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RESEARCH ARTICLE

Strategic Urban Projects through the Lens of Circularity: The Case of Masterplans in the Brussels Capital Region

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Abstract

This article explores how circularity principles are integrated into urban design and planning, with a focus on Strategic Urban Projects (SUPs) in the Brussels Capital Region (BCR). It examines the role of the *Plan d'Aménagement Directeur* (PAD, in English simply 'regulatory masterplan') as both a regulatory and strategic urban design and planning instrument for embedding circularity-driven ambitions within urban transformation processes. Through a comparative analysis of three such master plans as carefully selected case studies, the research examines the main question: how planning instruments, stakeholder dynamics, and urban design strategies contribute to more circular, resource-conscious, and inclusive urban development. The study draws on a literature review, semi-structured interviews, urban design analysis, and a simplified methodology to estimate the weight of construction material stocks and flows moved or preserved in each project and its scenarios.

Findings show that *circularity*-inspired ambitions introduce a critical shift by decelerating urban transformations. This shift reveals an inherent tension between urban planning practices that tent to mainly focus on transformation, and *circularity*'s call for a slower pace of change in the physical layout of urbanity. Negotiating this friction is crucial, as it necessitates balancing urban development objectives with the ecological impacts of transformations. The study underscores the importance of integrating top-down policies with bottom-up civic engagement and academic research to foster a pluralistic approach to *circular* urbanism. Thus, through this analysis, the article advances the hypothesis that SUPs can serve as experimental platforms for advancing *circular* paradigms, while acknowledging the challenges of operationalising *circularity* in practice.

Keywords Urban Planning · Urban Circularity · Circular Cities · Circular Urban Regeneration · Brussels · Inclusivity · Spatial Practices · Sustainable Urban Design

1. Introduction

In recent years, Western post-industrial cities have increasingly embraced the principles of the circular economy (CE) as part of their urban transformation agendas. Despite this growing interest, urban planning practices remain rooted mainly in linear models, with limited tools to assess the material and ecological implications of development processes. This disconnect has prompted calls for more integrated approaches that account for the quantities of resources, materials, and waste mobilised by urban change. In urban planning debates, several key concepts and ambitions mobilising *circularity* have emerged, including 'circular cities' (Williams, 2021), 'urban circularity' (Marin and Meulder, 2018; Verga and Khan, 2022), 'circular urbanism' (Grisot, 2021), the 'circularisation of territorial metabolism' (Kampelmann, 2017; Athanassiadis *et al.*, 2018;

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Christis, Athanassiadis and Vercalsteren, 2019), and the 'territorialization of circularity' (Amenta, Russo and van Timmeren, 2022; Furlan *et al.*, 2022). These frameworks reflect a growing academic and policy interest in embedding circular principles into urban systems and in urban design and planning practices.

Urban Circularity (UC) is used in this article as a critical lens to question and rethinking planning and design practices. Rather than a fixed design strategy, UC builds on existing scholarship (Marin & Meulder, 2018; Verga & Khan, 2022a; Verga & Khan, 2022b; Bortolotti, Verga & Khan, 2023) and shifts the focus from closing material loops to examining how urban transformations mobilise resources, generate waste, and impact human and ecological systems. It calls for more frugal (Arnsperger and Bourg, 2016), resilient, and just spatial practices that prioritise the preservation and adaptive reuse of existing material configurations, challenging the dominant demolition-reconstruction paradigm (Pomponi and Moncaster, 2017; Hart *et al.*, 2019; Joensuu, Edelman and Saari, 2020; Çimen, 2021; Verga and Khan, 2022a; Sala Benites, Osmond and Prasad, 2023; Zhang, Gruhler and Schiller, 2023). In a nutshell, *circularity* is increasingly used to question how urban contexts are transformed more generally, paying closer attention to the movements of the materials involved and the ecological impacts they have (including extraction, production, logistics, disposal, etc.). This perspective shifts the focus from more technological challenges (i.e., efficiency-driven) to more cultural and institutional challenges (i.e., sufficiency-based), aiming to fulfil people's foundational needs while considering overall material flows and ecological impacts.

This article focuses on the meso-scale of urban transformation (districts and neighbourhoods), where strategic planning intersects with design implementation. Despite its relevance, this scale remains underexplored compared to city-wide or building-level approaches (Appendino *et al.*, 2021; Soto, Thomson and Uti Nchor, 2024; Pekdemir, Guaralda and Limb, 2025). By examining Strategic Urban Projects (SUPs) in the Brussels Capital Region (BCR), the study aims to bridge the gap between theoretical frameworks and practical applications of circularity in urban design and planning. This approach enables a context-based and nuanced exploration of urban planning and socio-political processes, thereby grasping the frictions and potential of deploying circularity-inspired ambitions and strategies in SUPs.

Brussels has positioned itself as a leader in *circularity*-driven urban policy, notably through the Circular Economy Regional Plan (2016–2020) and the Shifting Economy programme (2022–2030). While early initiatives focused on economic sectors and material reuse, recent efforts have expanded to include spatial and ecological dimensions. Central to this shift is the adoption of the *Plan d'Aménagement Directeur* (PAD, or in English normative master plans), a hybrid planning tool that combines strategic vision with regulatory authority, enabling more precise guidance of SUPs.

This article investigates how *circularity*-inspired ambitions are embedded in SUPs through planning instruments, stakeholder engagement, and design strategies. In this article, SUPs are analysed through three case studies, each corresponding to a BCR's master plan. These three cases studies highlight how these projects operationalise *circularity*, who drives these agendas, and what factors support or hinder their implementation. The study also reflects on the potential of SUPs to serve as experimental platforms for advancing *circular* urbanism. By focusing on case studies of urban projects, researchers can deepen the links between strategic planning and project implementation, as these projects serve as experimental grounds (Appendino *et al.*, 2021). Urban design is an interdisciplinary field, and the process of design(ing), at the core of the planning discipline, involves relating general principles to site and program requirements, which are always context and time-dependent (Carmona and Tiesdell, 2007).

The main objective of this article is to study the material and ecological implications of urban transformations and to understand the socio-spatial processes shaping them, including design factors and urban planning strategies. To achieve this, the study addresses four interrelated research questions: What is the planning landscape in the BCR and which urban planning tools and strategies are being used in SUPs to support circularity-inspired agendas? How do current SUPs integrate circularity ambitions and which design approaches and variables (such as density, typology, material intensity and floor area ratio) influence these projects? Who is driving the circular agenda in urban planning and design? What factors encourage or hinder the adoption of circular paradigms in SUPs?

To answer these questions, the article combines theoretical ideas from international literature with empirical analysis of three BCR case studies. The research investigates four key aspects emerging from the research questions: (i) the implementation of *circularity*-inspired ambitions in urban transformation projects; (ii) the stakeholders driving these initiatives; (iii) the analysis, evaluation, and operationalisation of *circularity*-oriented strategies; and (iv) the site-specific and project-specific urban morphologies, planning processes, and broader design factors influencing each project's development. The research identifies the key players, challenges, and drivers of these projects, providing a clearer understanding of how *circularity* is integrated into urban transformations. Through case analysis, the article highlights the forces driving the move towards *circularity*, including strategies, actions, and socio-economic and spatial consequences. It also addresses how to support more inclusive *circular* urban designs and projects.

After this introduction, Section 2 outlines the materials and methods used. It analyses the planning ecosystem in BCR, identifying the most commonly used planning tools to drive SUPs while facilitating the integration of *circularity*-inspired ambitions. In the materials sub-section, the three case studies of SUPs are briefly described. Section 3 presents the results of the in-depth analysis based on semi-structured interviews and desktop research. It focuses on the analysis of three SUPs, offering an understanding of how *circularity* ambitions are integrated into these urban projects, including how *circularity* is understood and materialised, by whom, for whom, and why. It also inquires the drivers and barriers to its deployment. Section 4 presents a comparative analysis of the findings from each case and discusses them in relation to the research questions. Finally, Section 5 provides the conclusions and suggests avenues for further research.

2. Methods and materials

2.1. Methods

This research mobilises a mixed-methods approach, combining theoretical insights from international literature with empirical analysis of three case studies: SUPs in the BCR. The methodology is rooted in urban planning and design disciplines, integrating spatial, regulatory, and material dimensions of strategic urban transformations at the neighbourhood or district scale, where planning and design decisions directly influence spatial configurations, material flows, and socio-ecological dynamics. *Circularity* is used as an analytical lens to examine how circularity-oriented ambitions are embedded in urban design through the development of SUPs, with particular attention to material aspects. The research integrates findings from case studies with regional planning debates and international academic literature through three primary methods: (i) a review of scholarly literature, (ii) case studies analysis, (iii) desktop analysis of planning documents (from the regional planning agency) and grey literature (including NGO publications and press releases), and (iv) semi-structured interviews with public officials and experts in *circularity*. Additionally, a (v) typo-morphological and material stock and flow analysis (MSFA) was conducted to assess the spatial and architectural characteristics of each case study (SUP), enabling a comparative evaluation of physical features in relation to interview data and literature findings. Also, a final (vi) comparative analysis is developed to structure the discussion section. The combination of these approaches supports a robust interpretation of circularity ambitions and their practical implementation in both regional and international contexts.

The literature review was conducted using Scopus, applying the search string: "*circularity* OR circular AND city OR neighbourhood OR urban AND project OR development OR transformations OR masterplans" AND "urban planning" OR "urban projects". The search, performed in June 2025, yielded 111 English-language documents. After screening titles and abstracts, 25 articles were selected for further analysis. To complement this, the AI-based tool Elicit was used to refine research questions related to *urban circularity*, *circular cities*, *urban planning*, and *masterplans*. Initial queries retrieved four articles per question, later expanded to over 60, ranked by relevance. From each iteration, 20–30 articles were shortlisted and screened based on title, domain, citation count, and abstract relevance. This process resulted in 41 peer-reviewed articles, categorised according to four research questions (see Table 1). After integrating all sources, a final set of 58 articles was analysed in depth. Exclusion criteria included insufficient relevance to *urban circularity*, *circular cities*, or neighbourhood-scale planning.

Table 1. Overview of the research questions and the articles reviewed in the scoping literature review for this article, by the authors.

Literature review Scopus	Literature review Elicit RQ 1	Literature review Elicit RQ 2	Literature review Elicit RQ 3	Literature review Elicit RQ 4
Research of articles and book chapters using: "circularity OR circular AND city OR neighbourhood OR urban AND project OR development OR transformations OR masterplans" AND "urban planning" OR "urban projects".	In peer-reviewed article on the debate on urban circularity, circular cities and circular economies applied to urban design and urban planning and neighbourhoods or masterplans, which urban planning tools and strategies are being used in Strategic Urban Projects to support circularity-inspired agendas?	How do current Strategic Urban Projects integrate circularity ambitions? Which are the design strategies and variables (density, typology, material weights/intensity, FAR, open-to-buildup area ratios, etc.) that influence their implementation?	Who is driving the circular agenda? Who are the stakeholders (and the winners and losers) in circular urban planning and design?	What factors are encouraging or hindering the adoption of circular paradigms in Strategic Urban Projects?
28 articles selected out of 111	13 articles selected out of 20	11 articles selected out of 20	9 articles selected out of 30	8 articles selected out of 20

The case study method was chosen for its capacity to integrate practice and theory, aligning with the exploratory nature of this research (Leising, Quist, and Bocken, 2018). Case study research is a widely used methodology in the fields of architecture, urban design, and planning, particularly for topics in their initial exploration phase and inherently complex. Circular city transitions pose wicked problems—structurally complex issues with no clear solutions or goals, often remaining unresolved or having multiple solutions (Marin and Meulder, 2018). Appendino et al. (2021) also used case studies to explore the implementation of circularity strategies across different cities. Yin (2009) defines a case study as an empirical enquiry into a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and its context are unclear. Based on a summarising table of all key SUPs (see the table in Annex 2) and the outcomes of semi-structured interviews with a convenience sample of stakeholders and experts, three SUPs were selected as case studies following three main criteria: (i) commitment to *circularity* as a key ambition, (ii) importance as a milestone in the BCR trajectory in exploring the *circularity*-inspired strategy in urban planning and design, and (iii) accessibility to the data and experts who were interviewed to carry out the projects. The three case studies also present SUPs with different scale, urban context and morphologies, programs, and different evolution over time.

Seven semi-structured interviews were conducted between January and April 2024 and explored SUPs integrating *circularity*-inspired ambitions. At first, participants were asked to indicate a specific project they were familiar with and that they had some interest in embedding circularity-inspired ambitions. The form combined open-ended questions with multiple-choice items, allowing respondents to elaborate freely while also enabling structured comparison across cases. Open-ended questions invited participants to describe the selected SUPs, including its location, urban morphology, existing infrastructure, and development process, the project's ambitions, the types of interventions undertaken, and the programmatic needs. Multiple-choice questions structured responses around key dimensions such as stakeholder composition (public, private, or mixed), the socio-demographic profile of intended end-users, and the nature of the site (e.g. brownfield, suburban, central urban fabric). Additional closed questions addressed sustainability and circularity ambitions, as well as circular design and construction strategies. The form also included a section on the project lifecycle, asking participants to indicate the phase in which circularity was most emphasised, spanning feasibility and design through execution to long-term use. Further questions assessed enabling and constraining factors, such as stakeholder motivation, regulatory frameworks, technical capacity, and the availability of assessment and monitoring tools. These were presented using Likert-scale items, allowing respondents to rate the impact of each factor from "very negative" to "very positive." Based on these subjects, a comparative framework was applied to facilitate comparative analysis of the shortlisted SUPs researched as case studies.

Table 2. Overview of the convenience sampling interviewed.

Interviewees	Public administration officials responsible for developing SUPs in Brussels	Researchers and Belgian Urban Circularity experts
Number of semi-structured interviews conducted	4	3

The authors then undertook desktop research first, and then a typo-morphological analysis of the projects, drawing upon publicly available documents and findings from the semi-structured interviews. Drawing on urban design and planning disciplines, a first framework was developed based on a typo-morphological analysis was applied to each case: an analysis of key-design factors. This included the study of spatial configurations, building typologies, density, FAR (floor area ratio), and open-to-built ratios. The second framework focused on design strategies and MSFA, providing a quantitative and spatial understanding of material intensity and transformation approaches. The MSFA applied in this study operationalises the notion of Urban Metabolism (UM) by quantifying how SUPs mobilise material stocks and flows, thereby revealing their impact on the regional construction material balance, and circularity objectives (Ooghe *et al.* (2023). Therefore, the material intensity of SUPs was assessed using a simplified methodology developed by Ooghe et al. (2023), based on Environmental Impact Reports (EIRs) and spatial plans. This included estimating inflows and outflows of construction materials (in tons/m2) and evaluating scenarios based on demolition, renovation, and new construction.

Case studies were also assessed for their approaches to transformations (whether maintaining, reusing, or adapting existing structures) and their relationship between programme and form. This analysis integrated design-based quantifications with qualitative reflections on the specific characteristics of each project. The analysis also considered the influence of site-specific planning and design decisions on the overall impacts associated with construction material flows. MSFA indicators included the proportion of existing structures retained or demolished, material inflow and outflow per square metre, and total material movement per hectare.

The weight of the existing building stock and demolitions is estimated to range from 1.6 to 1.7 tonnes per square metre, depending on building typology. In calculating the 1.6/1.7 ratio, assumptions were made based on the typological characteristics of the built environment under study. Specifically, most buildings analysed are medium- to high-rise structures constructed using reinforced concrete or solid brick. The estimated mass of new construction is 1.8 tonnes per square metre. Regarding renovations, lightly renovated scenarios are estimated to weigh one-fourth (1/4) of the weight of demolitions of the existing building stock (1,6-1,7 tons/m2) and one fourth of the weight of new construction (1,8 tons/m2), while heavily renovated scenarios are estimated to weight half (1/2) of the weight of demolitions and new constructions. These metrics provided insight into the environmental impact, resource consumption, and waste generated by each redevelopment scenario. Together, these frameworks enabled a comprehensive comparative analysis, combining qualitative insights on stakeholder dynamics and strategic ambitions with quantitative data on material performance and design choices. This dual approach facilitated a nuanced understanding of how circularity is conceptualised and operationalised in distinct urban redevelopment contexts, highlighting both strategic intentions and material consequences.

The comparative methodology employed in this study integrates the two analytical frameworks to discuss *circularity* in urban redevelopment projects. The first framework is based on structured tables synthesising findings from semi-structured interviews and document analysis. Each case study is presented in the Results section through a dedicated table, divided into three parts to ensure clarity and comparability across projects. The first part summarises sustainability ambitions, the second outlines circularity ambitions, and the third provides an evaluation of factors influencing the implementation of these ambitions. This framework aimed to understand how *circularity* is interpreted across different urban contexts, which strategies are explicitly associated with *circularity*, which overlap with broader sustainability goals, and which actors are actively promoting the circular agenda. It also identified key levers and barriers to implementation. Evaluation criteria were applied using a symbolic scale (from “+++” to “- - -”) to present first the results of case studies analysis and the to assess the relative influence of ambitions (e.g., ecological, economic, energy-related), stakeholder engagement (e.g., public authorities, designers, researchers, private developers), and systemic challenges (e.g., underdeveloped value chains, lack of monitoring tools, regulatory rigidity). The second framework used for comparison focuses on typo-morphological elements and the quantification of key variables that indicate the quantities of construction materials mobilised per project. Presenting results in this way enables readers to quickly grasp the ambitions and strategies of each project and to understand the enabling or constraining factors that shape their implementation.

2.2. Materials

2.2.1. Urban planning and design landscape in Brussels Capital Region

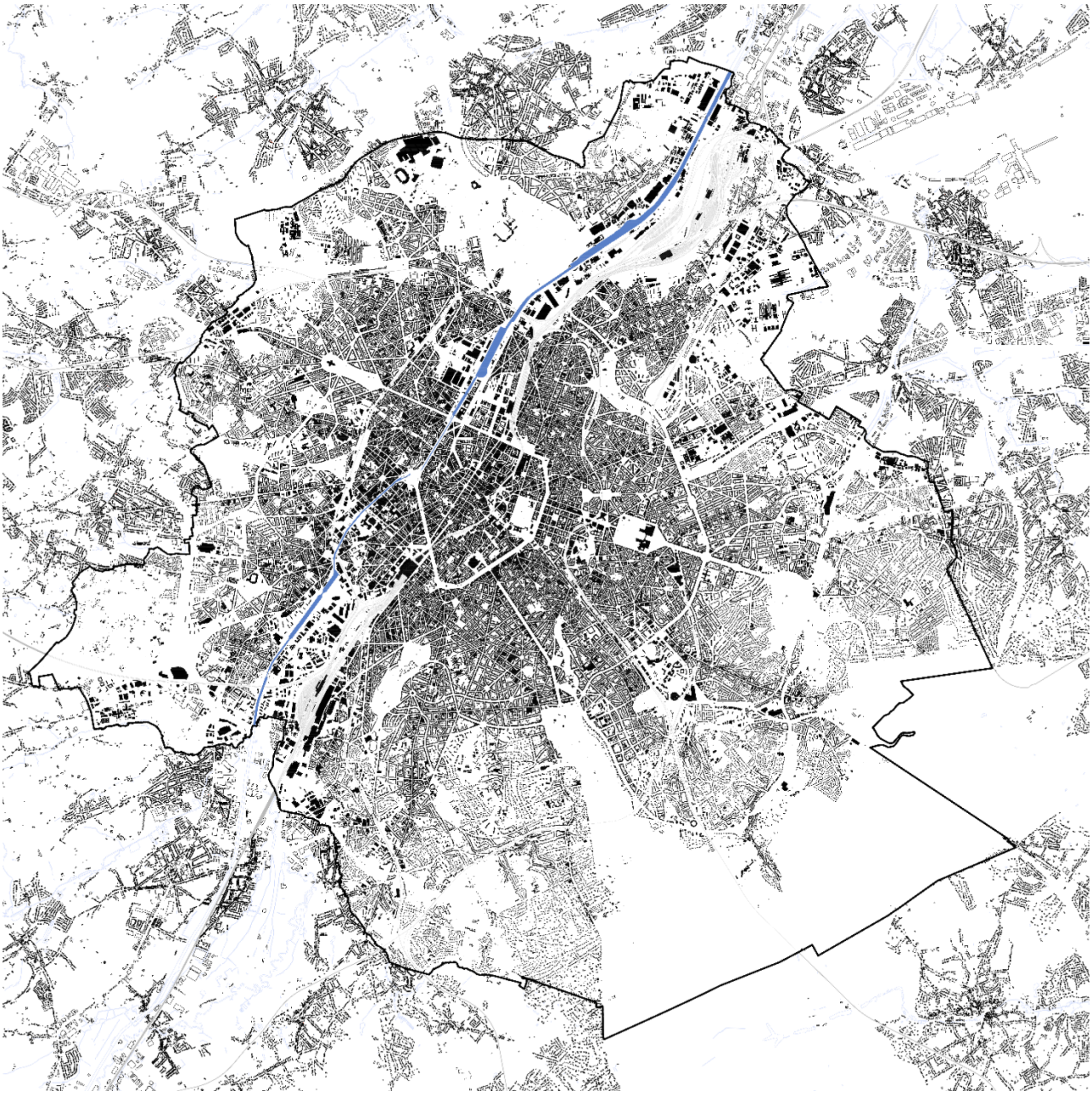

Figure 1. A map of the Brussels-Capital Region (BCR) and its surroundings, showing the built environment and waterways as empty-void spaces. The black perimeter delineates the BCR, while the adjacent areas in the Flemish Region are also included. By the authors (2025).

The Brussels Capital Region is composed of 19 municipalities and is surrounded by the Flemish region. It has 1.25 million registered residents and over 400,000 daily commuters, with many additional unregistered inhabitants. With a population density of 7,642 inhabitants per km², space for new development is increasingly scarce, while housing costs continue to rise, contributing to significant social inequalities, particularly in access to affordable housing. In response to these challenges, and to address the uneven distribution of environmental quality and climate risks, regional authorities have prioritised the development of more dwellings, and the improvement of green infrastructure, water management, and biodiversity, as outlined in the Regional Sustainable Development Plan (PRDD). Another key agenda is supporting the 'productive city,' which promotes local economies, including circular economies, and re-localises urban metabolic functions. This involves bringing activities such as urban agriculture, composting facilities, manufacturing, salvage activities, and waste treatment closer to urban centres, where resources are consumed, and waste is produced. This model aims to minimise ecological footprints and reduce external dependencies through circular and reverse logistics value chains, and more efficient resource and waste management. However, these agendas often compete for limited land and resources, necessitating complex trade-offs and negotiations (Verga and Khan, 2022b; Baumgartner, Bassens and De Temmerman, 2024). **Figure 1** presents a map of the BCR and its surroundings, highlighting the built environment and waterways. The boundary of the BCR is clearly marked, and adjacent areas in the Flemish Region are also included.

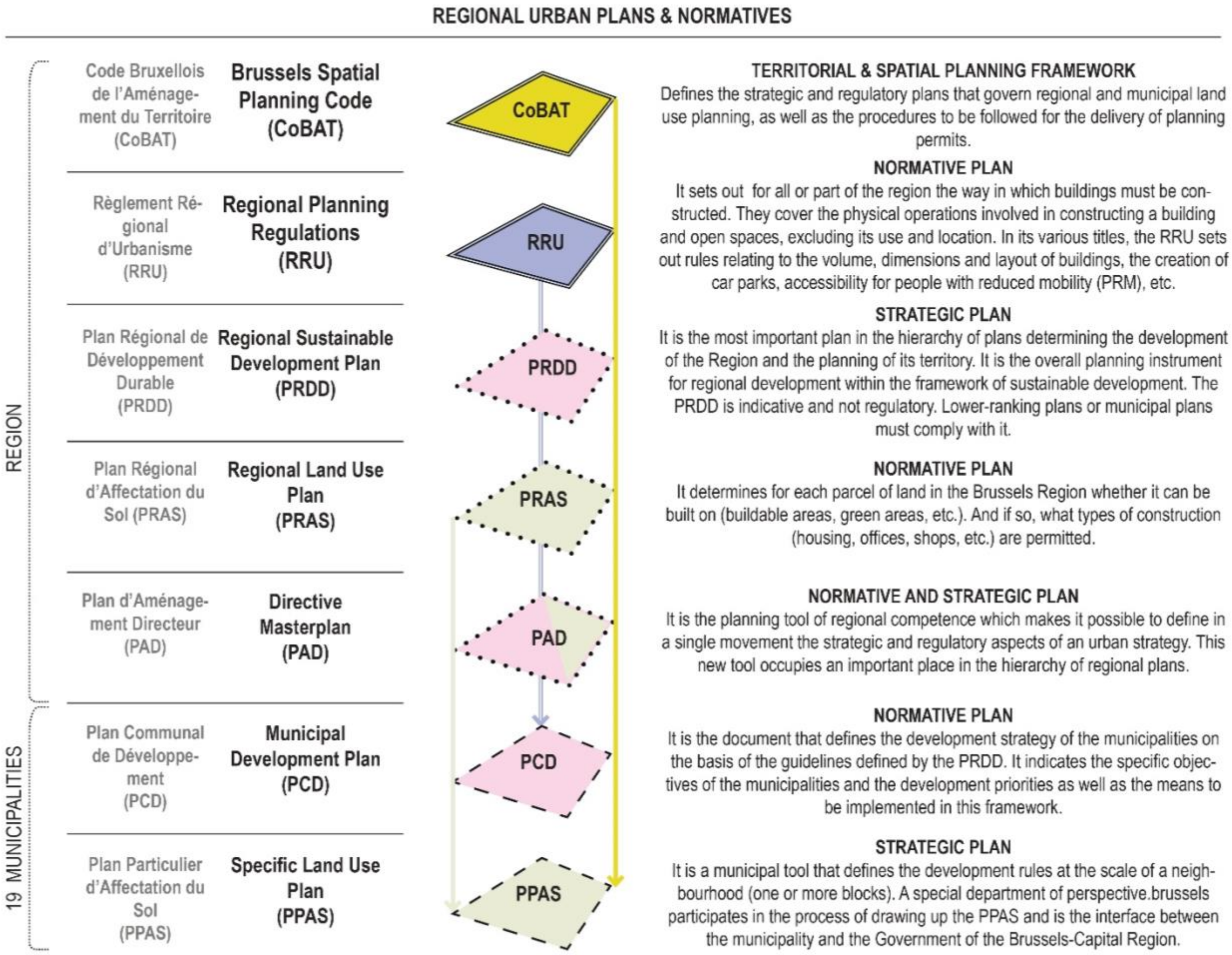

Figure 2. Scheme summarising Brussels Capital Region's (BCR) planning tools, by the authors (2025).

The urban planning and design (UPD) landscape in the BCR is structured through a hierarchical system of legislative, normative, and strategic instruments that cascade from the regional to the municipal scale, with the *Plan d'Aménagement Directeur* (PAD) acting as a hybrid tool bridging these levels. At the top, the *Code Bruxellois de l'Aménagement du Territoire* (CoBAT) defines procedures for land use and planning permits, while the *Règlement Régional d'Urbanisme* (RRU) establishes binding rules for building dimensions, accessibility, and spatial layout. Beyond its technical function, the RRU can serve as a critical lever for *circularity* by embedding requirements that favour less disruptive and resource-conscious approaches, such as renovation over demolition, thereby influencing all building permits across the region. Strategically, the *Plan Régional de Développement Durable* (PRDD) sets the long-term vision, while the *Plan Régional d'Affectation du Sol* (PRAS) translates this vision into land-use designations. At municipal level, the *Plan Communal de Développement* (PCD) and *Plan Particulier d'Affectation du Sol* (PPAS) localise strategies and zoning regulations, providing the regulatory substrate for implementation. For a more comprehensive understanding of urban planning tools and strategies in the BCR, see **Figure 2**, which highlights the regulatory and strategic tools. It illustrates the hierarchical and functional structure of Brussels' urban planning instruments.

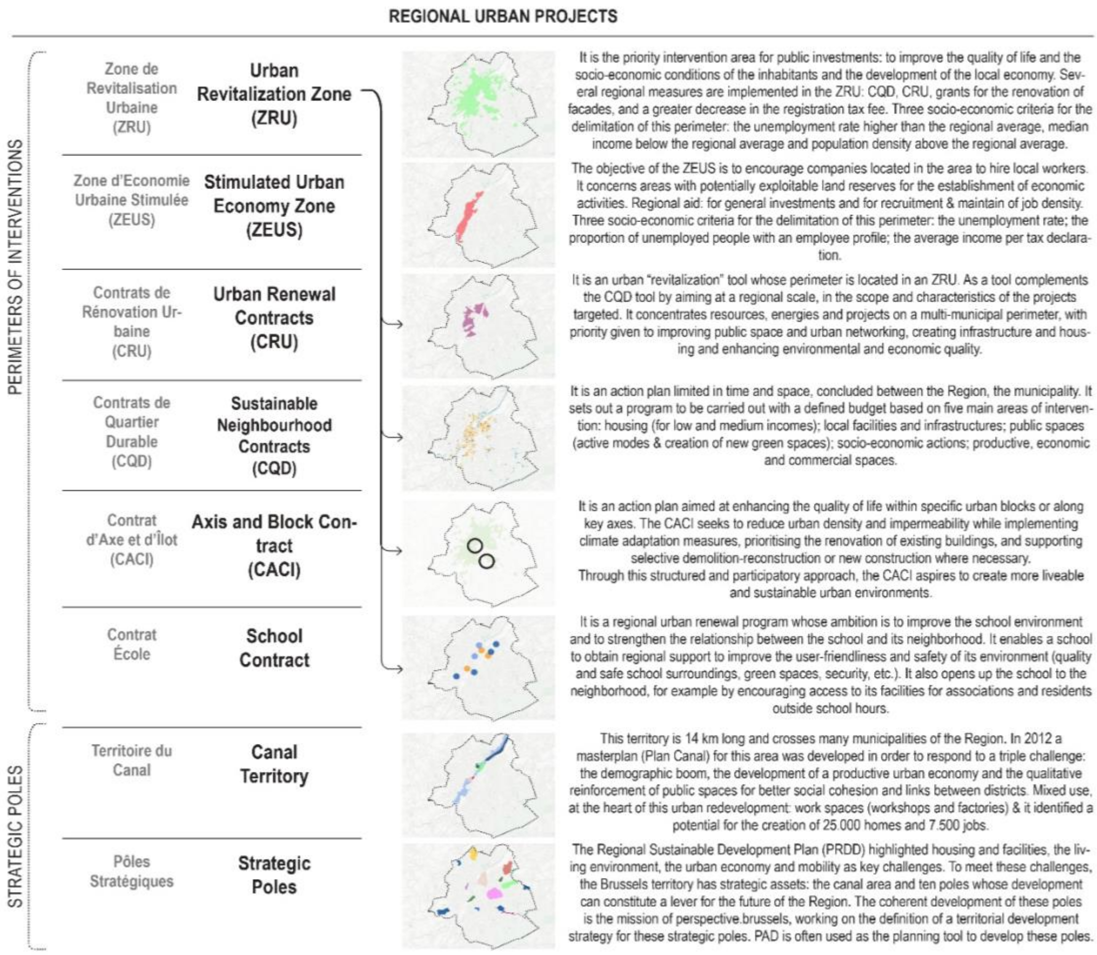

Figure 3. Publicly run strategic urban renewal projects and strategic poles in the BCR, by the authors (2025).

Figure 3 maps the spatial and thematic instruments used to operationalise urban transformation across Brussels. Central to this framework are the Strategic Poles, identified by the PRDD as key leverage zones for regional development. These poles are targeted through PADs, which serve as the primary planning tool to articulate coherent territorial strategies. Surrounding these poles are various intervention perimeters, notably the *Zone de Revitalisation Urbaine* (ZRU), which prioritises areas with socio-economic vulnerabilities: high unemployment, low median income, and high population density. Within ZRUs, multiple contractual tools operate: *Contrats de Quartier Durable* (CQD) and *Contrats de Rénovation Urbaine* (CRU) focus on neighbourhood-scale improvements, while the *Contrat École* enhances school environments and community integration. The *Contrat d'Axe et d'Îlot* (CACI) addresses climate adaptation and urban permeability at block and axis levels. This figure illustrates the BCR's *urban renewal investment programmes*, which target priority intervention areas through socio-economic initiatives and infrastructure upgrades (e.g. public spaces, amenities, services, and social housing). While these projects contribute to circularity goals, their dispersed and localised nature places them outside the scope of this research, which focuses on masterplans and large-scale urban developments rather than neighbourhood-level transformations. The *Zone d'Economie Urbaine Stimulée* (ZEUS) promotes local employment through economic incentives. Together, these instruments form a multi-scalar, multi-sectoral strategy for urban renewal, with PADs often serving as the coordinating framework.

UPD in Brussels faces significant challenges, particularly in implementing large-scale urban transformation projects. Historically, the region has struggled to operationalise publicly run urban projects. Many strategic plans (formerly known as '*schémas directeurs'* in French, or *'richting schema*' in Netherland) have failed to translate their vision into coherent, operational implementations, due to the lack of regulatory requirements (Delmotte, Hubert and Tulkens, 2009). In response, since 2018, the region has implemented a new urban planning instrument, the PAD (normative master plan), targeting strategic areas that had long been designated for redevelopment.

Circularity ambitions are at times explicitly present in PADs, yet they vary significantly across projects. Despite this, PAD procedures do not currently require environmental impact assessments that evaluate *circularity*-related issues. Embedding *circularity* metrics such as MSFA analysis into PAD approval processes would strengthen this link. This variability in ambition and practice underpins the rationale for this article's focus: to examine how *circularity* is interpreted and materialised within PADs, by whom, for whom, and why.

2.2.2. The PAD, Plan d'Aménagement Directeur (normative masterplan) PADs have been developed to coordinate territorial transformation, often within strategic areas, and follow a structured process (preparation, elaboration, public inquiry, adaptation, approval, and operationalisation) though their invention is recent and their deployment remains uneven. In fact, PADs are the latest tool to implement urban transformation on strategic urban areas and include a strategic section and a regulatory section: the strategic section indicates the main principles and guidelines for the development of the area in question, while the regulatory section sets binding elements for both private and public authorities (perspective.brussels 2017).

The regulatory value of the PAD determines the land-use plan for the perimeter (housing, offices, green spaces, etc.). Within a defined perimeter, the PAD abrogates the regulatory measures of other plans that conflict with it. Therefore, a PAD determines: (i) the land-use plan, (ii) the general layout of public spaces (structuring of roads, public spaces, landscape), (iii) the characteristics of the buildings (such as height, typologies, etc.) (iv) the organisation of mobility and parking and (v) the protection of heritage. The regional agency for urban planning (perspective.brussels) is responsible for the implementation of the PADs. The procedure (described in the decrees of the government of the BCR) comprises several stages: i) a draft plan is produced, then ii) the environmental impacts of the draft are analysed in an Environmental Impact Report (EIR), followed by iii) a public inquiry. After the public inquiry and before the government adopts the masterplan definitively, iv) the government submits the dossier to the regional development commission for its opinion and integrates its feedback.

PADs in the planning tool have made masterplanning both strategic and normative. This means that the tool guides major SUPs in the BCR. This tool is at the intersection of planning and urban design. Its scale allows for imposing architecture principles and even details, if needed. The PAD, as a new urban planning tool that overrides all other planning instruments, has faced significant criticism from civil society organisations and residents' committees, who argue that it undermines democratic processes and has harmful environmental effects. The citizen platform "*Bas-les-PAD"*, in particular, opposes the government's pro-density approach, calling for reduced construction based on lower demographic growth projections and emphasising the importance of social housing and urban green spaces ('Collectif Bas les PAD', 2025). Additionally, PADs are often criticised for being too disruptive, involving heavy demolitions, and for fostering elitism and accelerating gentrification (Scohier and Inter-Environnement Bruxelles, 2024). Considering these concerns, it is crucial to implement effective governance and participatory planning. To overcome these tensions, effective governance and participatory planning became essential. Therefore, we have observed the emergence of a new phase: the development of the so-called "shared vision" documents in strategic sites that have undergone significant criticism or plan revisions (i.e. the "Law district") or that concern very complex sites (i.e. "Schaerbeek Formation").

PADs have also been selected in this article as the urban tool for analysis due to their significant impact on the regional building material balance. They have been estimated to have significant impacts on the regional MFA, particularly concerning heavy materials, as highlighted by Ooghe *et al.* (2023). If the material intensity and the long-term impacts of construction materials are not adequately addressed, there is a substantial risk of exacerbating the overall UM balance of the BCR, especially regarding construction materials and waste. The PADs' potential to worsen the UM balance is a critical concern, as the tendency has been (until recently) to privilege demolition and reconstruction over maintaining and reusing infrastructures and buildings, particularly those not designated as heritage. Additionally, despite the emphasis on circularity, the salvaging and reuse of construction components and materials remain marginal. According to local experts, the BCR has only managed to harvest around less than 1% of reused elements and materials in projects that prioritise circularity (Rotor). Despite a decrease in waste quantities across all other sectors, the construction sector is the only one to have seen a significant increase (+135%) over the last 20 years (Statbel, 2024). In the context of the growing awareness of the heavy impacts of SUPs, scholars are establishing an interesting interrelation between the overall MFA of a specific circumscribed context (in this case the region) and the impacts that each SUPs realisation could have on that overall balance (Ooghe *et al.*, 2023). Significantly, Ooghe (2023) shows that some specific projects involving large-scale demolition and very dense new construction could worsen the construction materials balance of the BCR by doubling it (for both the outflows and the inflows). In this context, UM assessments applied to SUPs are essential for quantifying resource and waste flows. They provide crucial information on the material intensity of urban transformations, enabling the establishment of clear and measurable *circularity*-inspired strategies.

From the landscape of all PADs in the BCR (see **Table 3**), three PADs (*Casernes d'Ixelles-Usquare*, *Loi-EU Disctrct-Cityforward*, and *Défense- Ex-NATO*) were selected for further analysis due to their specificities and elements they bring to light, and the ambitions of circularity they carry.

Table 3. Comprehensive list of all Plan d'Aménagements Directeurs (PADs) in the Brussels Region, by the authors (2025).

PAD name	Project preparation	Project elaboration	Public inquiry and feedback for approval	Project adpatation (if needed)	Second approval	project adpatation (if needed)	final approval	operationalisation	approx. size	Urban context	Program	Main characteristics	
PAD - Casernes d'Ixelles - Usquare	▒	▒	▒	▒	▒	▒	▒	█	4 Ha	Historical urban fabric, former military barracks sites from the 19th century	Research facilities, housing, student housing, services, food hall, public spaces	Pioneering circularity in collaboration with universities	Barracks reconversion - heritage and transformation
PAD - Défense	▒	▒	▒	▒	▒	▒	█		100 Ha	Peripherical brownfield of the former NATO site and national defence facilities in the vicinity of the national airport, at the boarded between Flanders and the Brussels Region	Offices, housing, urban productive facilities, services, green & public spaces	Project developed across Flemish and Brussels Regions	New urbanisation, creations of new buildings, infrastcrtures and landscapes
PAD - Gare de l'Ouest	▒	▒	▒	▒	▒	▒	█		25 Ha	Central brownfiled reconversion next to rail and metro lines	Housing, productive activities, offices, shops, and key facilities like an Infrabel railway training school	Create a new residential district,a large park, and facilities of local and regional importance	New urbanisation, conersion of brownfield into a 3ha parck, with a temporary occupation prefiguration
PAD - Herrmann-Debroux	▒	▒	▒	▒	▒	▒	█		43,5 Ha	Brownfield sites and logistics areas along the axis linking second ring to the highway E11 exiting the region	New mixed-use neighborhood in a current parking areas, and the creation of new green spaces	Redevelopment of the E411 axis into an urban boulevard	Transform the viaduct infrastructure into a multimodal mobility hub and creating a new mixted neighbourhood
PAD - Heysel	█								170 Ha	Expo area, with national monuments, stadium and large infrastructures, at the borded between Flanders and the Brussels Region	Urban hub with a conference center, shopping mall, hotels, and recreational facilities, mixed housing, services, sports & cultural spaces, and schools	Develop a compact, mixed-use neighborhood combining urban densities and green spaces	Develop a new mixed-use neighborhood, improvement of green proximity spaces and we regional amenities
PAD - Heyvaert	▒	▒	▒	▒	▒	▒	█		50 Ha	Central neighbourhood in a dense and historically industrial ares (centered on used car trading) struggling with soil pollution, little green spaces and poor housing provision	Preserving productive spaces, creating high quality housing and social housing, collective facilities, open and green spaces	Improving public spaces, accessibility, and green spaces	Converting industrial areas into housing and green spaces, keeping/renewing urban producctive spaces
PAD - Josaphat	▒	▒	▒	█					30 Ha	Periferical brownfield linked to former railing infrastrcutures	Affordable housing, urban industry, school and sport facilitites, a large green are for biodiversity, green and public spaces	Long process with citizens and activism acoposing it to keep the area as a common and for bioversity	Mixed-use neighborhood with a focus on accessible housing, functional mioxity (urban industry), mobility and green spaces for biodiversity
PAD - Max (Maximilien Vergote)	▒	▒	█						62 Ha	Area at immediate proximity to the city centre on the bank of the canal	New metropolitan park connecting a new metropolitan museum, residential, recreational, and port-related functions	Numerous projects are already underway within this area, reflecting the ambition to drive its transformation	At least 25% of the floor space in residential projects exceeding 2,000 m² for public housing, maintaining the port and productive activities
PAD - mediapark.brussels	▒	▒	▒	▒	▒	▒	█		85 Ha	Peripherical site at proxility of the E40 highway entry, housing the two-languages national media telecomunications (RTBF & VRT)	New mixed neighbourhood with the two new headquarters of RTBF and VRT, housing, community amenities, business spaces, and a large park	The redevelopment of the mediaparck mixed area is coupled with the the Parkway-E40 masterplan, previously elaborated	Transforming the television campus with spaces for innovative businesses and media-related facilities, public spaces for events and leisure
PAD - Porte de Ninove	▒	▒	▒	▒	█				6 Ha	Central area, between two of the Region's key routes, the Canal and the Petite Ceinture, and at the junction of 3 municipalities	Large connecting park with horeca, sport facilities, playgrounds, housing (half of them public)	Redevelopment of a former industrial site at a strategic connection point that is now a large open green space	Builings on the endge and in a central part of a site, where green space will connect all functions shaphe the urbanity (nowadays ill-defined)
PAD Midi	▒	▒	▒	▒	█				45 Ha	Central area around the Brussels South station, the international station of Belgium, across two municipalities	New national rail company headquarters, hosuisng, services, public spaces and green spaces	Conversion of former railway properties into residential areas, and the creation of parks and public spaces	Over the last decades, the stratgic area "quartier midi" has mobilised many plans and projects to redevelop the zone
PAD - Loi / EU district	▒	▒	▒	▒	▒	▒	stop		12 Ha	Central area, very densly built, with little open spaces and mainly dedicated to offices, housing EU institutions	Mixed use re-development, adding housing in a mostly office-driven area, new horeca, services, amenities and green spaces	Focus on creating more mixity (adding housing) and making more active ground floors and façades	The PAD stopped because of heavy critiques, it was substituted by a "shared vision" document and now a masterplan focusing on key-builings to be reconverted
PAD - Bordet	▒	▒	▒	stop					200 Ha	Peripherical area on the regional edge, next to the airport and with rail connection characterized by a patchwork of different functions (housing, large logistical areas, shopping, industry, offices, tec.)	Mixed use densification of a scattered area, new metro line station and multi-modal mobility platform	Project that wished to rethink and reshaepe the area, meking it more "urbna" and coherent for the upcoming metro line	It stopped due to the many uncertanities and the proximity to other PAD site with higher priority

Table 3 was developed to provide a comprehensive list of all PADs. The PAD *Gare de l'Ouest* (25 Ha) targets a brownfield adjacent to rail and metro infrastructure. The program includes housing, offices, shops, and a railway training school. The project is in an advanced phase, with temporary occupation and a 3-hectare park planned. *Midi* (45 Ha), around Brussels South station, includes housing, public spaces, and the new headquarters of the national rail company. It builds on decades of planning and is progressing toward implementation. *Max* (62 Ha), near the canal, proposes a metropolitan park, museum, housing, and port-related functions. Several projects are underway, with public housing quotas included. Peri-urban PADs such as *Herrmann-Debroux* (43.5 Ha) aim to redevelop highway corridors into mixed-use neighbourhoods. The

plan includes transforming the E411 viaduct into a multimodal hub and creating green spaces. *mediapark.brussels* (85 Ha) focuses on redeveloping a media campus near the E40 highway into a mixed-use area with housing, business spaces, and a large park. It is linked to the Parkway-E40 masterplan and is in the elaboration phase. *Heysel* (170 Ha), a large expo site, proposes a compact mixed-use neighbourhood with housing, hotels, cultural and recreational facilities, and schools. It is progressing through the planning stages. Some PADs address former industrial areas, such as *Heyvaert* (50 Ha), a dense area with soil pollution and limited green space, which aims to preserve productive uses while improving housing and public space. *Josaphat* (30 Ha), a peripheral brownfield, includes affordable housing, urban industry, and biodiversity-focused green areas. The project has faced public opposition and is undergoing adaptation. *Porte de Ninove* (6 Ha) proposes the redevelopment of a central industrial site into a large park with housing and sports facilities. Two PADs were halted. *PAD Loi* (12 Ha), in the EU district, proposed adding high-rise buildings, including housing and services, to an already dense office zone. It was stopped due to public critique and replaced by a shared vision and masterplan. *PAD Bordet* (200 Ha), a peripheral area near the airport, was discontinued due to planning overlaps and uncertainties. *Casernes d'Ixelles* (4 Ha) involves the transformation of historic barracks into a mixed-use campus with student housing and public amenities and is in the operational phase. *Loi* represents a conceptual shift toward mixity in a mono-functional district, despite its cancellation. *Défense* (100 Ha), located on the former NATO site, is a large-scale cross-regional project aiming to create a new urban district with housing, offices, and green infrastructure, currently in the elaboration phase.

2.2.3. Three case studies The three selected case studies are PAD *Ixelles Barracks-Usquare",* PAD *"Défense"*, and PAD *"Loi – EU District"*. These cases were chosen for their distinct differences in urban context, scale, stakeholders, ambitions, and programme. While the first two are in the final phases (last approval and operationalisation), the PAD "*Loi – EU District*" represents a unique case where its deployment was halted to radically reposition regional ambitions, ultimately opting for a new strategy and masterplan, namely "City Forward", focusing on offices buildings reconversion, with a significantly developed circular approach to the built environment. **Figure 4** shows a spatialised sum-up of the three case studies, highlighting their localisation in the BCR and the main characteristics of the urban context, and **Table 4** presents the main characteristics of the projects.

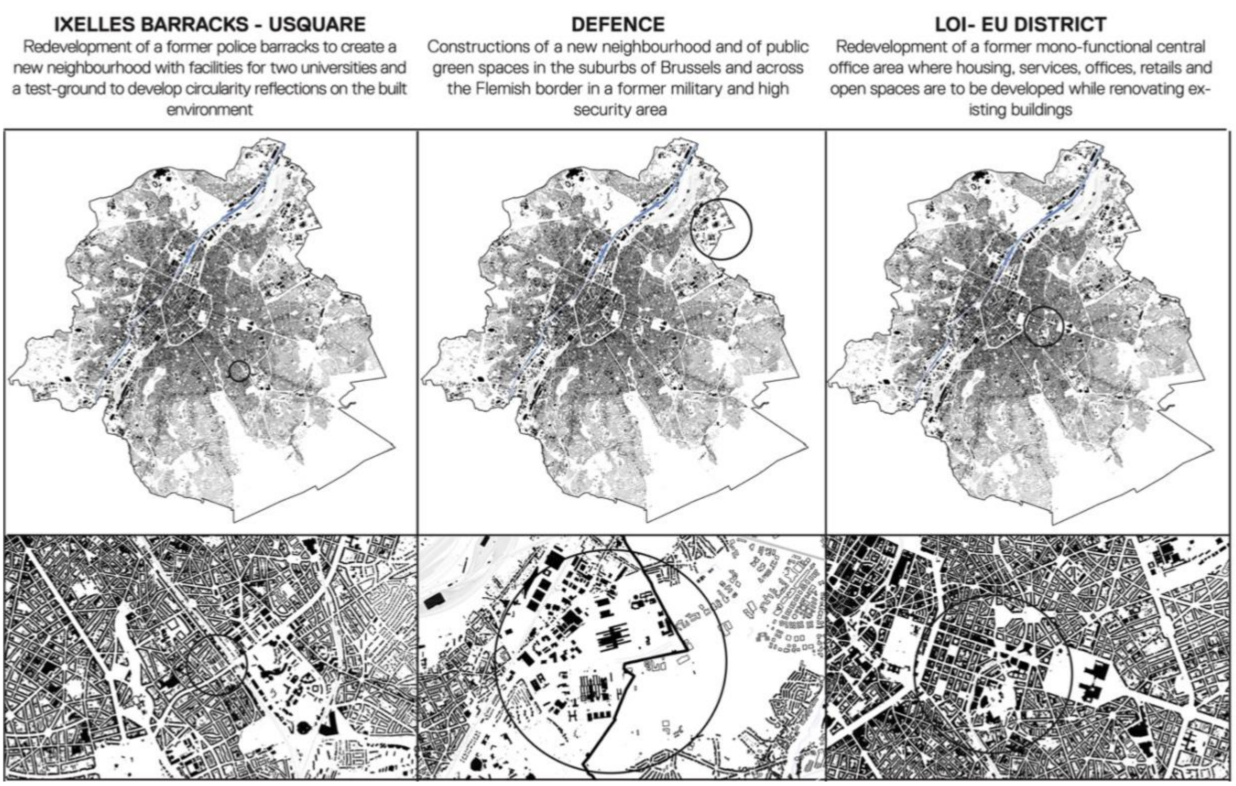

Figure 4. Localisation within the Brussels Capital Region (BCR) of the three case studies analysed, by the authors (2025).

Table 4. Overview of the main characteristics of the three selected case studies, by the authors (2025).

	IXELLES BARRACKS USQUARE **PAD Usquare**	**DEFENCE EX-NATO** **PAD Defence**	**LOI - EU DISTRICT** **PAD Loi District (stopped)** + **Masterplan "Cityforward"**
Urban context The existing	• In the urbanisation around the city centre • along a strategic axis (train line and avenue) • Dense & historical consolidated urban fabric It is a former police barrack site featuring middle-low-rise buildings, with some constructed in brick and others in prefabricated concrete.	• In suburban areas with loose urban fabric • Open landscape: In agriculture and farm lands • along a strategic axis (boulevard towards the airport) The site is a former defence site (barracks, military grounds, etc.) which is currently being dismantled.	• In the urbanisation around the city centre • along a strategic axis (highway, avenue, connection, etc.) • Dense urban fabric A mono-functional office district, with the presence of European institutions and other related organisations.
Property status	Public	Public (Flanders & BCR)	Private European Commission
Surface of the area	**4,6 Ha** **4 Ha** only constructible parcels	**156 Ha** **41 Ha** only constructible parcels	**14,5 Ha** **11 Ha** only constructible parcels
FAR of the area	**1**	**0,1**	**3,4**
FAR of the buildable plots only	**1,2**	**0,4**	**5,8**
Future program	Universities' facilities Student housing Social housing Business incubator Food market & commerce	Economic activities Housing Services & a large metropolitan park	Office Housing Commerce and Services

Each case study represents a distinct form of urban transformation *Ixelles Barracks-Usquare* and *Loi – EU District* are both located in central urban areas and focus on the reconversion and adaptation of existing buildings, whereas *Défense* represents a more peripheral development on a site that will be entirely rebuilt. *Loi – EU District* specifically entails the transition of a mono-functional office zone into a more diverse, mixed-use district. The projects also adopt different approaches to sustainability and circularity, which will be further explored in the following sub-sections. *Ixelles Barracks-Usquare* integrated circularity principles from the outset, while *Loi – EU District* initially planned for large-scale demolitions and reconstructions but later shifted towards a new masterplan, "*Cityforward*", based on key office buildings and aiming at developing adaptive reuse in response to public opposition. In contrast, *Défense* aims to serve as a model for the development of a sustainable (and circular) newly built neighbourhood.

- ***The "Ixelles Barracks-Usquare" case study***

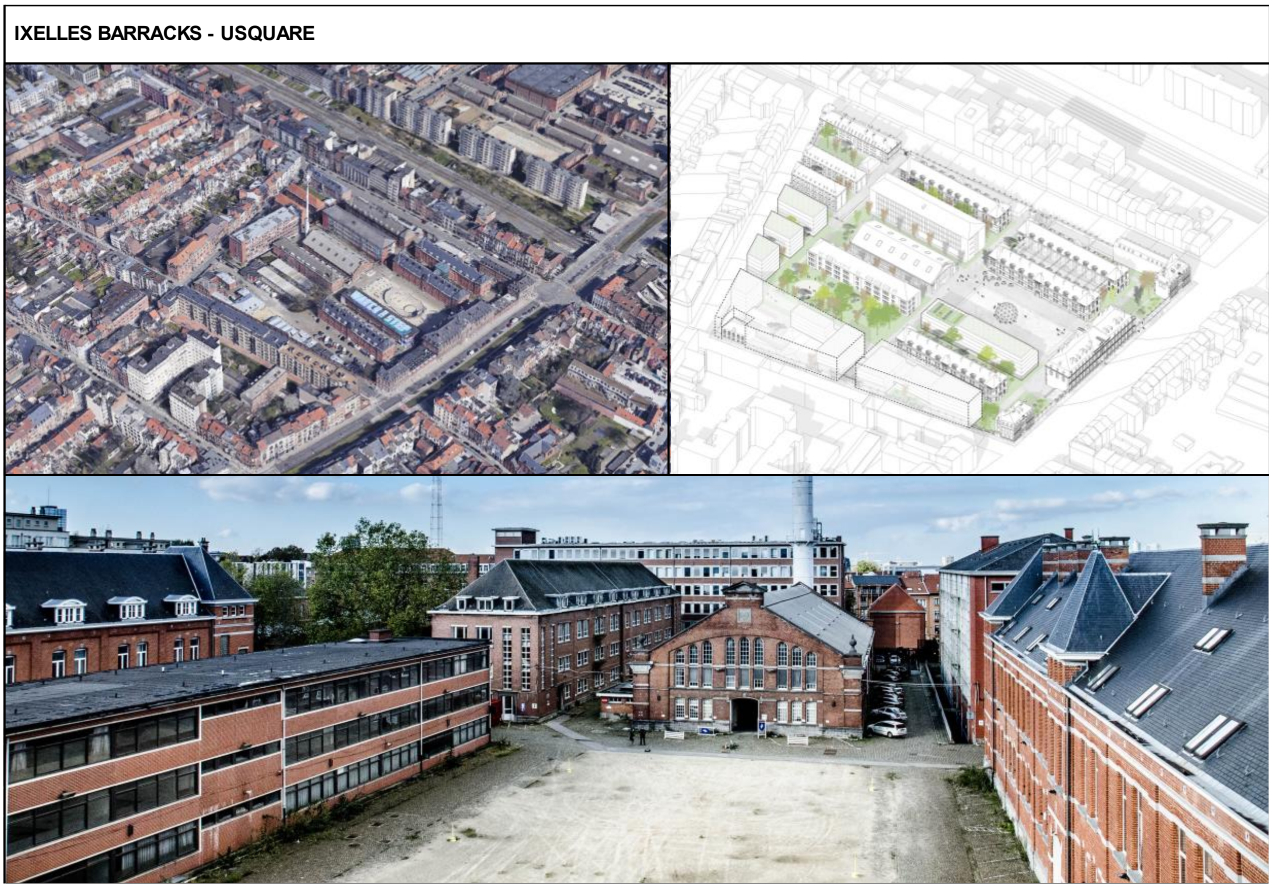

Figure 5. PAD *Ixelles Barracks-Usquare*, composition by the authors (2025) with aerial view from GoogleMaps(2024) and images retrieved from the website of perspective.Brussels (2024).

The *Ixelles Barracks-Usquare* PAD focuses on the transformation of a former police barracks into a sustainable, mixed-use urban neighbourhood. Located in a dense, historically consolidated area near major transport corridors, the site originally featured a mix of deteriorated 20th-century buildings, including early brick structures and post-war concrete blocks, many with asbestos, lead piping, and poor insulation. Previously enclosed and car-oriented, 90% of its open space was sealed. The redevelopment is phased. The first phase, funded by European and regional sources (FEDER), is led by public stakeholders and the two Brussels Free Universities (ULB and VUB). It includes university facilities housed in renovated heritage buildings. The planning process involves perspective.brussels, the urban development agency (SAU), and university research centres, which also monitor and assess circularity strategies. The project targets a diverse user base: students, young professionals, families, and vulnerable groups. The program includes student and social housing, subsidised units, university spaces, a fablab, business incubators, a food hall, public services, and cultural amenities and services. Public spaces will feature green areas for urban agriculture, a central square, and extensive bike parking.

Circularity was not central in the initial feasibility study but became a key ambition following FEDER funding. This led to a PAD shaped by heritage and sustainability goals, including the demolition of post-war buildings and reconstruction aligned with the historical urban grid. The PAD is now operational, with some university facilities already delivered. The redevelopment includes light renovation of early buildings, heavy renovation of asbestos-containing structures, and selective demolition to open the site and integrate geothermal infrastructure. The process unfolded through feasibility studies, PAD development, design competitions, and temporary occupation during planning (see **Figure 5**).

- ***Ex-PAD "Loi", European District "Cityforwards" masterplan as case-study***

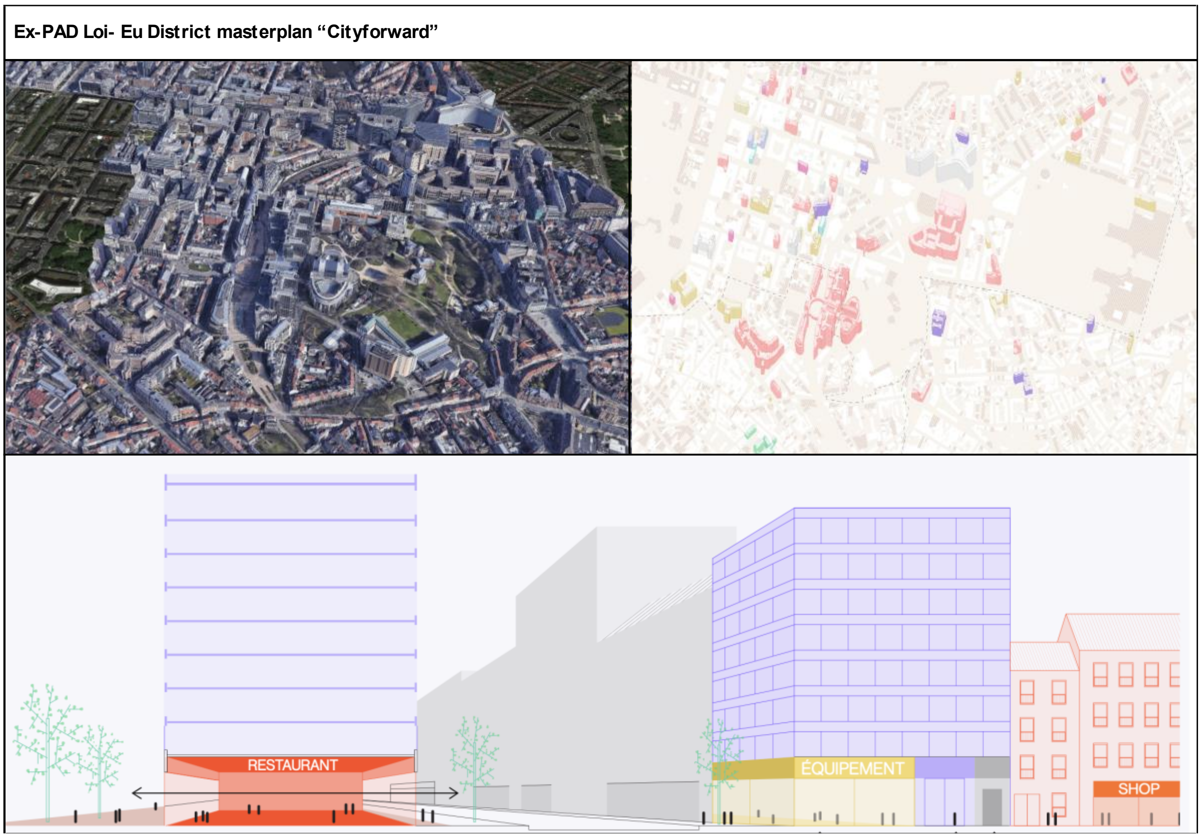

Figure 6. Ex-PAD Loi- Eu District, nowadays masterplan "Cityforward", by authors (2025) with an aerial view from GoogleMaps (2024) and images retrieved from the website of perspective.brussels (2024).

Located adjacent to the city centre, the district is situated along a strategic axis, surrounded by a dense urban fabric. In the past decades, it served as an office district for European institutions and related organisations. The building stock in the district is heterogeneous, characterised by low permeability and inward-facing buildings that do not contribute to urban life. Earlier plans, such as the PAD "Loi", proposed high-density redevelopment through demolitions and towers, but were replaced by a non-binding "shared vision" following public opposition.

The current transformation, led by the *Cityforward* masterplan, prioritises reuse, energy efficiency, and minimal demolition. As part of a significant real estate operation, 23 buildings are being transferred from the European Commission to the Belgian state and redeveloped through a public-private partnership (*Cityforward* with Whitewood), affecting over 300,000 m². The initiative, in collaboration with the Brussels Capital Region and local municipalities, aims to introduce housing, services, and amenities.

The project (see **Figure 6**) seeks to convert a mono-functional office area into a mixed-use neighbourhood with 70% office space, 25% housing, and 5% public amenities and retail. It focuses on activating ground floors and greening inner blocks, with partial demolition and extensive reuse. Competitions led by regional planning agencies (perspective.brussels, BMA, urban.brussels) target strategic buildings for adaptive reuse. Future users will include a broad demographic from vulnerable groups to students, professionals, expats, and tourists, reflecting the district's evolving role and commitment to *circularity*.

- ***Defence and ex-NATO site case study***

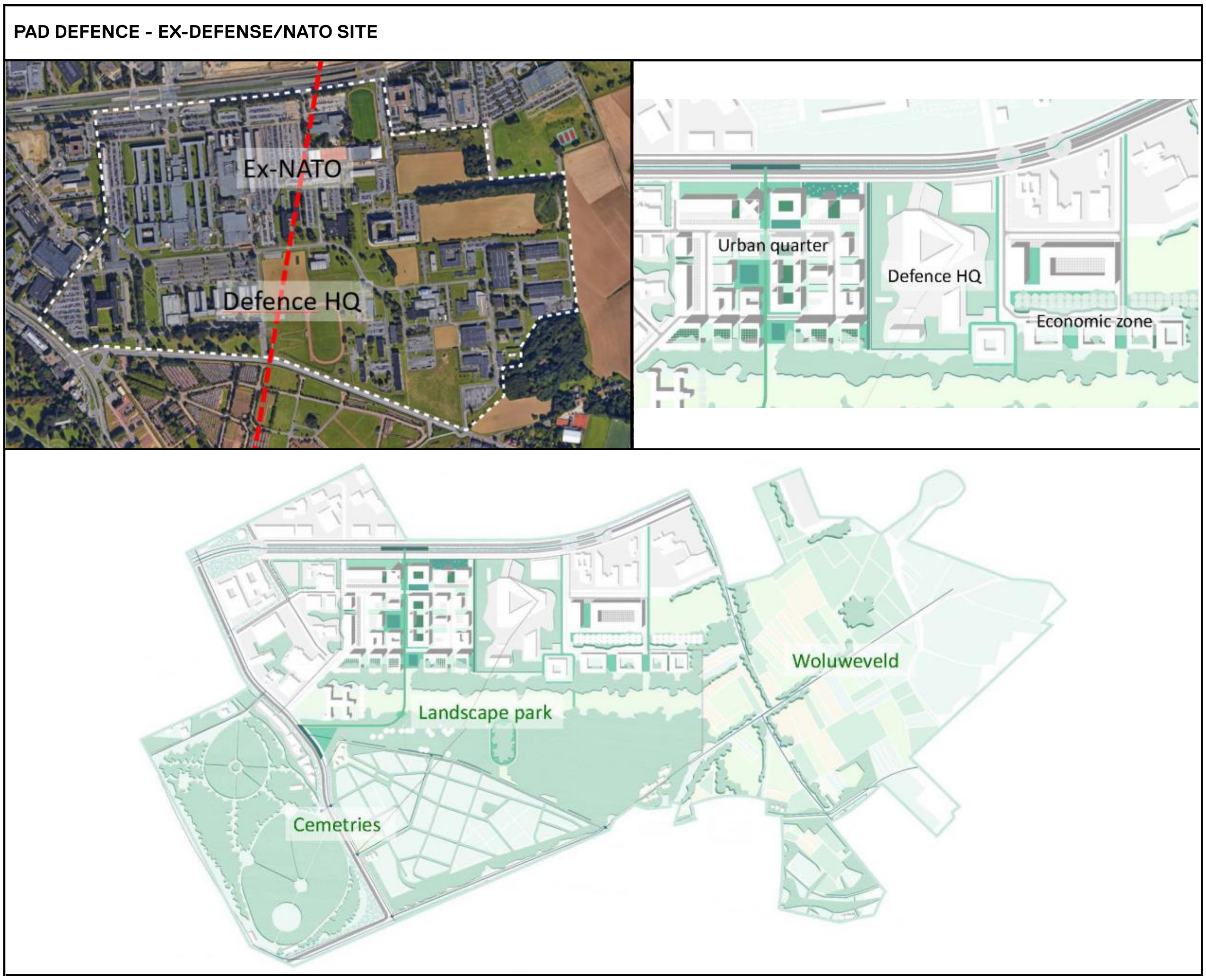

Figure 7. PAD "Defense" and the ex-NATO site, by authors (2025) Images retrieved from the website of perspective.brussels (2024).

The *Défense and ex-NATO* project redevelops a former military and high-security site spanning Brussels and Flanders into a new neighbourhood featuring metropolitan green spaces, economic activities, and the Belgian Defence headquarters. Positioned along a strategic axis to the airport, the site comprises low-rise buildings, extensive concrete surfaces, and surrounding farmland. While the original NATO buildings (1950–1970) are to be demolished, parts of the *Défense* site may be reused. Planning involves collaboration between the Brussels and Flanders authorities. A 2019 agreement set urban principles, including densification along the airport axis and open landscapes towards Flanders. Strategic plans (PAD for Brussels, GRUP for Flanders) were developed between 2020 and 2024, with approval expected in 2024. The project will proceed through operationalisation and design-build phases, beginning with the Defence HQ. The Brussels section will include housing, services, economic activities, and a 4-hectare urban park; the Flanders section will feature a 33-hectare forest and further economic development (illustrated in **Figure 7**).

Phase 1 includes feasibility studies, a master plan, and a project brief. Led by public stakeholders, the initiative aims to transform the site into a mixed-use neighbourhood with green infrastructure. Public engagement is integrated via formal enquiry procedures, although the area currently lacks residents due to its former use as a high-security campus. The new project is intended to serve a diverse population, including students, professionals, expats, and tourists (for its proximity to the national airport).

3. Results

This section is structured into three main parts. First, it synthesises findings from the literature review, outlining the conceptual frameworks, governance debates, and methodological approaches that inform circularity in urban projects. Second, it presents the empirical analysis of three case studies, examining how circularity ambitions are embedded in planning instruments, design strategies, and stakeholder dynamics across distinct urban contexts. Finally, it reports on the typo-morphological analysis and Material Flow Analysis (MFA), which quantify material intensities and assess the spatial and architectural characteristics of the selected masterplans, providing insights into their resource implications and circularity potential

3.1. Literature review

The discourse on *circularity* in urban projects (particularly at the neighbourhood or district scale) is still in its early stages. As a result, there is a limited body of academic literature offering comparative analyses of urban case studies that embed *circularity*-inspired ambitions. However, recent literature reveals a growing body of work that can be grouped into eight thematic categories, each reflecting a distinct focus within urban projects and circularity.

3.1.1. Theory: frameworks for circularity in urban projects This category includes studies that conceptualise and theorise *circularity*, offering analytical models and critiques of existing paradigms. Pekdemir et al. (2025) provide a systematic review of circular paradigms, Marin and Meulder (2018) and Marjanović *et al.* (2022) propose holistic frameworks. Singhvi, Athanassiadis and Binder (2025) analyse different circular spatial transformation strategies.

3.1.2. Agency & governance: stakeholders in circular urban projects This strand focuses on the role of practitioners and governance actors in shaping circular transitions. Moosavi, Perrotti and Stephan (2025) explore how metabolic thinking influences practitioners' perceptions and actions, highlighting the importance of agency in planning and design processes. Van den Berghe and Vos (2019) analyse how circularity is framed through discourse and institutional structures in urban redevelopment.

3.1.3. Planning for urban transformations: policies to support urban circular practices Planning-oriented literature examines how *circularity* is embedded in urban policies and strategies. Hubmann *et al* (2022) analyse circular regeneration in Amsterdam's Buiksloterham district. Sánchez Sánchez Levoso *et al.* (2020) propose a methodological framework for implementing circular strategies.

3.1.4. Metabolic approaches in urban projects Kennedy, Pincetl, and Bunje (2011), Pistoni and Bonin (2017), Grulois, Tosi, and Crosas (2018), and Arciniegas *et al.* (2019) apply urban metabolism as a planning and (territorial) design tool.

3.1.5. Tools: monitoring and evaluation methodologies in urban projects This category includes research focused on tools to assess and guide *circularity* in urban projects, through Life Cycles Analysis (LCA) and MFA (Appendino *et al.*, 2021; Saadé *et al.*, 2022; Ooghe *et al.*, 2023; Gobbo *et al.*, 2024). Holistic assessment tools and GIS-based ones are also proposed (Arciniegas *et al.*, 2019; Wandl *et al.*, 2024).

3.1.6. Built environment in urban projects These studies address architectural and spatial design strategies at the neighbourhood scale (Sala Benites, Osmond and Prasad, 2023), with proposals for a regenerative design model. Stolz, Li and Wellinger (2025) focus on building obsolescence, and Elwakil, Schroder and Steemers (2023) analyse maker space typologies.

3.1.7. Landscape in Urban Projects The field of circular landscape design is well established and closely linked to territorial metabolic strategies and reflections within landscape design (Amenta and Van Timmeren, 2018; Fabbricatti and Biancamano, 2019; Marin, 2019)**.**

3.1.8. Nature-Based Solutions in Urban Projects Nature-Based Solutions (NBS) are increasingly recognised for their role in enabling circularity-driven transitions. Tsatsou, Frantzeskaki and Malamis (2023) provide a scoping review of circular water systems, while Morgado et al. (2025) present Christiania as a living lab for resilient and regenerative urban water strategies.

In conclusion, there remains a significant gap in research that integrates urban project analysis with broader considerations of urban design and circularity, including design factors, and the material impacts of such transformations. This study contributes to advancing these debates and supports the emergence of an interdisciplinary field that bridges urban planning and design, addressing governance, design strategies, and wider reflections on circularity ambitions and their implications for urbanism and the transformation of urban environments.

3.2. Case studies

3.2.1. The "Ixelles barracks - Usquare" case study In the *Ixelles barracks – Usquare* case study has been developed as a phased project that has embraced over the year the ambition of being exemplary first in terms of sustainability, and then also in terms of *circularity*. The highlighted sustainability goals include local energy production (geothermal and solar), soil permeability enhancement, and water management strategies. *Circularity* ambitions focus on preventing construction waste, reusing materials, maintaining building integrity, and promoting repair and refurbishment. The project also integrates CE principles by aiming to create local jobs, support sustainable value chains, and foster local food systems, including a large local food hall (see **Table 5**).

Table 5. Sum-up of the factors discussed during the interview on the project Usquare, by authors (2025).

SUSTAINABILITY AMBITIONS	• Creation of local energy: geothermal energy, solar energy. • Soils' permeability and vegetation enhancement & enhancing soils' quality. • On-site water management in building and water reuse & in open space. • Insulation of the building stock (energy performance). • Creation of high-performing new buildings. • Use of bio-sourced materials (wood, hemp, clay, stone, etc.). • Use of local construction materials (local supply chains). • Low-tech/simple details/solutions.
CIRCULARITY AMBITIONS	**BUILT ENVIRONMENT:** • PREVENTION: net-zero soil hardening. • PREVENTION OF CONSTRUCTION WASTE: avoiding/reducing demolitions. • MAINTAINING OF BUILDINGS/INFRASTRUCTURES: • extending the lifespan of artefacts in their integrity. • REUSE OF BUILDINGS/INFRASTRUCTURES (in their integrity). • REPAIRING/REFURBISHING OF BUILDINGS/INFRASTRUCTURES • REUSE OF PARTS: reusing reclaimed components and materials ON SITE. • REUSE OF PARTS: reusing reclaimed components and materials OFF-SITE. • REPAIRING/REFURBISHING OF PARTS: reusing reclaimed components and materials. • DOWN-CYCLING: reusing parts and materials in a less qualitative function (i.e., bricks, into rubble). • MORE RECYCLING: maximising the separation if waste streams from demolitions.

Table 5 (cont.). Sum-up of the factors discussed during the interview on the project Usquare, by authors (2025).

CIRCULARITY AMBITIONS	**NEW CONSTRUCTION:** • circular buildings strategies such as design for disassembly & reuse (pace-layering). • Integrating reclaimed components and materials into projects/tendering templates. • reusing reclaimed components and materials. • use of local materials; • use of biosourced materials;
	CIRCULAR ECONOMIES: • local job creations, providing training (qualified labour) & follows-ups of pioneering practices (R&D, test cases, etc.) • supporting/creating new value chains (also sustainable food hall).
	CIRCULAR FOOD: • creating/keeping spaces for local agriculture & local compost and food waste management
	EVALUATION OF FACTORS
Impacting positively the implementation of “circularity-inspired ambitions”	+++ High sustainability ambitions / exemplary project +++ Innovation ambitions + Economic ambitions (development of local economies) + Ecological ambitions (ecosystems, water, green, biodiversity, etc.) + Energy-related ambitions = Demographic pressure-related ambitions (more housing and services) - - Policies and regulations (PAD that imposed the re-establishment of the historical urban layout, obliging the demolition of a building accounting for 20% of the building stock) - - “Abstract” volumetric feasibility study prior to studying the existing potential for the refurbishment of the existing buildings stock (barracks, opens spaces layout, etc.)
Impacting positively the motivation of stakeholders	+++ Motivation of university researchers’ team (using Materials’ Stocks Flows Analysis to assess scenarios) +++ Motivation of designers’ team ++ Motivation of public stakeholders (administrations) ++ Lobbying of local/circular value chains = Motivation of citizens/NGO = Motivation/will of politicians - Motivation of private stakeholders (resistance to change)
Impacting negatively the implementation of “circularity-inspired ambitions” Legend Impacts: +++ (very positive) ++ (positive) + (somehow positive) = (not influential) - (somehow negative) - - (negative) - - - (very negative)	- - - Underdevelopment of circular materials value chains - - Underdevelopment of circular technical details and specification - - Underdevelopment of tools to evaluate/asses the impacts of projects - - Lack of knowledge of circularity in urban projects - - Lack of pertinent inspiring case-studies - Underdevelopment of tools/guidance for the early stages of a circular design - Lack on in-depth urban metabolism analysis on the site (context) - Lack on in-depth urban metabolism analysis on the potential impacts of the project = Underdevelopment of legal frameworks for circularity experimentations - - - Lack of shared culture of “care” and maintenance - - Lack of motivation in stakeholders - - Lack of “easy-to-use” monitoring tools - Lack of tools for monitoring - Difficulties in the following up due to too many actors - - Lack of “easy-to-use” monitoring tools - Lack of motivation in stakeholders = Difficulties in the following up due to too many actors

The implementation of *circularity* ambitions in this urban project is shaped by both enabling and constraining factors. Key drivers include strong sustainability and innovation goals, supported by economic and ecological objectives such as local economic development, ecosystem management, water system improvement, and biodiversity enhancement. Energy ambitions also contribute, though less prominently. Constraints include regulatory barriers, notably the PAD's requirement to restore the historical urban grid, leading to demolition and a 20% loss in floor area, contradicting circular principles that favour refurbishment (Ooghe et al., 2023). Positive contributions come from university researchers, design teams, public stakeholders, and local *circular* value chains. However, resistance from private actors, underdeveloped material value chains, immature technical standards, and limited expertise in *circular* urban design hinder progress. Additional barriers include inadequate impact assessment tools, a lack of urban metabolism analysis, and challenges in stakeholder coordination.

3.2.2. Ex-PAD "Loi", European District "City Forwards" masterplan as case study

Table 6. Sum-up of the factors discussed during the interview on the project Loi-Eu District "Cityforward" masterplan, by authors (2025).

SUSTAINABILITY AMBITIONS	• Creation of local energy: solar energy. • Biodiversity enhancement. • Soils' permeability and vegetation enhancement. • Reduction of Urban Heat Island Effect. • On-site water management in building and water reuse. • Insulation of the building stock (energy performance); • Creation of highly performing new buildings.
CIRCULARITY AMBITIONS	**BUILT ENVIRONMENT:** • PREVENTION: net-zero soil hardening. • PREVENTION OF CONSTRUCTION WASTE: avoiding/reducing demolitions. • MAINTAINING OF BUILDINGS/INFRASTRUCTURES: • extending the lifespan of artefacts in their integrity. • REUSE OF BUILDINGS/INFRASTRUCTURES (in their integrity). • REPAIRING/REFURBISHING OF BUILDINGS/INFRASTRUCTURES • REUSE OF PARTS: reusing reclaimed components and materials ON SITE. • REUSE OF PARTS: reusing reclaimed components and materials OFF-SITE. • REPAIRING/REFURBISHING OF PARTS: reusing reclaimed components and materials;
	NEW CONSTRUCTION: • Circular building strategies such as design for disassembly & reuse (pace-layering); • Integrating reclaimed components and materials into projects/tendering templates. • Reusing reclaimed components and materials;
	CIRCULAR ECONOMIES: • creating and support new value chains;
EVALUATION OF FACTORS	
Impacting positively the implementation of "circularity-inspired ambitions"	+++ High sustainability ambitions / exemplary project +++ Economic ambitions (development of local economies) +++ Demographic pressure-related ambitions (more housing and services) +++ Policies and regulations, as the new RRU (Regional Urban Regulations) being adopted will impose the reduction of demolitions, and improve sustainability obligations ++ Ecological ambitions (ecosystems, water, green, biodiversity, etc.) + Energy-related ambitions = Innovation ambitions/pilot project

Table 6 (cont.). Sum-up of the factors discussed during the interview on the project Loi-Eu District "Cityforward" masterplan, by authors (2025).

EVALUATION OF FACTORS	
Positively impacting the motivation of stakeholders	+++ Motivation of public stakeholders (administrations) +++ Motivation of citizens/NGO ++ Motivation/will of politicians ++ Motivation of private stakeholders + Motivation of designers' team = Lobbying of local/circular value chains
Impacting negatively the implementation of "circularity-inspired ambitions" Legend Impacts: +++ (very positive) ++ (positive) + (somehow positive) = (not influential) - (somehow negative) - - (negative) - - - (very negative)	- Underdevelopment of circular materials value chains - Underdevelopment of legal frameworks for circularity experimentations - Underdevelopment of tools to evaluate/assess the impacts of projects - Underdevelopment of tools/guidance for the early stages of a circular design - Lack of in-depth urban metabolism analysis on the site (context) - Lack of in-depth urban metabolism analysis on the potential impacts of the project = Lack of knowledge of circularity in urban projects = Lack of relevant inspiring case studies = Underdevelopment of circular technical details and specifications - - - Lack of shared culture of "care" and maintenance - - Lack of tools for monitoring - - Lack of "easy-to-use" monitoring tools - Lack of motivation in stakeholders = Difficulties in the follow-up due to too many actors

As summarised in **Table 6**, sustainability goals focus on enhancing local energy production through solar power, improving biodiversity, increasing soil permeability, and reducing the urban heat island effect. *Circularity* strategies prioritise minimising construction waste, reusing existing buildings and materials, and extending infrastructure lifespan. The project also aims to foster new value chains to support urban *circular* economies. Several factors positively influence the integration of *circularity* ambitions. These include strong sustainability objectives, economic goals linked to local development, and demographic pressures requiring increased housing and services. The introduction of revised Regional Urban Regulations (RRU), which impose stricter sustainability and *circularity* requirements (such as limiting demolitions) further strengthens these ambitions. Ecological goals, including ecosystem restoration, water management, and biodiversity enhancement, also play a key role, alongside energy-related objectives promoting sustainable development.

Motivation-related factors are crucial to successful implementation. Public stakeholders, citizens, and NGOs show strong commitment, supported by political will and active engagement from private stakeholders. Design teams also play a significant role. However, lobbying efforts from local or *circular* value chains have had limited impact.

Key barriers include underdeveloped *circular* material value chains, a lack of legal frameworks for experimentation, and the absence of robust tools for evaluating project impacts and guiding decision-making. Limited use of urban metabolism analysis (both on-site and in projected outcomes) further complicates integration. Additional challenges include the absence of a shared culture of care and long-term maintenance, inadequate monitoring tools, and the complexity of coordinating multiple stakeholders.

3.2.3. Defence and ex-NATO site case study

Table 7. Sum-up of the factors discussed during the interview on the PAD "Defense" and the ex-NATO site, by authors (2025).

SUSTAINABILITY AMBITIONS	• Creation of local energy: solar energy, geothermal energy or other; • Biodiversity enhancement; • Soils' permeability and vegetation enhancement; • Enhancing soils' quality (de-pollution) • Reduction of Urban Heat Island Effect; • On-site water management in open space (nature-based solutions) • On-site water management in building and water reuse; • Creation of highly performing new buildings.
CIRCULARITY AMBITIONS	**BUILT ENVIRONMENT:** • PREVENTION: net zero soil hardening; • PREVENTION: reduction of demolition operations; • REUSE OF BUILDINGS/INFRASTRUCTURES (in their integrity); • REPAIRING/REFURBISHING OF BUILDINGS/INFRASTRUCTURES • REUSE OF PARTS: reusing reclaimed components and materials ON SITE; • REUSE OF PARTS: reusing reclaimed components and materials OFF-SITE; • DOWN-CYCLING: reusing parts and materials in a less qualitative function (i.e., bricks, into rubble);
	NEW CONSTRUCTION: • circular buildings strategies such as design for (very long) lasting • circular buildings strategies such as design for disassembly & reuse (pace-layering); • integrating reclaimed components and materials into projects/tendering templates; • use of biosourced & circular construction materials • Use of local materials
	CIRCULAR ECONOMIES: • creating/keeping spaces for local industries/manufactures;
	CIRCULAR FOOD: • creating/keeping spaces for local agriculture; • encouraging local food value chains

EVALUATION OF FACTORS	
Impacting positively the implementation of "circularity-inspired ambitions"	+++ High sustainability ambitions / exemplary project +++ Innovation ambitions ++ Ecological ambitions (ecosystems, water, green, biodiversity, etc.) + Policies and regulations, as the new RRU (Regional Urban Regulations) being adopted will impose the reduction of demolitions, and improve sustainability obligations + Economic ambitions (development of local economies) + Energy-related ambitions = Demographic pressure-related ambitions (more housing and services) - - Programmatic ambitions in planning prior to studying the existing potential for the refurbishment of the existing buildings stock (barracks, open spaces layout, etc.)
Impacting positively the motivation of stakeholders	+ Motivation of public stakeholders (administrations) + Motivation of designers' team + Motivation/will of politicians + Lobbying of local/circular value chains + Motivation of designers' team = Motivation of citizens/NGO = Motivation of private stakeholders

Table 7 (cont.). Sum-up of the factors discussed during the interview on the PAD "Defense" and the ex-NATO site, by authors (2025).

EVALUATION OF FACTORS	
Impacting negatively the implementation of "circularity-inspired ambitions"	- - - Underdevelopment of tools to evaluate/assess the impacts of projects
	- - - Underdevelopment of tools/guidance for the early stages of a circular design
	- - Lack of in-depth urban metabolism analysis on the site (context)
	- - Lack of in-depth urban metabolism analysis on the potential impacts of the project
Legend	- - Underdevelopment of circular materials value chains
Impacts:	- Lack of knowledge of circularity in urban projects
+++ (very positive)	- Lack of relevant inspiring case studies
++ (positive)	- Underdevelopment of legal frameworks for circularity experimentations
+ (somehow positive)	= Underdevelopment of circular technical details and specifications
= (not influential)	- - Lack of shared culture of "care" and maintenance
- (somehow negative)	- Lack of tools for monitoring
- - (negative)	- Lack of "easy-to-use" monitoring tools
- - - (very negative)	- Lack of motivation in stakeholders
	= Difficulties in the follow-up due to too many actors

As shown in **Table 7**, sustainability ambitions driving the project include the development of local energy sources (solar and geothermal), enhanced biodiversity, improved soil quality, and water management through nature-based solutions. The project also aims to reduce the urban heat island effect and promote water reuse in buildings and open spaces. *Circularity*-inspired ambitions focus on reducing demolition, and prioritise reuse, repair, and refurbishment of buildings and infrastructure on the former defence site. Strategies such as design for disassembly, use of bio-sourced materials, and local resources are integrated. The project also supports *circular* economies by creating spaces for local industries and agriculture, fostering local food value chains.

Several factors shape the integration of circularity ambitions. Strong sustainability and innovation goals are key drivers, especially in exemplary projects. Ecological considerations (ecosystem enhancement, water management, and biodiversity) play a crucial role. Policy and regulatory frameworks, particularly the upcoming Regional Urban Regulations (RRU), are expected to support *circularity* by limiting demolitions and reinforcing sustainability obligations. Economic and energy-related objectives also contribute. Motivational factors include strong public stakeholder support, committed design teams, and political engagement. However, due to the site's current closure and low residential presence, citizens and NGOs have had limited influence. Private stakeholders have also played a minor role, as the site is federally owned and primarily developed by public actors.

Key barriers include the lack of tools for early-stage impact evaluation, limited urban metabolism analysis for both site context and projected outcomes, underdeveloped *circular* material value chains, and insufficient knowledge of *circularity* in urban projects. The absence of relevant case studies and legal frameworks for experimentation further complicates implementation. Additionally, a weak shared culture of care and maintenance, along with inadequate monitoring tools, undermines long-term success.

3.3. Typo-morphological analysis and MFA evaluation of masterplans' scenarios

Building on the mixed-methods framework described earlier, this section presents the findings of the typo-morphological analysis and the material stock-and-flow assessment applied to the three masterplans. It examines the areas retained, demolished, or renovated across the different scenarios explored prior to selecting the preferred option, allowing for an evaluation of the material intensity associated with each transformation path. **Figure 8** illustrates the evolution of the projects from feasibility studies to the final chosen scenarios.

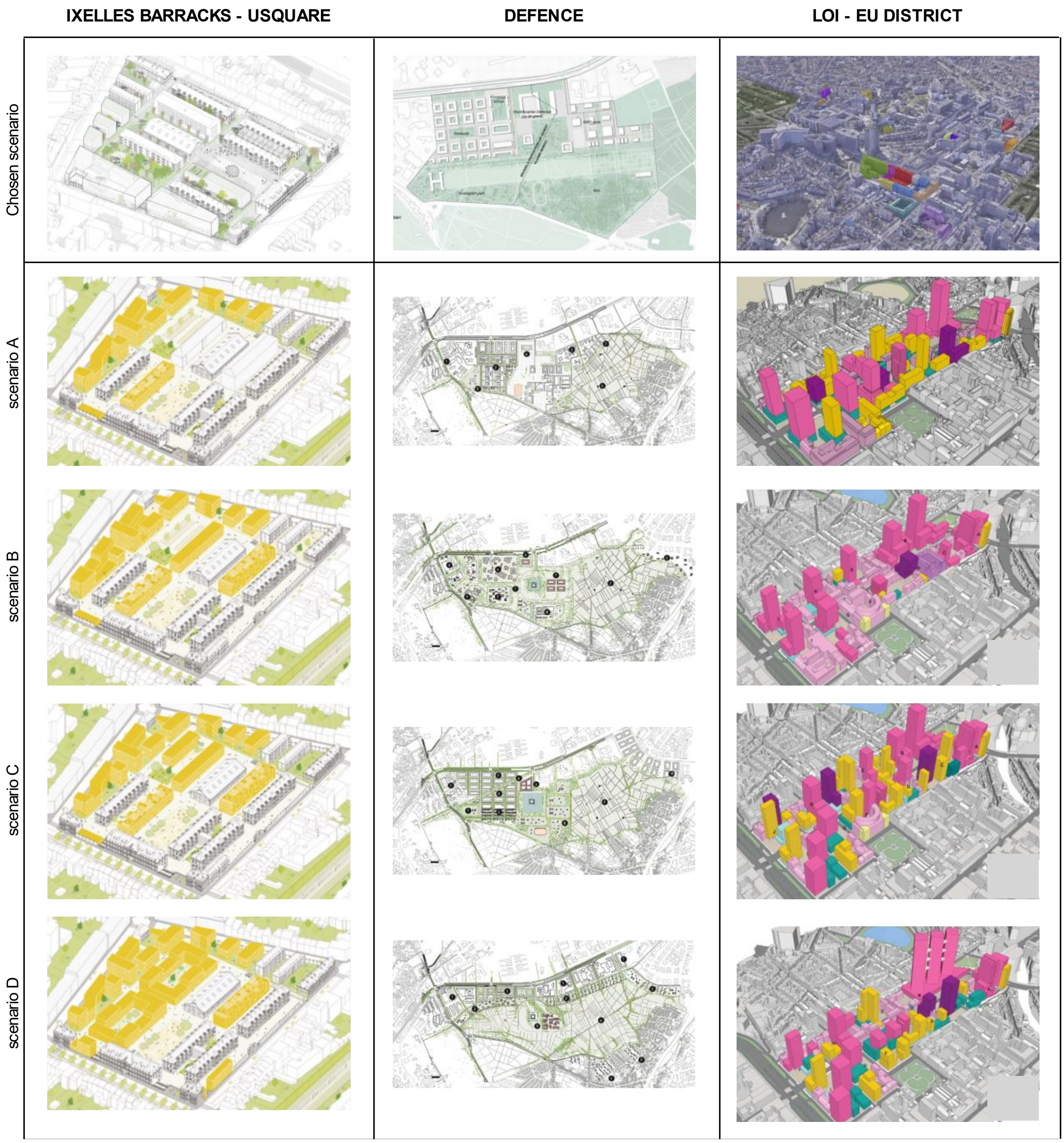

Figure 8. Overview of the projects' evolutions in between scenarios studied and scenario chosen (on the top), by the authors (2025).

The analyses estimate the absolute quantities of materials mobilised (based on surfaces reported in the Environmental Impact Reports and spatial plans) for a range of possible urban layouts (**see Figure 8 and Table 8**). These estimations serve as rule-of-thumb indicators to compare scenarios and understand their overall implications. They draw on detailed weight coefficients for different building typologies and construction materials (Ooghe et al., 2023). Their purpose is to offer a rapid, comparable assessment of the quantities of materials potentially moved by each scenario, rather than to provide definitive impact calculations.

Table 8. Calculations' formula by Ooghe V. (2023), case studies jointly developed and studied by Ooghe and Verga (2025).

PAD		IXELLES BARRACKS - USQUARE					DEFENCE - EX-NATO					LOI - EU DISTRICT				
scenarios		A	B	C	D	FINAL	A	B	C	D	FINAL	A	B	C	D	"CITYFORWARD"
existing buildings above ground	m²	48.533					171.000					635.871				?
projected buildings above ground	m²	52.790	54.200	52.602	63.896	56.898	597.334	585.420	1.056.260	956.334	535.000	824.552	810.386	1.061.413	893.989	300.000
difference with existing situation	m²	4.257	5.667	4.069	15.363	8.365	426.334	585.420	885.260	546.334	125.000	188.681	174.515	425.542	258.118	?
existing floor ration area (density)	FAR	1,2					0,4					5,8				
projected floor ration area (density)	FAR	1,4	1,4	1,4	1,6	1,5	1,5	1,4	2,6	5,6	1,3	7,5	7,4	9,0	8,1	equivalent or less than the existing
total surface of buildable plots (land)	m²	39.105					410.000					109.863				
under ground	m²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
onsite water infiltration	m²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
extensive green roofs	m²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
existing footprint built (impermeable)	%	45%					4,5%					85%				
footprint built (impermeable)	%	40%	41%	41%	44%	44%	-	-	-	-	-	61%	66%	66%	60%	less than the existing
	m²	15.541	16.173	16.173	17.157	17.345	-	-	-	-	-	66.691	72.102	73.033	62.783	-
impermable (unbuilt)	m²	20.356	19.961	19.693	18.977	16.469	-	-	-	-	-	30.290	33.260	32.005	40.775	-
permable (green)	m²	3.208	2.971	3.239	2.971	5.291	-	-	-	-	-	12.882	4.501	4.825	6.306	-
exisitng kept	%	56%	52%	49%	50%	62%	0%	0%	0%	0%	2%	22%	49%	30%	33%	40-70%
	m²	27.150	25.151	23.791	24.151	30.017	0	0	0	0	12.000	140.913	311.585	192.067	212.925	-
demolished	%	33%	48%	48%	55%	20%	100%	100%	100%	100%	98%	78%	51%	100%	70%	30-60%
	m²	15.998	23.382	23.382	26.860	9.516	171.000	171.000	171.000	171.000	159.000	494.958	324.286	443.805	422.946	-
light renovation (1/4 out/in)	m²	32.535	25.151	23.791	24.151	37.397	0	0	0	0	6.000	70.457	155.793	96.033	106.463	-
heavy renovation (1/2 out/in)	m²	0	0	0	0	1.620	0	0	0	0	6.000	70.457	155.793	96.033	106.463	-
new construction floor area	m²	20.255	29.049	28.811	39.745	17.881	597.334	585.420	1.056.260	956.334	523.000	683.639	498.801	824.347	681.064	-
preserved buildings' stock	tons	39.042	30.181	29.029	28.981	46.172	0	0	0	0	19.200	149.720	331.059	204.071	226.233	-
demolitions' outflow	tons	25.597	37.411	37.411	42.976	15.226	273.600	273.600	273.600	273.600	254.400	841.429	551.286	754.468	719.008	-
heavy renovation outflow	tons	0	0	0	0	1.296	0	0	0	0	4.800	56.366	124.634	76.826	85.170	-
light renovation outflow	tons	13.014	10.060	9.516	9.660	14.959	0	0	0	0	2.400	29.944	66.212	40.814	45.247	-
total outflows of materials	tons	38.611	47.472	46.928	52.636	31.480	273.600	273.600	273.600	273.600	261.600	931.261	749.922	876.910	854.748	-
light renovation inflow	tons	14.641	11.318	10.706	10.868	16.829	0	0	0	0	2.400	31.705	70.107	43.215	47.908	-
heavy renovation inflow	tons	0	0	0	0	1.458	0	0	0	0	4.800	63.411	140.213	86.430	95.816	-
new construction inflow	tons	36.459	52.288	51.860	71.541	32.186	1.134.935	1.112.298	2.006.894	1.817.035	993.700	1.230.550	897.842	1.483.824	1.225.915	-
total inflow of materials	tons	51.100	63.606	62.566	82.409	50.472	1.134.935	1.112.298	2.006.894	1.817.035	1.000.900	1.325.667	1.108.162	1.613.469	1.369.640	-
total of moving materials in & out	tons	89.711	111.078	109.493	135.045	81.953	1.408.535	1.385.898	2.280.494	2.090.635	1.262.500	2.256.927	1.858.083	2.490.379	2.224.388	-
total materials used (preserved + outflows+ inflows)	tons	128.753	141.259	138.523	164.027	128.125	1.408.535	1.385.898	2.280.494	2.090.635	1.262.500	2.406.647	2.189.142	2.694.449	2.450.620	-
new final building stock	tons	90.142	93.787	93.291	107.425	96.645	1.134.935	1.112.298	2.006.894	1.817.035	1.020.100	1.475.387	1.439.221	1.817.539	1.595.872	-
material outflow / final floor areas	tons/m²	0,73	0,88	0,89	0,82	0,55	1,90	1,90	1,90	1,90	1,91	1,13	1,00	1,00	1,00	-
material inflow / final floor areas	tons/m²	0,97	1,17	1,19	1,29	0,89	1,90	1,90	1,90	1,90	1,87	1,61	1,37	1,52	1,53	
total of moved materials/ final floor areas	tons/m²	1,70	2,05	2,08	2,11	1,44	0,14	2,41	1,31	2,38	3,91	2,74	2,00	2,00	2,50	-
outflow / land	tons/m²	1,00	1,20	1,20	1,30	0,80	0,67	0,67	0,67	0,67	0,64	8,50	6,80	8,00	7,80	-
	tons/ha	9.874	12.140	12.000	13.460	8.050	6.673	6.673	6.673	6.673	6.380	84.766	68.260	79.819	77.801	-
inflows / land	tons/m²	1,30	1,60	1,60	2,10	1,30	2,77	2,71	4,89	4,43	2,44	12,10	10,10	15,00	12,50	-
	tons/ha	13.067	16.266	15.999	21.074	12.907	27.681	27.129	48.949	44.318	24.412	120.665	100.868	146.862	124.668	-
preserved / land	tons/m²	1,00	0,80	0,70	0,70	1,20	0,00	0,00	0,00	0,00	0,05	1,40	3,00	2,00	2,10	-
	tons/ha	9.984	7.718	7.423	7.411	11.807	0	0	0	0	468	13.628	30.134	18.575	20.592	-
total moving material / land	tons/m²	2,30	2,80	2,80	3,50	2,10	3,44	3,38	5,56	5,10	3,08	20,50	16,90	23,00	20,20	-
	tons/ha	22.941	28.405	28.000	34.534	20.957	34.355	33.802	55.622	50.991	30.793	205.431	169.127	226.680	202.469	-

Table 8 shows the main results of the analysis of the material intensity of each scenario, including the chosen/final one. The final chosen options for the *Ixelles Barracks-Usquare* project and the *Loi-EU district* project consistently have the lowest material impacts compared to those studied. This is due to stakeholders' commitment to promoting circularity, preserving existing building stock, limiting demolitions, and new constructions, thereby achieving a lower material intensity balance. In the case of *the Defence-Ex-NATO* project, the necessity of demolishing 'almost' everything has led to the development of alternative circular strategies. Although the 'tabula rasa' approach was initially adopted, recent studies have shown the benefits of retaining one large building on-site for renovation and preserving open space infrastructures as the foundation for a future large metropolitan park. The 'tabula rasa' approach was mandatory for the *Ex-NATO* site due to previous agreements requiring the complete demolition of their infrastructures. In the following sub-sections, each project will be further detailed, analysing the factors that influenced the embedding of *circularity*-inspired ambitions and strategies.

4. Comparative analysis of results and discussion

4.1. Integrating *circularity*-inspired ambitions in strategic urban projects

The comparative analysis of the three case studies (see **Table 9**) reveals varied interpretations of *circularity* in SUPs. While *Usquare* and the *Loi–EU District* adopt a predominantly architectural approach, focusing on exemplary refurbishment, adaptive buildings and local material reuse, the *PAD Défense* project mainly sees *circularity* through an economic lens and highlights the creation of spaces for local circular economies. This project also considers *circularity* strategies as guidelines to be integrated into the design and construction of new exemplary buildings (leading, for example, the material choices). Its near "tabula rasa" redevelopment facilitates the integration of broader metabolic considerations.

Table 9. Comparative table of the three case studies, highlighting specificities and interpretations of *circularity*, by the authors (2025).

	PAD Ixelles Barracks-Usquare	**Ex-PAD Loi European District "City Forward" masterplan**	**PAD Defence and ex-NATO**
How	The site was identified as a strategic area for redevelopment by the region. Following this, a volumetric feasibility study was conducted, and a PAD was subsequently launched. At the same time, the application for an FEDER (European and regional funding) was introduced, bringing circularity's ambitions to the fore.	After over 10 years, the PAD Loi has been abandoned. It has been replaced by a non-binding "shared vision" carried out by the region, and a masterplan entitled "City Forwards" is currently being drawn up by the regional planning agencies.	Being a site across two regions (Brussels and Flanders), the development of a shared strategy has been crucial (agreement found in 2019). In 2020, strategic plans for the BCR (PAD) and for Flanders (GRUP) were developed and were approved in 2024.
Who	Public stakeholders and Brussels Free Universities (ULB & VUB) are leading a redevelopment project. A temporary occupation took place during the design phase, and partially during construction.	This project, led by both public authorities and private real estate stakeholders, aims to create a mixed-use urban development, equally divided between public and private ownership.	Public stakeholders from Brussels and Flanders plan to transform a former military and high-security area into a new neighbourhood. Citizens and associations participate through public inquiries.
What	Renovation of heritage buildings, adaptation of more recent ones, and demolition and reconstruction of some. The project integrates university facilities, student and social housing, business incubators, and public services. The plan includes green spaces, a food hall, and extensive bike parking.	The new masterplan is divided into key sites occupied by former EU office buildings. The plan prioritises reuse and renovation, with partial demolition where necessary. The programme allocates 70% to offices, 25% to housing, and 5% to public amenities and retail.	"Tabula rasa" approach: all built from scratch. The project includes housing, economic activities, public facilities, a park (4 ha), and a forest (33 ha), alongside a new Belgian Defence HQ. The area will serve diverse social groups, from low-income families to expats and tourists, creating a mixed-use zone.
Interpretation of Circularity	Emphasis on the built environment, heritage preservation and construction waste prevention (limiting demolitions), maximising salvaged construction material and their reuse, repair, and refurbishment. Use of local and bio-sourced materials. Focus on circular economy principles, local job creation (mainly in construction industry), and sustainable food economy.	Emphasis on construction waste prevention (limiting demolitions). Promoting adaptive reuse and lifespan extension of the existing building stock.	Emphasis on the design of new buildings (design for adaptive re-use, for dismantling, etc.). Focus on the use and re-use of local and bio-sourced building materials. Promoting local industries and urban circular economies, and local job creation. Support for local food systems and agriculture.

Project characteristics significantly shape *circularity* integration. Heritage sites like *Usquare* prioritise preservation, often involving stricter, more costly procedures. Dense urban areas face constraints, while less dense zones allow for wider resource cycling (e.g., water, food, energy, organic waste). Newer developments such as PAD *Défense* and *ex-NATO* adopt an almost "tabula rasa" approach, enabling broader metabolic strategies to be deployed. What also emerged is that early-stage integration of circularity ambitions enables holistic interventions, including reassessment of existing structures and optimisation of material flows. Furthermore, location-specific challenges and opportunities (such as the degree of community engagement, whether from scientific, local, or NGO communities) can significantly influence the extent to which circular principles are effectively embedded in urban projects. In this regard, urban regulations may play a pivotal role by promoting less destructive approaches to the built environment through the implementation of more stringent guidelines and requirements for projects involving heavy demolitions.

The *Usquare* case study reveals a tension between the strict and often costly practices required for heritage preservation (where value is embedded in the artefacts) and the challenges of conserving unlisted buildings and infrastructure, which are more vulnerable to extensive demolition and transformation by default. In theory, a preliminary circular approach (such as the R-imperative scale for the built environment proposed by Verga and Khan (2022)) would encourage planners and designers to strategically select building functions that require minimal alteration and support long-term usability, with functions fitting buildings, not the other way around. This reduces both the inflow of new construction materials and the outflow of waste generated by transformation projects. A pertinent example of this principle, where "function follows form" rather than the conventional "form follows function", is the alternative scenario proposed by the NGO The Shifters for PAD *Mediapark*. As outlined in their report (see Section 4.3 from an explanation of the report by Aine, Lancrenon and The Shifters Belgium, 2020), where they advocate for extending the program (functional needs) beyond the designated site boundary in order to identify existing buildings suitable for adaptive reuse, the proposal advocates extending the programme beyond the designated site boundary to identify existing buildings suitable for adaptive reuse. This approach challenges perimeter-based planning and seeks to minimise new construction by repurposing existing structures to accommodate evolving functional needs.

Universities played a key role in *Usquare*, guiding and assessing *circularity* practices and their trade-offs. However, cultural, technological, governance-related, and economic gaps remain. Shifting focus from transformation to lifespan extension requires a paradigm shift in how urban environments are studied and reshaped.

To compare approaches succinctly, three recurring logics can be identified: "transform to maintain", "transform to reuse", and "transform to adapt". These approaches reflect different priorities and underline the importance of tailoring *circular* strategies to local conditions, yet they may carry significant risks if applied uncritically. *Usquare* and *Cityforward* primarily exemplify "transform to maintain" and "transform to reuse", leveraging dense, centrally located fabrics to minimise demolition and embed material reuse. They typically involve light interventions in early 20th-century buildings and more substantial renovations in post-war structures, enabling new functions such as university facilities, public services, and housing. In contrast, *Défense–ex NATO*, situated in a peripheral context with limited existing stock, illustrates "transform to adapt", emphasising new construction designed for longevity, flexibility, reversibility, and selective dismantling, combined with large-scale green infrastructure and nature-based solutions. Nuances nevertheless exist within these categories. Conservation-oriented practices (what could be termed "transform to restore") may prioritise heritage to the extent of removing non-listed elements, undermining material conservation. Likewise, "transform to reuse" may rely on selective demolition while recovering only a small proportion of materials, and "transform to adapt", despite its reversibility ambitions, often demands substantial material inputs and may still lead to future demolition. These contradictions illustrate how interpretations of *circularity* remain inconsistent and how such strategies can generate rebound effects that reinforce over-extraction and waste if not rigorously assessed within broader environmental and governance frameworks.

The case studies demonstrate the varied interpretations of *circularity* and the importance of adaptable planning approaches tailored to specific urban contexts and project goals. The emphasis on particular strategies (whether heritage conservation, material efficiency, sustainability performance, or design innovation) reflects each project's priorities. Despite progress in urban planning tools and frameworks, significant gaps persist. These include cultural shifts across disciplines, technological limitations, governance challenges, and economic constraints. A shift from transformation-focused approaches to those that extend infrastructure lifespan requires a fundamental rethinking of how urban environments are studied and reshaped.

The comparative analysis of the three case studies reveals varied interpretations of *circularity* in strategic urban projects, reflecting broader debates in the literature on how circular economy principles are integrated into urban planning and design (Pekdemir, Guaralda and Limb, 2025; Singhvi, Athanassiadis and Binder, 2025; Tondelli and Marzani, 2025). Notably, the case studies reveal that *circularity* is interpreted beyond the reuse of building materials, encompassing broader resource cycles such as water, food, and local energy production and distribution. This expanded understanding reflects the evolving discourse on urban metabolism and supports calls for more integrative research led by planners and designers (Bortolotti, Verga and Khan, 2023).

To conclude, we highlight four key findings: (i) blurred boundaries between sustainability and *circularity* ambitions; (ii) the influence of project type, location, and development stage; (iii) distinct *circularity* approaches; and (iv) the impact of programmatic requirements on renovation and demolition strategies. These findings underscore the need for context-sensitive planning. The overlap between sustainability and *circularity* is evident in shared goals and frameworks. For instance, local energy production is common across all projects, yet distinctions between sustainable energy and *circularity*-driven cycles remain unclear. This calls for a more precise definition of *circularity* in urban development. *Circularity* is also framed as a driver of economic development, notably in BCR's policies such as PREC and Shifting Economy, which promote it as a strategy to align growth with sustainability. However, this framing can blur environmental and economic priorities, complicating policy implementation and impact assessment.

4.2. Design factors

Table 10 presents key design variables assessed across the three urban redevelopment projects, based on quantitative data from **Table 5** and the evaluative framework by Ooghe *et al*. (2023). These metrics are relevant for early-phase assessments of material intensity, which is critical for evaluating *circularity* potential. The comparative framework offers insight into how design choices (such as density, building depth, and permeability) affect material intensity and environmental impact.

Table 10. Overview of design variables of the three case studies, quantifications are based on Table 5 and on the rule of thumb for quantifications developed by Ooghe (2023).

Key Design Variables	Ixelles Barracks - Usquare	Defence - Ex-NATO	Loi - EU District City-forward
Design Approaches	**Transform to maintain** **Transform to reuse** Emphasis on preserving buildings, especially those inscribed on the heritage list. Light renovation of early 20th-century buildings and heavy renovation of 1970s-80s buildings. A building I being demolished to be reconstructed.	**Transform to adapt** Extensive demolitions and new constructions. The focus is on designing new buildings for adaptive reuse and selective dismantling. Limited renovation (one building and a few infrastructures reused).	**Transform to maintain** **Transform to reuse** Renovation of office buildings with an emphasis on adaptive reuse of the existing, limiting demolitions. Heterogeneous building stock characterised by low permeability and inward-facing buildings.
Program & Form	**Program follows Form for most of the building's stocks** Efford made to fit new program into existing heterogeneous buildings. The heritage building was used by university facilities, public services and a food hall, while more standardised buildings from the 70's are to be reconverted into housing.	**Form follows program** The site has been entirely changed based on a new program. Only one building and a few existing infrastructures will be renovated and reused. Mixed-use development including economic activities, housing, public facilities, and a new Defence HQ.	**Program & form meet halfway** Renovating and converting office buildings into new mixed-use developments including housing, services, offices, retail, and green spaces.

Table 10 (cont.). Overview of design variables of the three case studies, quantifications are based on Table 5 and on the rule of thumb for quantifications developed by Ooghe (2023).

Key Design Variables	Ixelles Barracks - Usquare	Defence - Ex-NATO	Loi - EU District City-forward
Variables of the chosen scenario	**Density:** middle-high density in a historically consolidated urban fabric. **FAR: 1.5** for buildable plots. **Typology:** Mix of low-rise buildings constructed throughout the 20th century. **Materiality:** Keeping brick and concrete buildings. New buildings will include reused materials, and locally sourced materials. New constructions: no detailed data on the choices -concrete, wood, steel, etc. (depends on the selected competitions entry).	**Density:** middle density in a low-density and loose urban fabric. **FAR: 1.3** for buildable plots. **Typology:** Three main kinds of buildings: enterprises headquarters, mixed used buildings with productive activities and housing, and residential. **Materiality:** New constructions: no detailed data on the choices -concrete, wood, steel, etc. (depends on the selected competitions entry). Attention to sustainable materials in new constructions, and focus on local value chains, are possible but not decided upon yet.	**Density:** very high density in a consolidated urban fabric. **FAR: < 5,8** equivalent or less than the existing **Typology:** Mix of low-rise buildings constructed throughout the 20th century. **Materiality:** Keeping the existing structures of concrete buildings. New constructions: no detailed data on the choices -concrete, wood, steel, etc. (depends on the selected competitions entry). Attention to sustainable materials in new constructions, focus on local value chains are possible but not decided upon yet.
	Material Weights/Intensity: Existing kept: **62%** Demolished: **20%** Material outflow/final floor areas: **0,55 tons/m²** Material inflow/final floor areas: **0,89 tons/m²** Total of moved materials/final floor areas: **1,44 tons/m²** Total moving material/land: **21.000 tons/hectares**	**Material Weights/Intensity:** Existing kept: **2%** Demolished: **98%** The area had very few buildings, so the quantity of demolished materials is quite low in the overall impact. Material outflow/final floor areas: **0,64 tons/m²** Material inflow/final floor areas: **2,4 tons/m²** Total of moved materials/final floor areas: **2,36 tons/m²** Total moving material/land: **30.800 tons/hectares**	**Material Weights/Intensity:** Existing kept: **40-70%** Demolished: **30-60%** Material outflow/final floor areas: **--tons/m²** Material inflow/final floor areas: **-- tons/m²** Total of moved materials/final floor areas: **-- tons/m²** Total moving material/land: **-- tons/hectares**
	Open-to-Built Area Ratios: Emphasis on creating open spaces and green areas. On-site water management strategies. **footprint built (impermeable): 44%**	**Open-to-Built Area Ratios:** Emphasis on creating metropolitan green spaces and a forest. Rainwater Infiltration, enhanced biodiversity and soil quality through nature-based solutions. **Footprint built (impermeable): 60%**	**Open-to-Built Area Ratios:** Focus on greening inner urban blocks. enhancing soil permeability and reducing the urban heat island effect. **footprint built (impermeable): less than the existing**

Design approaches reflect varying degrees of intervention, shaped by existing conditions, heritage value, and programmatic goals. In *Defence (ex-NATO)*, the principle of "form follows programme" dominates, with new spatial configurations accommodating mixed-use developments including housing, public services, and institutional headquarters. A more balanced approach is seen in the *EU District*, where programme and form are aligned through the renovation of office buildings into mixed-use spaces integrating housing, retail, services, and green areas. This reflects efforts to adapt existing structures to evolving urban needs while limiting demolition.

Most projects adopted scenarios with limited demolitions, based on the percentage of retained structures, extent of demolitions, and material inflows and outflows per square metre of final floor area. This is evident in *Ixelles Barracks – Usquare* and the *EU District – Cityforward* masterplan, where design strategies aimed to reduce material outflows. In less dense areas like *Defence – Ex-NATO*, the impact of demolitions is relatively lower due to the larger site and higher proportion of new construction. In contrast, dense urban contexts tend to produce higher material outflows due to the compactness of existing structures. Material intensity scores reveal different approaches: *Usquare* retained 62% of existing structures, with 20% demolished, resulting in 1.44 tons/m2 overall, including 0.55 tons/m2 outflow and 0.89 tons/m2 inflow. *Defence – Ex-NATO* retained only 2%, with 98% demolished, leading to 2.36 tons/m2, including 0.64 tons/m2 outflow and 2.4 tons/m2 inflow. *Loi – EU District* adopted adaptive reuse with retention rates between 40–70% and demolitions from 30–60%, though material intensity data is pending. Other sustainability factors, such as energy production and water management, were considered but excluded due to data limitations.

The comparative analysis of the design approaches reveals how *circularity*-oriented design is shaped by context-specific variables, including existing building conditions, heritage value, density, and programmatic goals. The relationship between program and form also emerges as a critical factor, influencing whether existing structures are retained or replaced. Across all cases, efforts to integrate green infrastructure, manage water on-site, and reduce impermeable surfaces highlight a growing emphasis on bioclimatic and ecological performance. These findings underscore the need for flexible, context-sensitive planning frameworks that can accommodate diverse interpretations of *circularity* while responding to local urban conditions and broader ambitions.

4.3. Circularity and Urban design and planning landscape in BCR: Who is supporting and developing the circular agenda?

The integration of *circularity*-inspired ambitions in SUPs in the BCR is shaped by the interplay of three key actor types: universities and research institutions, activists and NGOs, and institutional/public actors. Each plays a distinct but complementary role in promoting, steering, and challenging the implementation of circular strategies.

Universities and independent research organisations have been instrumental in advancing *circularity* in urban planning and design. In the BCR, academic institutions have contributed foundational studies on UM, identifying key sectors for intervention and informing regional CE policies (Athanassiadis, Bouillard and Khan, 2013; Athanassiadis, 2017; Athanassiadis et al., 2018). Their role extends beyond theoretical contributions to active involvement in project development and assessment. The *Ixelles Barracks – Usquare* project exemplifies this role. University researchers not only participated in the design process but also conducted material flow analyses and monitored *circularity* strategies throughout the project lifecycle. Their involvement ensured that circular ambitions were grounded in empirical data and critical evaluation. Universities offer an unbiased perspective, often filling analytical gaps left by public administrations and private design offices, which may lack the time, expertise, or independence to conduct in-depth assessments. Moreover, academic institutions help bridge the gap between policy and practice by developing simplified methodologies for evaluating material intensity and resource flows. These tools are essential for early-stage project assessment and for embedding circular principles into design decisions. Their contribution is particularly valuable in contexts where circularity is still emerging and where robust evaluation frameworks are lacking.

Activists and NGOs have played a pivotal role in contesting and reshaping urban planning practices in the BCR. Their engagement has often emerged in response to SUPs perceived as overly disruptive or exclusionary. Through organised campaigns, alternative proposals, and public mobilisation, these actors have influenced the trajectory of several strategic projects. A notable example is the PAD *Loi – EU District*, where civic opposition led to abandoning the original PAD and developing a new masterplan, *Cityforward*. NGOs such as The Shifters proposed alternative scenarios that prioritised adaptive reuse over demolition, using tools to quantify the carbon emissions of different design choices. Their advocacy contributed to a shift in planning priorities, demonstrating the power of bottom-up mobilisation to promote less material-intensive, more inclusive urban transformations. Similar interventions have occurred in other contested sites, such as Josaphat and *Mediapark*, where NGOs defended ecologically valuable areas and challenged demolition-led redevelopment. These grassroots efforts have helped foreground circularity as a socio-political issue, not just a technical one. They have also pushed planning agencies to adopt more participatory approaches, such as developing “shared vision” documents prior to regulatory planning. By challenging planning mechanisms and advocating for more inclusive approaches, these actors have contributed to reshaping urban policies, fostering broader sustainability, and promoting *circularity*. Thus, their role is essential in ensuring that *circularity* is not reduced to a technocratic agenda but remains responsive to community needs and ecological concerns.

Public institutions, including regional planning agencies and municipal administrations, are central to operationalising circularity in SUPs. The introduction of the PAD as a hybrid planning tool (combining strategic vision with regulatory authority) has enabled more precise integration of circular ambitions into urban development. PADs now serve as the primary instruments for guiding large-scale transformations in Brussels. Institutional actors have also supported circularity through policy innovation. The forthcoming "Good Living" Regional Urban Regulations (RRU) aim to limit demolitions and promote adaptive reuse, aligning regulatory frameworks with circular principles. These policies reflect a growing institutional commitment to sustainability and *circularity*. However, public actors also face challenges. Fragmented governance, underdeveloped material value chains, and limited technical capacity often constrain the implementation of circularity. In some cases, planning instruments like PADs have been criticised for fostering elitism and accelerating transformations towards gentrification. The *Ixelles Barracks – Usquare* project, for example, faced criticism for demolitions mandated by the PAD's requirement to restore the historical urban grid, despite *circular* ambitions. Notwithstanding these tensions, institutional actors remain key enablers of circularity. Their ability to set standards, allocate resources, and coordinate stakeholders is crucial for scaling circular practices.

Circularity-inspired ambitions in the BCR, therefore, stem from both top-down governmental strategies, bottom-up civic activism and academic institutions' engagement, resulting in a complex landscape of hybrid processes that foreground diverse CE strategies. The interplay between institutional directives and grassroots mobilisation underscores the necessity of a pluralistic approach to UC. This evolving entanglement of formal and informal efforts are driving UC transformations, embedding sustainability and inclusivity into future planning paradigms.

Although academic discourse on *urban circularity* remains emergent, inclusivity is increasingly recognised as vital. Scholars such as Sánchez Levoso et al. (2020) highlight that the successful implementation of *circularity* strategies requires the active participation of local stakeholders in both identifying and validating *circular* solutions. Similarly, (Amenta et al., 2019; Remøy et al., 2019) advocate for the use of living labs, whereas (Mirzoev et al., 2022) underscore the importance of long-term participatory processes, particularly in ensuring the inclusion of marginalised communities. Vanhuyse et al. (2021) examine the extent to which the current literature addresses the social impacts of the transition to *circular* cities and find that social impacts have rarely been considered, with a limited scope only covering employment and governance. Furthermore, Wuyts (2022) critiques the absence of intersectional environmental perspectives within "*circularity"* discourse, drawing attention to the role of informal *circular economy* actors often overlooked in mainstream narratives (Wuyts, 2022; Wuyts and Marin, 2022). In Brussels, the significant contribution of political ecology researchers stresses the danger of an "urban sustainability fix" by selectively incorporating ecological goals into governance strategies (KębEowski, Lambert and Bassens, 2020; Lambert, Santos and Bassens, 2022). Other debates on *circularity* in cities highlight that it can be seen as both a neoliberal "spatial fix" that reproduces existing urban inequalities and a potential space for socio-ecological transition that challenges neoliberal urbanism (Bassens, KębEowski and Lambert, 2020). Some argue for a degrowth perspective, emphasising inclusiveness and social justice in *circular* city practices beyond eco-efficiency (Visconti, 2021), while others highlight the inherent limitations of the notion of *circularity* (Savini, 2019), even proposing an end to it (Savini, 2025).

In sum, UC in the BCR emerges as a multifaceted and hybrid process, driven by institutional policies, universities (and research institutions), and grassroots activism. Universities and research institutions play a pivotal role in advancing circularity through rigorous analysis and unbiased perspectives, while civic activists and NGOs challenge traditional planning methodologies, advocating for more inclusive and less impactful approaches. This hybrid process underscores the need to integrate both top-down and bottom-up strategies to foster circular urban transformations.

4.4. Factors encouraging or hindering the adoption of *circularity*-inspired approaches

The comparative analysis highlights several shared and context-specific factors shaping the implementation of *circularity* across the three urban redevelopment projects (see **Table 11**). Strong sustainability ambitions and local economic development goals consistently emerge as key drivers, supported by active engagement from public stakeholders, design teams, and political actors. Common barriers include underdeveloped material value chains, limited technical specifications, weak assessment tools, and fragmented stakeholder coordination. Overcoming these challenges requires integrated governance, robust monitoring frameworks, and early-stage urban metabolism analysis to ensure that *circularity* ambitions translate into coherent and impactful urban strategies.

Table 11. Comparative table of the three case studies, highlighting key factors (drivers, enablers and barriers) that impact the integration of circularity-inspired ambitions and strategies, by the authors (2025).

	PAD Ixelles Barracks - Usquare	**Ex-PAD Loi European District "City Forward" masterplan**	**PAD Defence and ex-NATO**
Drivers	Overall high sustainability and innovation ambitions (exemplary project). Economic objectives supporting local economies. FEDER (European funding) for an exemplary regional project. Research-driven objectives are driven by the two universities.	In response to previous criticism, strong emphasis on sustainability and innovation. Demographic pressures for increased housing and services. The revised forthcoming regional urban regulations (RRU) promoting circularity and sustainability obligations (limiting demolitions). Focusing on setting an example by piloting the conversion of office buildings to mixed use and housing, and moving from a car-centred to a soft mobility approach.	Overall high sustainability and innovation ambitions (exemplary project). The revised forthcoming regional urban regulations (RRU) promoting circularity and sustainability obligations. Economic objectives supporting local economies.
Enablers	Strong commitment from public stakeholders, university researchers, and design teams; advocacy from local and circular value chains.	Strong engagement from public stakeholders, citizens, and NGOs; political will; involvement of private stakeholders; motivated design teams.	Commitment from public stakeholders, political support, and design teams' motivation.
Barriers	Policies and regulations (historical grid re-establishment leading to demolitions); underdeveloped circular materials value chains resulting in higher costs of salvaging and re-using materials; immature regulatory frameworks; lack of robust assessment tools; insufficient urban metabolism analysis; absence of a shared culture of care and maintenance.	Underdeveloped circular materials value chains; lack of legal frameworks supporting circularity experimentation; absence of robust impact assessment tools; limited urban metabolism analysis; weak monitoring tools; absence of a shared culture of care and maintenance.	Underdeveloped tools for impact evaluation; absence of in-depth urban metabolism analysis; fragmented efforts among multiple stakeholders; lack of relevant case studies; weak legal frameworks for circularity experimentation; absence of a shared culture of care and maintenance.

The literature review highlights the drivers, enablers, and barriers to implementing *circularity* ambitions in urban projects and urban planning. Key drivers include the need to re-functionalise vacant public spaces and restore brownfield sites, alongside integrating green elements and systems to regulate climate, air, and water quality, enable nutrient and water cycling, and provide recreational spaces (Andreucci and Croci, 2021). Enabling conditions include comprehensive governance frameworks, stakeholder collaboration, awareness-raising, and the use of sustainability assessment tools (Rajčić et al., 2024; Wandl et al., 2024). Experimental formats such as living labs also support innovation in *circular* strategies (Amenta et al., 2019). However, barriers encompass technological, economic, policy, organisational, sociocultural, institutional, ecological, environmental, and consumer-related factors (Andreucci and Croci, 2021; Wandl et al., 2024). Specific challenges include budget constraints, limited market applicability, inadequate policies, absence of consistent datasets, and lack of engagement in decision-making processes (Arciniegas et al., 2019; Campbell-Johnston et al., 2019; Bilal et al., 2020; Rajčić et al., 2024; Wandl et al., 2024). Regulatory frameworks often lack transparency and accountability, and the absence of data to demonstrate the benefits of circular development weakens political support (Williams, 2022). Additionally, misalignment between design tools and participatory research approaches presents further obstacles (Cambier, Galle and De Temmerman, 2020).

A recurring theme is the lack of reliable data and robust tools for evaluating project impacts, as seen in *Ixelles Barracks – Usquare*, which reflects broader concerns in the literature (Wandl *et al.*, 2024). Economic barriers, such as high upfront costs and limited financial incentives, are also common across both domains.

The *Usquare* and *Ex-PAD Loi – EU District* cases highlight the financial challenges of developing local economies and sourcing *circular* materials. Regulatory developments could positively influence *circularity* implementation, particularly in the *EU District*, where civic opposition to earlier plans led to a more sustainable and less disruptive redesign. This case also illustrates the growing influence of citizen and NGO advocacy, which has been less impactful in other projects like *Mediapark* and *Josaphat*. Cultural resistance and a lack of consumer awareness are barriers noted in both the literature and the case studies, typical to the construction and real estate sector (Peirani and Cochard, 2021; Verga and Khan, 2022a). The *Ixelles barracks-Usquare* case study specifically mentions the lack of a shared culture of care and maintenance, which is a barrier also identified in the general findings (Peirani and Cochard, 2021; Rajčić *et al.*, 2024). Digital technologies offer promising opportunities for monitoring urban metabolism and improving resource management, as discussed by D'Amico *et al.* (2021, 2022), but require further development and integration.

Overall, the comparison underscores the importance of addressing technological, economic, policy, and sociocultural barriers through integrated governance, stakeholder engagement, and improved data and monitoring systems.

4.5. Material intensity, paving the way for a more resource-conscious approach to urban transformations

Circularity-inspired policies are often grounded in UM studies, which quantify resource and waste flows at various scales. While recent efforts have begun to spatialise metabolic stocks and flows (Bahers *et al.*, 2022), extensive UM studies remain time-consuming and data-intensive, limiting their applicability in urban design and planning. To address this gap, scholars (Saadé *et al.*, 2022; Bahers and Rosado, 2023; Ooghe *et al.*, 2023; Gobbo *et al.*, 2024) have developed simplified methodologies for integrating metabolism analysis into the evaluation of urban and architectural scenarios. This is particularly relevant given the construction sector's significant impact, accounting for over one-third of regional material flows. Incorporating material footprint data into early design phases allows planners to assess how individual projects contribute to regional resource balances, promoting less resource-intensive and more circular urban layouts.

The methodology used in this research, based on Ooghe et al. (2023), draws on publicly available Environmental Impact Reports (EIRs) and spatial plans to establish indicators for material consumption, waste production, and land use. By quantifying footprints (in square metres and hectares) and material weights (in tons), this approach provides a transparent, replicable framework for assessing urban projects through a circularity lens. Despite its strengths, the approach has limitations. It relies on generalised coefficients and predefined indicators (e.g. demolition ratios, new construction estimates), which may oversimplify the complexity of material flows. Urban transformations most often develop through variations (i.e., in building typologies, renovation strategies, and material lifecycles) that are not fully captured. Moreover, while land-use metrics (e.g., built/unbuilt and permeable/impermeable ratios) offer insights into spatial efficiency, they do not account for qualitative environmental factors such as biodiversity, microclimatic effects, or liveability.

The case studies illustrate these tensions. *Ixelles Barracks – Usquare* and *Loi – EU District* show reduced material impacts due to preservation and limited new construction, while *Defence – Ex-NATO* initially adopted a "tabula rasa" approach but later recognised the value of retaining existing structures. These examples highlight the need to expand *circularity* assessments beyond building materials to include open space and infrastructure redevelopment. Material intensity in redesigning open spaces should be quantified using typology-based methodologies (Ooghe, 2023), and early design data (e.g., feasibility studies) should include indicators for water management, energy production, and soil permeability.

Ultimately, these data and tools empower planners, designers, researchers, and public authorities to incorporate material considerations into project negotiations and evaluations. This supports a more holistic understanding of the trade-offs between programmatic ambitions, spatial and qualitative goals, and the diverse environmental impacts associated with each transformation. As the BCR shifts away from demolition-led urban transformation, this marks a significant evolution in planning practice towards more resource-conscious, spatially integrated, and *circular* urban development.

5. Conclusions

This article investigates how *circularity*-inspired ambitions are being integrated into urban planning and design practices by analysing three publicly led regulatory masterplans (PAD) in the BCR. By examining the planning landscape, design strategies, stakeholder dynamics, and enabling and constraining factors, the study offers a critical reflection on the potential of SUPs to serve as experimental grounds for advancing *circular* paradigms in urban transformation. The planning landscape in the BCR is characterised by a complex ecosystem of tools, with the PAD emerging as a central instrument for integrating *circularity* into strategic urban development. PADs combine normative and strategic dimensions, enabling public authorities to guide SUPs with greater precision. However, their implementation also raises concerns about inclusivity and environmental impact, particularly when demolition-led approaches are favoured. While PADs offer regulatory strength, they also face criticism for being overly disruptive and lacking inclusivity, highlighting the need for participatory governance and more adaptive planning instruments.

The findings show that *circularity* in urban development manifests in diverse ways, shaped by project-specific contexts and objectives. Some initiatives prioritise the reuse of construction materials, others focus on maintaining and refurbishing existing infrastructure, while certain projects aim to create new buildings designed for adaptability and longevity. Three main approaches emerge: "transform to maintain", "transform to reuse", and "transform to adapt". These reflect different priorities and underline the importance of tailoring circular strategies to local conditions, yet they may carry significant risks when applied uncritically. These varied approaches highlight the complexity of operationalising *circularity* and the need for context-sensitive strategies rather than universal models. At the project scale, design variables, such as density, floor area ratio (FAR), building typology, materiality, and technical choices (heating, ventilation, water management, etc.), play a critical role in determining the environmental footprint of urban transformations. Time is also a key parameter, as longevity and slower transformation cycles constitute structural dimensions of *circularity*.

From a governance perspective, a hybrid constellation of actors advances the *circular* agenda in the BCR. Public administrations set strategic frameworks and regulatory standards; universities and independent research institutions provide critical analysis and technical expertise; civic associations and NGOs advocate for less disruptive and more inclusive planning practices. This interplay between top-down and bottom-up initiatives fosters a pluralistic and evolving landscape for *circular* urbanism.

Key drivers highlighted by this research include strong sustainability ambitions, economic goals linked to local development, and supportive regulatory frameworks such as the forthcoming "Good Living" RRU. Enablers comprise committed public stakeholders, motivated design teams, and civic engagement. Barriers persist, including underdeveloped *circular* material value chains, immature technical specifications, a lack of robust assessment tools, and fragmented stakeholder coordination. The absence of a shared culture of care and maintenance further undermines long-term success. Several priorities emerge from this analysis: (i) the development of accessible tools to assess the impacts of early-stage urban design; (ii) the inclusion of resource and waste considerations not only for buildings but also for infrastructure and open spaces; (iii) the alignment of programme requirements with existing built environments; and (iv) the evaluation of urban and environmental qualities beyond material flows. A main insight is the tension between traditional planning paradigms, which favour transformation and growth, and *circularity*'s emphasis on minimising resource use and environmental impact. This perspective calls for slowing the pace of transformation and questioning the necessity of physical modifications to existing spatial layouts. Such a shift requires a fundamental rethinking of how urban change is conceived and implemented.

Despite these insights, the study is limited by its geographic focus on the BCR and its selection of case studies. Future research should expand the scope to include national and international comparisons and track the long-term impacts of *circularity*-inspired strategies. The study also highlights the importance of quantifying material flows (inflows, outflows, and existing stocks) within the built environment. Extending this approach to open spaces and infrastructure, and integrating indicators for energy, water, biodiversity, and soil permeability, would enhance the comprehensiveness of *circularity* assessments. Developing user-friendly tools for early-stage evaluation and embedding urban metabolism analysis into planning processes will be essential to advance a more *circular urbanism*.

In conclusion, the findings point to the need for a paradigm shift in urban development. This shift involves moving away from extractive practices centred on demolition and reconstruction and embracing approaches that value existing material arrangements. It is not only technical but also cultural, requiring a reassessment of how urban environments are valued and transformed. Public administrations should embed long-term resource management principles into planning frameworks. Universities and independent research organisations play a key role in assessing and guiding projects, while citizen associations are essential in defending existing material layouts and advocating for less disruptive urban transformations. SUP approvals should prioritise environmental and social resilience over short-term economic gains. Rather than focusing on the perpetual replacement of the built environment, cities must foster a more resource-conscious approach in which buildings and infrastructures are maintained, adapted, and repurposed to meet contemporary needs. Establishing the foundations for a transition to a more *circular urbanism* is essential to ensure that urban development aligns with ecological limits while fostering more equitable and liveable urban environments.

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Authors' contributions G.C. Verga and Ahmed Z. Khan conceived and designed the study. G. C. Verga performed the literature review and semi-structured interviews, wrote the first draft of the manuscript, and conducted the comparative analysis of the results. V. Ooghe developed the calculations for assessing material intensities of urban projects and, together with G.C. Verga, created the table presenting the quantitative results. A.Z. Khan supervised the study including review and editing of all the draft versions. G.C. Verga, A.Z. Khan and V. Ooghe reviewed and edited the final draft.

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Declarations

Competing Interests The authors declare no competing interests.

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