Approaching sufficiency measure integration in sustainability assessment of neighbourhoods

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Abstract

For the built environment, sustainability targets aim towards renewable energy supply and energy renovation strategies, combining efficiency and consistency measures. The sustainability strategy of sufficiency, with its perspective of enabling and promoting changes in societal practices towards an absolute reduction of consumption appears to be necessary, but is underrepresented in sustainability measures and policies. Further, the environmental impact of the built environment in form of energy, material and land consumption is not limited to CO_2-emissions and equivalents; also, it includes not only buildings, but their surrounding infrastructure, as i.e. regenerative energy supply and sustainable mobility depend on synergies and interactions at the neighbourhood scale. Sustainability Assessment (SA) offers a tool to holistically approach impacts in terms of ecological, economic as well as socio-cultural dimensions. Thereby, SA of buildings is already widely spread, the assessment of a buildings broader spatial impact in a neighbourhood perspective, as well as concerning planetary boundaries, however, is inconsistent. To develop measurable sufficiency criteria for the built environment, this investigation approaches sufficiency for buildings and their spatial relation by outlining relevant parameters based on a semi systematic literature review. Further, a synoptic analysis is approached to understand present sufficiency representation in existing neighbourhood SA (NSA) systems. Eight sufficiency-parameter are outlined which offer a framework to depict sufficiency related indicators in neighbourhood assessment. A table overview presents categorized quantitative and qualitative indicators. Additionally, the overall valuation percentage of outlined parameter is summarized. The findings provide a fundamental understanding of sufficiency barriers and carriers in neighbourhood sufficiency assessment (NSA) and constitute the basis to determine sufficiency indicators in a next research step.

Introduction

The built-up infrastructure shapes our surrounding, interaction and daily routines, combining housing, working, leisure and mobility in their physical expression in form of buildings, streets, neighbourhoods and cities. Sustainability targets, i.e. climate neutrality, approach renewable energy supply and energy renovation strategies for the built environment, combining efficiency and consistency measures. Sufficiency presents the third, but less implemented of the three mitigation strategies, aiming to promote and enable changes in societal practices towards an absolute reduction of consumption. Noted to be necessary (IPCC 2023), sufficiency is underrepresented in scenarios and policies (Balembois und Bourgeois 2022). In the built environment, this implies inter alia the consideration of a full life cycle perspective and a deeper understanding of buildings in a spatial relation. Climate neutrality measures, as regenerative energy supply and climate friendly mobility, depend on synergies and interactions between different buildings, highlighting the neighbourhood perspective. "There is a need to move the object of assessment in the form of a single building to a broader scope, including neighbourhoods, cities, or even national building stocks to facilitate GHG emission reductions

at a larger scale." (BBSR 2021, S. 15). Climate neutrality thereby demonstrates the politically dominating planetary boundary, while the environmental impact of the built environment in form of energy, material and land consumption is not limited to CO_2-emissions and equivalents. To address the built environment in its complexity, Sustainability Assessment (SA) systems present a holistic measurement process to evaluate impacts and operate as decision-making tools for directing actions towards a sustainable development. With their aim to capture ecological, economic as well as socio-cultural dimensions, they present comprehensive criteria lists determining sustainability standards, thus underlie the following investigation on sufficiency criteria. A previous publication analysing sufficiency as a criterion for SA of buildings already showed a present lack of sufficiency measures (Hock et al. 2022), feeding the assumption of a corresponding sufficiency gap in SA on a neighbourhood scale. Further, by approaching sufficiency-oriented neighbourhood design, Christ et al. (2023) highlight the need of quantitative approaches on sufficiency to guide sustainable urban planning towards an absolute reduction of resource consumption, supporting the research gap of sufficiency criteria for SA in the built environment. To approach sufficiency integration into SA criteria, the determination of sufficiency parameter is relevant for sufficiency measure allocation in SA. This subsequently allows the exploration of sufficiency representation applied Neighbourhood Sustainability Assessment (NSA) systems. Accordingly, the guiding research questions (RQ) of the investigation are as follows:

RQ1 What parameters determine sustainability strategies in the various dimensions of the built environment, scaling from detailed consideration of building components to a building's wider spatial relation?

RQ2 How is sufficiency approached within commonly represented Sustainability Assessment of neighbourhoods and what barriers or carriers of sufficiency are apparent?

Methodology and Structure

Answering the research questions builds upon four consecutive steps: definition, literature review, synoptic analysis and discussion. *First*, sufficiency and neighbourhood definitions are developed and followed by an introduction into SA, laying the theoretical basis for both research questions and towards sufficiency assessment. *Second*, sufficiency parameters of sustainable building as well as neighbourhood planning are determined by a literature review. Based on the table by Khouli et al. (2014), efficiency, consistency and sufficiency dimensions of buildings are reviewed and extended by a broader spatial perspective. Focusing on sufficiency criteria for SA, the literature was reviewed by a semi-systematic search using the Web of Science database, supplemented by literature already known to the author, in order to assure a comprehensive overview of dimensions and measures [RQ1]. *Third*, three neighbourhood SA tools are examined for the representation of sufficiency barriers and carriers in the parameters outlined [RQ2]. Fundamentally, this investigation focuses on rather densely built-up areas and aims to apply to the **urban or suburban** context. Further, neighbourhoods present the scope of the paper, as relevant synergies and interdependencies in the built environment relate to the interplay of more than one building, i.e. energy and mobility. Neighbourhoods thereby present a spatial structure significantly smaller than a city that encompass socio-cultural expressions and support a planning perspective towards SA criteria determination.

Sustainability in the Built Environment

SUSTAINABILITY AND STRATEGIES

Sustainability research comprises the three mitigation strategies of efficiency, consistency and sufficiency. Efficiency summarizes the optimization of technique, process and product to improve the input-output relation. Consistency aims towards closed material resource cycles and comprises renewable energies and the cradle-to-cradle concept (Behrendt et al. 2018). Sufficiency comprises the quantitative limitation of consumption and production based on changes in societal practices, often conceptualized in "consumption corridors" (Lage 2022). It currently finds growing attention in energy and circularity scenarios, including policy proposals. The latest climate change mitigation report (IPCC 2023) states sufficiency explicitly as a strategy to deliver human well-being and to stay within planetary boundaries. Concerning preservation and protection, Resilience is posing an adaptation strategy, embracing a systems capacity to react on and handle a crisis (BBSR 2018). By reducing the risk of failure, Wiese et al. (2022) see alongside sufficiency a higher certainty of security and resilience. Hence, there are correlations within the different strategy typologies. Further relating to sustainability strategies is the predominantly discussed climate neutrality. The term climate neutrality refers to a quantity of emissions which – if set to zero – complies with climate targets. Relevant is thereby the net-zero approach: thereby, mitigation strategies as enforceable are additionally supported by offsetting through net-negative emissions (IPCC 2023). Two options of offsetting compile the natural sink approach (in line with LULUCF EU objectives) and uncertain technologies such as carbon capture and storage (CCS) (Marignac et al. 2023). Brief definitions of the different strategies are summarized in Table 1.

TERMINOLOGY NEIGHBOURHOOD

Neighbourhoods incorporate various layers of observation in a confined part of urban structure. In a German context, the applied term "*Quartier*" gains increasingly in importance. It originated from the concurrent French term '*le quartier*' and refers to '*city quarter*' or *'urban district'*. Feldmann (2009) highlights the terms arriving in the urban sociologist understanding of *'social space'* within the Urbanism of the 60s. The term '*Quartier*' has thus been used in the context of housing, social spatial design and to capture such as migration processes within the city, specifically such as gentrification processes. The federal funding Program '*Soziale Stadt*' (Eng.: *'Social City'*) refers to the terminology '*Quartier*' in the social-spatial development since 1999 (Feldmann 2009). Feldmann approaches a definition on basis of its constructional/structural (physical) and immaterial attributes, outlining a '*Quartier*' as a definable part of the city with a rather high structural density, including

Table 1. Strategies towards climate mitigation, adaptation, and offsetting.

Type of Strategy	Strategy	Definition	Reference
Mitigation Strategy	Efficiency	Optimization of input-output relation	Behrendt et al. (2018)
	Consistency	Aiming towards closed material cycles or the integration of material flow into the natural metabolism	Behrendt et al. (2018)
	Sufficiency	Quantitative limitation of consumption and production based on changes in societal practices	Lage (2022)
Adaptation Strategy	Resilience	A systems capacity to react on and handle a crisis	BBSR (2018)
Net-zero Strategy	Offsetting	The net-zero strategy of net-negative emissions by compensatory measures	Own determination

mixed use, walkable local supplies and social interaction of its inhabitants.

Recently, the term has gained interest in a more general understanding of energy supply and has been included in laws and regulation – though, without a clear definition (Dena 2021). Leaving the scope of a single building allows connecting innovative and cost-effective renewable heat supply in the spatial relation of multiple buildings. Under the target of climate neutrality, a broader spatial perspective allows the linkage of sectors: connecting heating and cooling, electricity and mobility. The German Energy-Agency (Dena) therefore understands *'buildings in a spatial connection'* as a synonym for *'Quartier'*. Complemental, the German Building Energy Act (Ger.: *Gebäudeenergiegesetz*, GEG), § 107, highlighting the collective energy supply of buildings as a need for the characterization as 'Quartier' (Dena 2021, S. 7).

Reicher und Schmidt 2021, S. 32 approach the determination of 'Quartier' to bypass the administrative character of a district or county, describing a linkage of buildings significantly smaller than a city on basis of the socio-cultural expression of its spatial structures. Connecting everyday life with its infrastructure, housing and working define the representation and identification of a neighbourhood. A neighbourhood (Ger.: *Nachbarschaft*) is thereby distinguished by its stronger focus on social face-to-face relations, while 'Quartier' provides the functional setting of it. In the English translation, however, 'Neighbourhood' is seen as a common synonym for its understanding, and the term itself seen as an expression for interlinked politics.

While energy supply for operation is dominating the aim towards climate neutrality in the political debate, buildings and related infrastructure require land and retain embodied energy in their materials. In three groups, the major environmental impacts of the built environment are energy, material and land consumption (Xue 2013). Thus, the following understanding of 'Quartier' is based on resource consumption, the definition in the energy law context by Dena (2021, S. 11) and complemented by the consensus of Reicher und Schmidt (2021) to include socio-cultural expression of spatial structures: **The German term 'Quartier', in this research synonymously referred to as 'neighbourhood', describes multiple buildings in their environmental relation and in a societal context**. The environmental impacts of energy, material, and land describe the quantitative relation of neighbourhood resource dependencies, while the adequateness of those is captured in the qualitative understanding of its societal context. This determination underlies the following and forthcoming research steps towards sufficiency-assessment of neighbourhoods.

SUSTAINABILITY ASSESSMENT

Approaching environmental impacts on the built-up area, various methodologies as statistical models or simulations can be applied. SA presents a measurement process to evaluate impacts commonly combining ecological, economic as well as socio-cultural dimensions (Waer und Sibley 2005). Generally, Andes et al. (2019) defines SA as decision-making tool for directing actions towards a sustainable development. By opposing positive and negative aspects, SA aims to outline the best option for action by respecting interdependencies and conflict of objectives. Modelling a depiction of reality, its level of detail influences the accuracy of the assessment situation, while the level of abstraction is necessary for the appropriateness of effort and practical application.

Building Sustainability Assessment (BSA) approaches the design and evaluation of solitary buildings. On an institutional level, certification processes help to verify compliance with building and sustainability regulations. Generally, it may influence the planning process and serve as an educational tool towards sustainability. Demonstrating a buildings environmental, social and economic footprint, it may improve a buildings energetic performance, the material supply chain and user comfort, while efficiency gains by material and design can further reduce the life cycle costs of a building (UN habitat 2017). Characteristics of effective indicators are them being relevant, reliable, easy to understand and based on accessible data (Waer und Sibley 2005). Firstly introduced was the British system BREEAM in 1990, followed by the prominent US-American system LEED and in 2009, the German systems DGNB and BNB followed (Khouli et al. 2014). Demanding the consideration of a buildings full life cycle as a system criterion, **life cycle assessment** is thereby concerning the ecological quality of material and energy input by recording and classifying upstream impacts (BBSR 2019).

Extending building projects system boundaries, **Neighbourhood Sustainability Assessment (NSA)** aims to integrate assessment methodologies for environmental impacts at the city scale – including such as buildings, open spaces, networks and mobility. Assessing the environmental performance of the built environment, Lotteau et al. (2015) see the potential of addressing bio-climatic design, urban density, common goods and mobility in the neighbourhood as operational scale. While

multiple NSA systems and neighbourhood LCA methods exist on the market (Orozco-Messana et al. 2021), the complexity of the urban metabolism results in a variety of data input and system boundaries. This includes the variety of data depth, i.e. the detail of building construction, or the general inclusion of parameter, as i.e. mobility. Further, an important critique on NSA comprise their market-oriented incentives: most NSA tools "promote a specific type of urban development that effectively excludes regeneration projects from the urban sustainability conversation" (Boyle et al. 2018, S. 1). Urban regeneration (or transformation, renewal) describes the redevelopment of urban environments towards sustainable neighbourhoods. The valuation characteristic of NSA tools, however, focuses on the easily measurable aspects of sustainability in form of green technologies and design – resulting in market dynamics and social inequalities of affordability, predominantly applied to new construction projects. Collectively, Boyle et al. (2018) summarize NSA shortcomings in their **1:** prescriptive, static nature, **2:** lack of socio-economic criteria, **3:** lack of the comprehension of local realities by unifying concepts, **4:** being market-driven and **5:** their inadequate recognition of complexity. These shortcomings present the general challenge of SA in the concurrence of easy to apply but holistic indicators (Andes et al. 2019): As measured variable, indicators present the implementation level of sustainability criteria into valuation, connecting conception and operative layers. They aim to comprise the specification of local problems to the ideal of a broader, international harmonisation. In SA, an indicator is a quantitative or qualitative measurable parameter of a criterion, which categorizes the requirements or processes of the all-over valuation.

Criterion → Parameter → Indicator

Quantitative measurable and with thus, dominating indicators focus on technical improvements as i.e. energy saving due to insulation or improvement of recycling rates – thus, efficiency and consistency strategies. Connected to their research in a sufficiency-oriented communal district development project, Christ et al. (2023) formulate the need of sufficiency indicators for resource-conscious and socially just urban development and planning. Consequently, measurable sufficiency indicators in the built environment present a research gap.

Sufficiency Assessment

Sufficiency of Buildings implies a consideration of a building's full life cycle, combining building operation, production industry, user behaviour and waste generation – related to its material, land and energy consumption. Zimmermann et al outline five superior goals for building sufficiency: A consequent prioritization of existing building stock; the reduction of area consumption per person; adaptability; low-tech; and energy-conscious user behaviour (BBSR 2023). From the system boundaries of a building project, building sufficiency scales down into its interior design, utilization and material. Sufficiency in a spatial relation widens the perspective to synergy effects in the interplay of multiple buildings as well as open-spaces, mobility and use-specific patterns. The concept of a 15-minute-city highlights the value of mixed neighbourhoods for short travel distances. Additionally, multicoding of interior as well as exterior spaces allows multiple functions and offers adaptability and flexibility of use concepts (Deutscher Städtetag 2021). Widening a projects boundary to neighbourhood buildings, the broader spatial relation is further scaling out to such as urban design, legislation, and regional geography.

SUFFICIENCY PARAMETER IN THE BUILT ENVIRONMENT

To approach sufficiency parameter, an overview of sustainability strategies in the built environment is reviewed and extended based on the table by Khouli et al (2014), outlining efficiency, consistency and sufficiency measures in buildings. The building dimension (Building, utilisation unit, interior space, building component and material) is in this investigation supplemented by the broader spatial perspective covering the nearest block of houses, the neighbourhood, municipality, region and national setting. Focusing on sufficiency criteria for SA, English literature was reviewed by a semi-systematic search in the Web of Science database. The screening of titles and abstracts focused on the understanding of sufficiency as per definition in Table 1. The ambiguity of the term "sufficiency" – also including the meaning of the last out of an amount in a specific context (i.e. "sufficient daylight") – results in a high number of sort out as per definition. Further, the search is supplemented by publications already known to the author in sufficiency research in German and English language, recognizing the niche of sufficiency research as such and its representation in the German context.

Step 1: Web of Science → "Building" / "architecture" / "neighbourhood" AND "sufficiency" NOT "self-sufficiency" NOT "daylight sufficiency" NOT "seismic", period 2014–2023, 26.05.2023 (n=183)

Step 2: Screening of titles and abstracts: n =19 (sufficiency parameter related n=14)

Step 3: Literature already known to the author (n=13)

Final paper count *n=32* (with sufficiency parameter relation: *n=27)*

The coding scheme included publication, author, year, region, keywords; and clustered efficiency, consistency, sufficiency, resilience and offsetting as per definition (Table 1). The following Table 2 presents the findings for the three mitigation strategies and serves as a status-overview for identifying guiding sufficiency parameter.

To answer the first research question, the conducted semi systematic literature review clusters sustainability measures by spatial dimensions, as presented in Table 2. The research scope towards neighbourhood sufficiency assessment includes *Municipality, Neighbourhood, Block of Houses, Buildings* and *Utilisation Unit*. This allows the consideration of different use typologies in their interplay, as i.e. housing, education and commercial, in NSA systems, while the building level and its detailed construction is outside the scope. Further, the macro perspective of regional and national measures applies to political decision making and is non-influential by neighbourhood planning perspectives. Thus, within the research scope, the collected measures, marked in the table by coloured cells, are summarised to eight sufficiency parameters as follows in Table 3.

Table 2. Sustainability Dimensions in the built environment. The coloured cells mark the research scope of sufficiency parameters in neighbourhoods.

	Efficiency	Consistency	Sufficiency
Nation	• Subsidy schemes and regulations for renewable energies & insulation [16] • Remediation duty for existing buildings [16] • Tightening of performance standards for new construction [16]	• Embodied carbon (full life cycle approach) [27, 20] • Digital material database [20] • Renewable energy [21] & stop of fossil heating [29] • Legislation (i.e. law on life cycle management) [7] • Funding of renewable raw materials [20] & recycling quota [29] • Taxation of primary materials [29]	• Taxes for inducing for conscious heating behaviour *(distributional effect and equity considerations)* [16] • Information and Communication [20] • Introduction of consumption corridors [21] • Collective ownership and financing models [24] • National land use target [26]
Federal State (Region)	• Climate responsive design [6] • Include distance of transportation [20]	• Local material database & resale [22]	• Measures to increase co-living-concepts [18] • Building code (support of reuse, renovation and regenerative materials) [20]
Municipality	• Mandatory white/cool surfaces [1] • Mandatory external solar protections [1] • Technical (passive) efficiency measures [26] • Density of use [24]	• Renewable energy supply and/or generation on site [1] • Fossil free mobility concept [18] • Permit requirement for demolition [29]	• Walkable [includes access to public transportation], cyclable districts [1], multi-modal mobility concept [26] • Green spaces, spaces for playing and spaces (in buildings) for common activities [1] • Sharing infrastructure for services and products [24] • (Re)Use of existing buildings [26]
Neighbourhood	• Communal heat planning for neighbourhoods & districts [26]	• On-site energy generation by RES [1] • Energy storage [21]	• Neighbourhood stores (i.e. repair stores) [22] • “15 min city” (6 social functions: living, working, supplying, caring, learning and enjoying) [1] • Demographic and social diversity [16, 32]
Block of houses	• Serial renovation [30]		• Semi-private spaces to reduce privately used area [31]
Buildings	• Energy efficiency concepts (i.e. insulation, heat recovery) [3] • Area efficiency [30] • Window to Wall ratio [3] • Use of rooftop area [22]	• Reduction of environmental impacts of full life cycle (LCA) [30]	• Potential for change of use [30] • / Flexible floor plan design [22,26] • Reduction of enveloping (compactness) [30, 9]
Spatial Zones	• Performance-optimization (reduction of operational energy) [30] • Simplified maintenance [30]	• Health safety [30]	• Reduction of space requirement [30]
Interior space	• Increase of area efficiency [30]	• Reduction of environmental impacts of full life cycle [30]	• Equipment reduction [30] • Thermostat adjustment [1]
Building component	• Improve of technical material performance [30]	• Circular components [30] • Standardised components and intersections [10]	• Low Tech [30] • Comfort Standards [1]
Building material	• Improve of technical material performance [30]	• Increased share of renewable raw materials [30] • Use of reused /recycled material [21]	• Simplified detailed connections [30] • Less material by design [30]

Extended Table based on El Khouli, John & Zeumer 2014, S. 14. Literature is referred to as follows. Step 1&2: [1] Erba und Pagliano (2021); [2] Senkel und Otto (2022); [3] Santos-Herrero et al. (2021); [4] Podara et al. (2021); [6] Mehmood et al. (2022); [7] Bertoldi (2022); [9] Azami und Sevinç (2021); [10] Heusler (2016); [13] Koide et al. (2021); [15] Fishman et al. (2021); [16] Poncin (2021); [17] Bobinaite et al. (2022); [18] Zell-Ziegler et al. (2021); Step 3: [20] Deutscher Städtetag (2021); [21] Taillard et al. (2022); [22] Stadt Flensburg (2020); [23] Drebes (2021); [24] Zimmermann (2018); [25] Böcker et al. (2021); [26] BBSR (2023); [27] Steffen (2016); [28] Zell-Ziegler und Förster (2018); [29] Breidenbrach et al. (2021); [30] Khouli et al. (2014); [31] Hock (2020); [32] Khatibi et al. (2023).

Table 3. Sufficiency parameters of buildings in a spatial relation [RQ1].

Ref.-Nr.	Acronym	Parameter
01	MOBIL	Mobility Concept focused on Walking, Cycling and Public Transportation
02	SPACE	Green, Open and Common Spaces
03	FUNC	Functional Diversity
04	SHARE	Sharing Infrastructure for Services and Products
05	DIVERS	Demographic and Social Diversity
06	FLEX	Multi-functionality and Adaptability
07	STOCK	Prioritization of Existing Building Stock
08	AREA	Reduction of Space Requirement

Table 4. Overview of the three analysed NSA systems (DGNB District, BREEAM Community, SNBS Areal).

DGNB District	The German Sustainable Building Council (DGNB) developed its building certification system in 2009 and added a system for districts in 2012 – providing a globally recognised planning tool. It advocates its core topics of climate action, climate adaptation and resilience. Built upon the pillars of sustainability, the three pillars of ecologic, economic and socio-cultural qualities are supplement by technical and process qualities.	
	TYPOLOGIES	Urban districts, business districts, commercial areas, industrial sites, event areas, resorts & vertical cities.
	BASELINE SITUATION	New construction.
	TIME OF CERTIFICATION	Pre-certificate: concept (validity 3 years), certification: development (validity 5 years), district certification (unlimited validity)
	SOURCE	DGNB System Kriterienkatalog Quartiere Version 2020 (DGNB 2020)
BREEAM Community	Founded in 1990, BREEAM offered the first environmental assessment methods for building design. In 2011, BREEAM community was developed to include a more holistically SA for the master planning of large-scale developments. The categories summarizing the assessment criteria are governance, social and economic wellbeing, resources and energy, land use and ecology, transport and movement, and innovation.	
	TYPOLOGIES	/
	BASELINE SITUATION	New development and regeneration projects.
	TIME OF CERTIFICATION	Interim BREEAM communities certificate (pass or fail) for the planning concept. Final BREEAM Communities certificate and rating, including project layout and details (unlimited validity)
	SOURCE	BREEAM Communities Technical Manual SD202 – 1.2 2012 (BRE Group 2022)
SNBS Areal	The ETH Zürich developed the concept of a 2000-Watt-Areal in 1994 to address the growing issue of climate change, certifying its first project in 2012. Key is thereby the user as a factor and the budget of 2000Watt capping individual consumption in an energetic perspective. In 2023, the 2000Watt label was transferred to the SNBS Areal certification. The foundation of the SNBS Areal assessment are the interdependencies of society, economy and environment. These three pillars comprise 30 criteria, summarized in 12 themes.	
	TYPOLOGIES	/
	BASELINE SITUATION	In development. In operation. In transformation.
	TIME OF CERTIFICATION	Pre-certificate SIA-phase 2, certification SIA phase 5 (max 10 years after pre-certification, Re-certification (once after 5 years – than unlimited validity)
	SOURCE	Kriterienbeschrieb SNBS-Areal, Alle Nutzungskategorien, Version 2023.1 (NNBS 2023)

ANALYSIS OF EXISTING TOOLS

SA of buildings as well as of neighbourhoods differentiate in their variants between **typologies** (i.e. industrial vs residential) and **baseline situation** (new construction vs retrofitting). In number of certifications, new construction strongly dominates applied SA – opposing the sufficiency parameter of existing building stock prioritization. To gain an understanding of the current representation of sufficiency in NSA systems, the following synopsis analyses three NSA systems on the market (DGNB District (GER), BREEAM Community (UK), and SNBS Areal (CH)) by a systematic comparison of applied indicators. The different systems are summarized in Table 4.

The in RQ1 approached sufficiency parameters (Table 3) fundamentally cluster the NSA system synopsis to identify sufficiency related indicators, relevant benchmarks and measurement. Respective the eight outlined parameters of buildings in a spatial relation; the analysis reviews the criteria of each selected NSA system, clustering indicators by sufficiency parameter relation, measurement approach (quantitative/qualitative), and representation of sufficiency barriers and carriers. While carri-

ers depict the sufficiency parameter relation, barriers outline the lack or even opponent of sufficiency measure implementation by the systems assessment methodology. Further added is the valuation percentage assigned to the individual indicator, proportionally based on the valuation description in the respective system manual. The following Table 5 exemplarily presents the tool analysis.

In the complexity of neighbourhood planning with the interplay of different layers of environmental and social impact, the analysis sets a strict scope and recognizes concomitant limitations. Different neighbourhoods constitute different functions and not necessarily **include housing** (as i.e. industrial areas) or more than one function. Housing, however, comprises the majority of the building stock. Further, mixed neighbourhoods are a sufficiency parameter to promote short travel distances. Accordingly, this investigation does not consider different typologies, but focuses on neighbourhoods including housing and multiple other functions. For the DGNB district system, the analysis investigates only the indicators as assigned to urban districts (**Typology**).

Having a look on certified neighbourhoods, there is a trend of new development projects in the NSA certification, labelled as green and sustainable neighbourhoods. The reduction of land consumption and prioritization of existing building stock, however, mark essential sufficiency measures fundamentally opposing new development projects. Thus, this investigation does not differ indicators by new construction vs retrofitting, but perceives **transformation and urban regeneration** as essential sufficiency parameter as such, generally deprivileging new construction projects.

The analysis shows that various indicators exist to approach outlined sufficiency parameter. Table 6 depicts the number of quantitative and qualitative indicators collected in each system, together with observed sufficiency barriers and carriers respective each of the eight parameters. Subsuming, in the **DGNB District** System, indicators are assigned to all the parameters with a strong focus on quantitative approaches. As in the other two systems, the highest number of indicators represent mobility concepts. However, throughout the parameters, a strong focus on efficiency can be noted, as i.e. area efficiency measures instead of absolute reduction by parking or built-up area per person in *8: Reduction of Space Requirement*. Further, *7: Prioritization of Existing Building Stock* is only supported by the single indicator of neighbourhood LCA. LCA, however, applies area as a reference value, combining efficiency and consistency strategies in material and energy-related lifecycle consideration, while the overall reduction of land consumption is not addressed (Hock et al. 2022). Additionally, with its focus on new construction, the prioritisation of existing building stock is not systemically supported. **BREEAM Communities** focuses on qualitative indicators and valuation proof in form of document availabilities. In *5: Demographic and Social Diversity*, minimum space standards for housing are applied – providing a lower while no upper cap of area consumption. For *8: Area Consumption*, no indicator was assigned in the analysis, posing a major sufficiency gap. Further, in *1: Mobility Concept*, besides the support of cycling and walking infrastructure, integrated and secure parking is additionally encouraged, while there is no indicator to initiate reduced motorized traffic. Approaching neighbourhoods in transformation, an assessment of existing building stock is requested; Demolition needs to be justified by documentary evidence. **SNBS Areal** is the only system explicitly naming sufficiency as a strategy, assigning it to area demand reduction and the flexibility of use over time without constructional interventions. In terms of area reduction, a person related area consumption applies to housing, while all other building typologies only approach area efficiency. *1: Mobility Concept* includes incentives to reduce spaces for car parking. Further to underline is the guidance on existing buildings and infrastructure by record, (re)use and interim use.

Comparing the three systems, all systems support mixed neighbourhoods and short travel distances. Additionally similar in all systems is the support of sharing infrastructures in form of car pools, sharing vehicles, multi-modal mobility systems and interior as well as exterior meeting places in form of community facilities and shared offices. Further, access to green spaces is generally evaluated, while green versus sealed, pedestrian versus motorized traffic and public, semi-public or private spaces are not approached regarding distributional aspects. Hereon, the lack of distributional criteria is noticeable across the different parameters, as i.e. the reference value "*per person*" or "*hours of use*". While personal accounting relates to parking requirements and essentially guides the demand planning, it is rather applied to the minimum standards of design, but rarely to upper caps or budgets.

Regarding assessment systems and valuation, the weighting is of significant relevance for the interplay of different criteria or parameter, as well as the final impact of each (Sharifi et al. 2021). While the focus of this investigation is on the determination of relevant indicators for assessment as a first step, determining the approximate percentage of parameters and in-

Table 5. Exemplary overview of the NSA tool synoptic analysis. (The outlined qualitative/quantitative assessment approach feeds into the overview of sufficiency parameter representation in Table 6.)

Sufficiency Parameter	Ref. Number	NSA Criteria	Assessment				
			Indicator	Benchmark / Measurement	Quantitative	Qualitative	%
Green, Open and Common Spaces	2	DGNB SOC1.6 open space	Reachability of public open spaces within the district	[m_2/BGF] Target value: approx. 12 m² per inhabitant / 6 m² per workplace	x		0.4
			Suff. Potential: person-related provision of greenery Suff. Barrier: no cap ("the more the better") in urban areas may interfere with density				

Table 6. Synoptic Analysis of NSA tools (DGNB District, BREEAM Communities, SNBS Areal).

Sufficiency Parameter	DGNB District		BREEAM Communities		SNBS Areal		Barrier	Carrier
	Quantitative	*Qualitative*	*Quantitative*	*Qualitative*	*Quantitative*	*Qualitative*		
MOBIL	11	9	3	7	4	7	– local specifications/ dependencies – lack of distributional criteria – need of adequate demand planning – lack of quantitative upper cap – linear to use typology (neglecting individual or transformative user behaviour)	– safe and convenient cycling infrastructure – safe and convenient walking infrastructure – hierarchy of sustainable transport – multi-modal-transport system – convenient and inclusive public transportation – support of bicycle infrastructure for delivery – Incentives for car parking reduction.
SPACE	4	2		1	1	3	– efficiency focus (area) – omit of private land – lack of distributional criteria – lack of quantitative upper cap	– quality management of open spaces – sufficient access to greenery – semi-public spaces (urban commons) – support of inner-city densification
FUNC	4	1	2	4	1	1	– dependent on level of density and adequate demand planning – demographic specifications	– reduction of travel needs – local economies – support of new local offers /functions
SHARE	2	2		3		2	– difficulties to proof within planning phase – lack of distributional criteria	– sharing culture – community facilities – quality management of open spaces – infrastructure for multi-functionality
DIVERS	6	3	1	3			– lack of distributional criteria – lack of quantitative upper cap – need of adequate demand planning	– local attractiveness – social integrity and diversity – milieu protection – diversity of floor space offers
FLEX		2		1		2	– need of sufficiency orientation in trend research – overconsumption (holding space that might not be needed) – lack of indicator specification	– future demand orientation – flexibility and adaptability over time – infrastructure for multi-functionality – short-term room extensibility / cut-off

Sufficiency Parameter	DGNB District		BREEAM Communities		SNBS Areal		Barrier	Carrier
	Quantitative	*Qualitative*	*Quantitative*	*Qualitative*	*Quantitative*	*Qualitative*		
STOCK	1			2	3	2	– no systemic prioritization – dependent on expert opinion – lack of indicator specification	– consideration of embodied energy/ reuse – overview of building stock and capacity in early planning stages – demand orientation – support of in-between use concepts
AREA	3	1			1	3	– efficiency focus (area) – local specifications/ dependencies – lack of distributional criteria – need of adequate demand planning – lack of quantitative cap (or not ambitious (< 48m²)) – benchmarks only for housing, apart from that efficiency focused	– compactness & low-tech of industrial buildings *(only industrial)* – quantitative benchmarks for housing (*only SNBS*)

The table shows collected indicators potentially approaching the outlined sufficiency parameter (labelled by reference number 1–8), outlining quantitative or qualitative measurement and related sufficiency barriers/carriers. (1: Mobility Concept (MOBIL), 2: Green, Open and Common Spaces (SPACE), 3 Functional Diversity (FUNC), 4: Sharing Infrastructure for Services and Products (SHARE), 5: Demographic and Social Diversity (DIVERS), 6: Multifunctionality and Adaptability (FLEX), 7: Prioritization of Existing Building Stock (STOCK), 8: Reduction of Space Requirement (AREA)).

dicators gives an understanding of their influence on the final assessment result. Summarized to the eight sufficiency parameters, Figure 1 presents the valuation percentage for the three analysed systems. As accountable for the number of indicators, parameter 1: *Mobility Concept* mark the highest valuation percentage. Together, the parameters account in all systems for less than 40 %, including sufficiency barriers and carriers. With that, the coverage of potential sufficiency parameter does not imply their actual effectiveness or adequateness of measurement approach and benchmark setting.

DISCUSSION

The conducted semi-systematic literature review provides an approach to outline sufficiency parameter in the various dimensions of the built environment. Remarkably, the number of considerations on scope and limitations significantly highlights the complexity as well as potential incompleteness of sustainability parameter collection. The relatively small number of literature related to building and sufficiency found in the Web of Science database further underlines the low attention of sufficiency measures in building or neighbourhood design as of now. Conclusively, this also limits the quantitative coverage of possible sustainability measures. Additionally, to consider is the coexistence of criteria opposing sufficiency in SA system. The maximal fulfilment of one criterion may counter another in its potential. While this investigation focuses on the sufficiency potential by determining sufficiency parameter, a system may also apply parameter that oppose sufficiency in other criteria out of the investigations approach. Thus, further research of interdependencies opposing sufficiency is required.

Getting closer to the complexity of individual cases, ownership structures have a major impact on aspects as influence, participation, and distributional justice. A diversity of different owners prevents mono-structures and with that, segregation processes. Municipal ownership thereby allows conceptual bound allocation of plots and leasehold business models. Strongly connected to land politics (Baumgart 2022), ownership structures are in this investigation seen as part of the parameter on demographic and social diversity and represented as indicator in the DGNB system by very low percentage.

Further, to be noted is the role of digitalisation. While it may contribute to sustainability measures and may support sufficiency, it is not a guaranty in itself for it. Instead, it often implies severe rebound effects (i.e. maintenance, material, data security, …) and concepts such as the smart city are driven by IT-companies in economic interests (Höfner und Frick 2019). Hereon, subsistence and civil society empowerment are recognized as key drivers of digital sufficiency, combining technological sufficiency, data sufficiency, sufficiency in

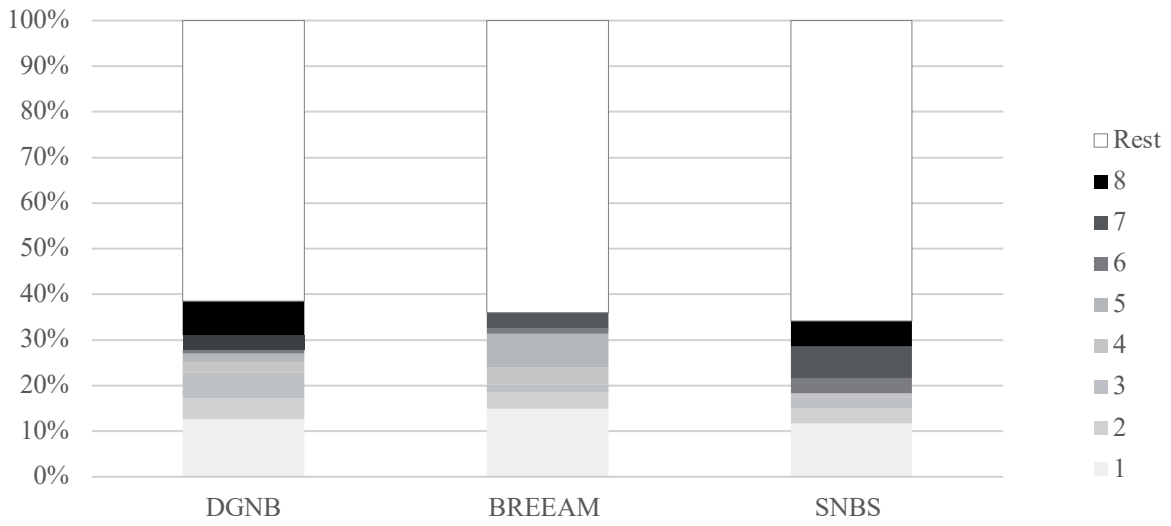


Figure 1. Valuation percentage assigned to the identified indicators clustered by eight sufficiency parameters (1: Mobility Concept, 2: Green, Open and Common Spaces, 3: Functional Diversity, 4: Sharing Infrastructure for Services and Products, 5: Demographic and Social Diversity, 6: Multifunctionality and Adaptability, 7: Prioritization of Existing Building Stock, 8: Reduction of Space Requirement).

use and economic sufficiency. As complex topic and ongoing debate, digitalisation is not considered in this investigation, while it is represented in form of Connectivity (SNBS Areal) and Smart Infrastructure (DGNB District) in two out of three systems.

Conclusion

While the necessity of sufficiency is scientific consensus (IPCC 2023), the identification of relevant measures towards sufficiency-oriented neighbourhood planning as well as connected indicators for valuation are still based on individual design decisions. Further, SA systems lack in their sufficiency criteria inclusion. The outlined parameters offer a fundamental understanding of sufficiency in the built environment. Further, they provide categories for a transparent and systematic analytical synopsis of existing NSA Systems. By outlining potential carrier and barrier of sufficiency by parameter assignment, the analysis lists indicators related to the eight-sufficiency parameter, while it does not offer a sufficiency indicator selection. In a next research step, each parameter needs to be approached specifically for a quantitative benchmark setting. Further, a qualitative measurement approach is essential to encompass individual local and social neighbourhood conditions. Generally, the balance between detailed influences and accuracy in contrast to the amount of effort for practical application underlines the challenge of adequate assessment towards sustainability and thus, also sufficiency assessment.

Sufficiency is not only about technical optimization processes (as efficiency and consistency), but the integration of the user into the valuation. Thus, a valuation is not only objective to the built environment, but also subjective to its use typology, user behaviour and user needs. The determination of quantitative sufficiency parameters poses a great potential to address planetary boundaries and include societal transformation towards an absolute resource consumption into SA. However, it is also vulnerable to critique and political difficulties by the determination of "adequate" in average consumption, confronting individual circumstances and desires. Further, it is still an open question for sufficiency assessment, whether quantifiable approaches can accompany the quality and situational understanding of planner's expertise. With that, sufficiency parameter and related indicators need to be under constant revision of ongoing scientific research.

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