security of the site and included in the administrative clauses.

In the case of demolition, the building can be dismantled to ensure selective waste sorting or reuse. In the project, an inventory of potential materials in the buildings which will be demolished with reuse potential, was made during the design phase. Even if the potential for material reuse is not high (as in this case study), a clause indicating how to dismantle and store recovered elements is essential.

Data management is based on a BIM protocol annexed to the procurement, which aims to improve the traceability of materials and components, as well as to deliver a 3D model in accordance with the as-built status. This can be achieved with an effective codification of building components linked to data sheets and certifications. In this case study, the material passport was not developed, partly because, to date, the material passport is still at initial development stage in Belgium and abroad and still lacks a solid, future-proof common framework [21].

Even if the public circular procurement of the Bracops hospital has not been launched to date, some barriers can already be foreseen. First, the financial pressure, i.e. the perception that products and services based on circular principles involve an higher price [22]. This can be overcome through supportive policies and legislation which can push public organisations to implement circular public procurement [18]. Reluctance to incur higher cost is often coupled with the lack of awareness by clients and the lack of a long-term perspective [23].

In term of prescription of technological solutions, the measures taken in this case study have been presented above. Despite the use of certifications or eco-labels, it remains difficult to define unambiguous criteria for comparing and guiding choices. For construction companies, presenting references for circular construction projects as a selection criterium for public tenders is a challenge since it is an emerging sector. To overcome this barrier, the procurers can evaluate the skills of the team presented by the company.

4. Conclusions and outlook

Now more than ever healthcare buildings need to cope with changing needs. Flexibility of buildings is essential not only from a circular perspective but also to respond to social needs as the Covid crisis has recently shown us. The case study of the Bracops hospital addresses the following research topics: How can circular principles be applied and assessed in the design of healthcare projects? How can circular design be integrated in the frame of a public procurement and which are, to date, the main barriers for such an integration?

The application of circular principles in the design has been studied from the masterplan analysis to the choice of building components and materials, considering the building as an evolving entity, conceived as a set of layers with a different lifespan. The flexibility of the new building is ensured by the modularity of the structure/plan; the standardization of the components (prefabricated façade system,

modular interior furniture etc.); the peripheral position of vertical circulation cores and sanitary supplies and drains; and the use of demountable partitions. This design strategy has been tested and optimised through the RBD protocol which provides a multicriteria analysis to test multiple use scenarios for building space and materials. However, the tool, which has been developed based on the Dutch building sector, should be more adaptable to other contexts and more automatised to ensure a real time assessment by the design practise. The adaptation of the Transformation Capacity (TC) tool to the context of the Brussels Region is already an ongoing project.

In order to integrate circular design in the frame of a public procurement, a policy support and a global strategy are essential. In this case study, a strategy was set up according to three aspects: architecture (design and materials selection), site management (management of construction and demolition waste) and data management (BIM management and material passport). Even if the public circular procurement of the Bracops hospital is still ongoing, some barriers have been already foreseen, such as: the financial pressure; the lack of awareness and of a long-term perspective by the client; the lack of references for circular construction projects by the construction companies; the difficulty of determining criteria for comparing technical solutions and the lack of a solid common framework for the material passport on a national scale.

The Flemish and Brussels public administration take an active role in setting up frameworks between the different stakeholders in which knowledge and pilot cases can be developed. This effort should be continued. Recently the Flemish administration has shifted gear and developed a new, focused approach, consisting of 6 thematic strategic agendas, amongst which 'circular construction' and works on 7 strategic levers to overcome barriers and spreading good practices. 'Circular procurement' is one of these levers. Central governance and coordination will be taken up by a Transition Manager [24].

More collaborative projects amongst industry-academia and dedicated research funding to capacity building in the industry can help to push the knowledge to the field. In this context the authors want to refer to the initiatives taken in the UK, where five UKRI National International Circular Economy Research Centres were established, amongst which one on construction materials, to bridge the practice-academia gap [25]. The Circular Economy Research Hub, acts as a central platform, connecting these Research Centres [26].

The Joseph Bracops hospital is a pilot and ongoing project which aims to contribute to the creation of a framework for circular design in healthcare projects. The research on this project, which provides a comprehensive approach from design to technical prescriptions, has revealed a lack of structured research on the subject and of tested assessment tools. Future work might contribute to improve this framework taking the Joseph Bracops hospital and its evolution as a benchmark in order to help overcome the identified barriers and to encourage more collaborative projects across industry-academia.

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