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SPECIAL ISSUE: Urban and regional infrastructures

A corpus-assisted discourse analysis of sustainability transitions in urban basic infrastructure services

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Abstract

Basic infrastructure services – water and sanitation, waste collection and management, transport, energy, and housing – form the foundation upon which cities are built. Sustainable and equitable provision of services is key to combating climate change, eradicating poverty and meeting targets set out in international sustainability agendas. However, even as the language of the sustainability transitions literature is being appropriated by governments, social movements and practitioners, the concepts of sustainability and sustainability transitions remain ill-defined and often narrowly applied. We conduct a corpus-assisted discourse analysis of the sustainability transitions literature on urban basic infrastructure services to tap into prevailing representations and conceptions. Findings show that the delivery of sustainable urban services is discursively framed as a predominantly institutional and economic challenge, favouring a top-down techno-managerial approach to transitions that applies technical fixes to environmental problems at the expense of social dimensions of sustainability. While some studies, such as those with a focus on the Global South and/or water and sanitation services, engage to a greater degree with issues such as justice and equality, they still tend towards technical and economic solutions. An integrated approach encompassing all dimensions of sustainability and a broader understanding of infrastructure services not as separate, single-purpose technologies but as part of interconnected systems with multiple social, economic and environmental objectives is needed if we are to transition to a more sustainable urban future.

Keywords

Urban basic infrastructure services, urban service delivery, sustainability transition, corpus-based discourse analysis, frame analysis

Introduction

Cities are engines of economic growth, sites of innovation, and provide spaces for social transformation and political inclusion. This is the case since urban areas concentrate technical, political and human capacity, which they attract and retain due largely to the availability and quality of infrastructure and the associated urban service delivery (USD) (Boex et al., 2016). The sustainable provision of basic infrastructure services is therefore fundamental for maintaining and improving the living standards of urban citizens, managing a city's ecological footprint, and harnessing opportunities for prosperity. USD encompasses the (mostly) physical, engineered systems that make a city, as well as the totality of interactions, rules, norms and values that govern those infrastructures. Urban basic infrastructure services (UBIS) include water and sanitation, waste collection and management, transport and energy, which “form the foundation on which human settlements are built and function” (Satterthwaite, 2014, p. 3), as well as housing, the primary means by which citizens access the other services (Satterthwaite, 2020).

UBIS are directly or indirectly responsible for a significant proportion of greenhouse gas emissions (Müller et al., 2013; Williams, 2013), yet their efficacy is also key in building the resilience of urban areas and their citizens to environmental shocks such as those caused by climate change. The transition to more environmentally sustainable and socially inclusive forms of USD is therefore urgently required if we are to achieve the objectives of the Sustainable Development Goals (SDGs) and the Paris Agreement, an imperative which has become all the more prominent in recent years as the COVID-19 crisis exposed the failings of the neoliberal development model (Dutch Footprint Group, 2020). It is widely agreed that standalone interventions will be insufficient to address these challenges at the required scale.

Accordingly, theory and practice are increasingly focused on sustainability transitions. A transition is a fundamental shift in the way sociotechnical systems are organised, which necessarily involves substantial technical, institutional, organisational, political, economic and cultural changes (Geels and Schot, 2010). Sociotechnical systems – including for example energy supply, water supply, and transportation networks – can be understood as networks of actors, institutions, material artefacts and knowledge which interact to deliver specific services to society (Markard et al., 2012). A *sustainability* transition, therefore, refers to the evolution of both social and technological institutions towards sustainability (Köhler et al., 2019).

Yet precisely what sort of sustainability transition could lead to more economically, environmentally and socially sustainable USD remains unclear. Within transitions studies, no single definition of sustainability has been agreed upon, and studies rarely make their interpretation of the term explicit (Fischer-Kowalski, 2011). Those that do, typically refer to the Brundtland definition of sustainable development (Frantzeskaki et al., 2012), a different, though related, concept defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 4).

The term *transition* (or *transformation*) remains similarly ill-defined: it is often unclear what sort of transition is sought, by and for whom (Scoones et al., 2020).

Beyond purely definitional issues, sustainability transitions in USD remain a relatively young subject with acknowledged conceptual gaps (Geels, 2011). Almost two decades since the first publication appeared in this field (Weber, 2003), it is worth taking stock of the state of the art by teasing out “incompleteness, hidden assumptions, unthought-of consequences [and helping] keep open for reassessment that which may otherwise slide into taken-for-grantedness” (Corvellec et al., 2021, p. 1). Accordingly, the objective of this paper is to offer an investigation of academic discourse in the field of sustainability transitions in USD. This is not only an academic exercise: with the language of sustainability transitions theory increasingly being appropriated by governments (e.g. “innovation policies”), research and policy organisations (e.g. “Coalition for Urban Transitions”) and social movements seeking to challenge the current system (e.g. “Transition Network”) (Feola, 2020; Swilling and Annecke, 2012), how the notion of sustainability is interpreted and how sustainability transitions are envisaged in USD research is of paramount importance.

In this context, we draw on a broad and perhaps the most universal definition of sustainability: that of the United Nations, which encompasses economic, environmental and social dimensions underpinned by institutional dimensions of sustainability (Figure 1). These pillars were explicitly embedded in the formulation of the United Nations’ SDGs (UN, 2012) and, despite some criticism of their theoretical foundations (Purvis et al., 2019), largely guide contemporary sustainability research and policy.

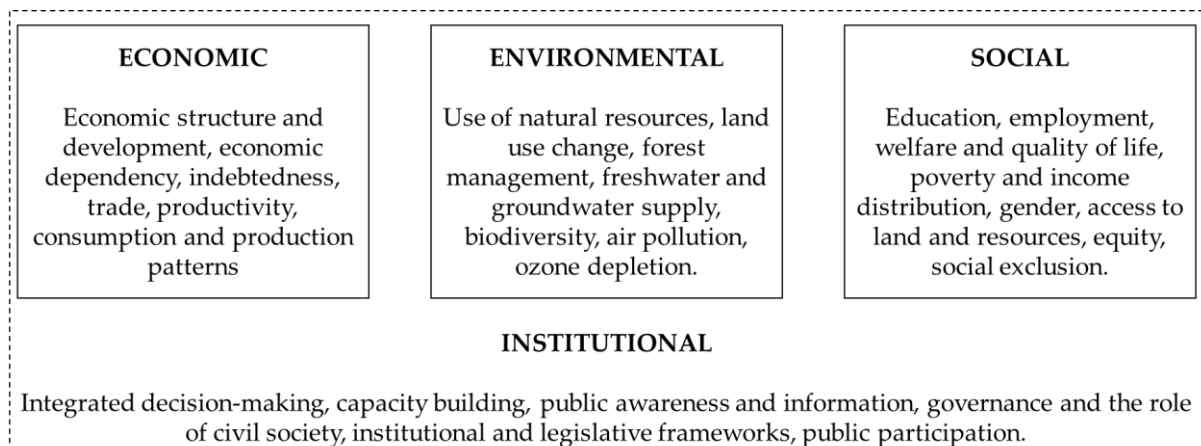


Figure 1: Dimensions of sustainability, adapted from United Nations (2001).

Against this backdrop, it has been asserted that sustainability transitions theory is too narrowly focused on technological innovation, economic efficiency and ecological considerations at the expense of social issues (Block and Paredis, 2019; Hegger et al., 2007; Lankoski, 2016;). Moreover, research has been critiqued for focusing on specific infrastructure

technologies without locating them within the entire system of social, economic, environmental and institutional inputs that determine the sustainability of USD (Corvellec et al., 2013; Oates et al., 2018) and for being primarily developed and applied in cities of the Global North (Markard et al., 2012; Oates, 2021; Wieczorek, 2018).

We analyse academic discourses on sustainable USD and their intersection with the UN's four dimensions of sustainability with a view to accessing the prevailing conceptions of sustainability, pinpointing the types of sustainability transitions envisaged for USD, and simultaneously identifying blind spots or gaps in the field. We specifically ask how sustainability transitions are envisaged in academic discourses on UBIS, and how they manifest differently in different geographical regions and for specific urban services. Systematic insight into the prevailing conceptions will enable us to describe the perceived scope of the field as well as its discursive limits. It is hoped that a broader understanding of sustainability transitions can ultimately help both theorists and practitioners to harness co-benefits across all four pillars of sustainability: economic, environmental, institutional and social.

The remainder of this paper is organised as follows. In Section 2, we briefly discuss discourse-analytic approaches as they have been applied to sustainability transitions theory. Section 3 describes our data and the corpus-assisted methodology we employed to collect and analyse it. Results are presented in Section 4, distinguishing between general findings, and findings specific to one UBIS sector and to one geographical region. Finally, Section 5 links our findings to the UN dimensions of sustainability and concludes with implications for transitions research.

Discourse analysis and sustainability (transitions) theory

In its broadest sense, discourse can be described as language-in-use (Blommaert, 2005, p. 2), although discourses can also be conceptualised in a more Foucauldian manner as ways of “constructing objects and concepts in certain ways, of representing reality [...] with attendant consequences for power relations” involving for example gender, class or ethnicity (Baker and McEnery, 2015, p. 5). Discourse analysis has been fruitfully applied in previous environmental and sustainability research, largely with a view to identifying different strands or typologies within institutional, activist or media discourses. For example, Dryzek (2013) distinguished between four types of environmental discourses: sustainability, survivalism, problem solving and green radicalism. Stevenson (2019) identified three international discourses on sustainable development: radical transformationism, cooperative reformism and statist progressivism. Focusing specifically on transition discourse, Audet (2016) used a qualitative coding approach to identify two main discursive strands: localism and technocentrism.

In recent years, a handful of climate and sustainability researchers involved with discourse-analytic approaches have engaged in interdisciplinary research with corpus

linguists (Feola and Jaworska, 2018; Grundmann and Krishnamurthy, 2010). Broadly, corpus linguistics involves the analysis of a large body of machine-readable texts that, due to its size, defies analysis by hand (McEnery and Hardie, 2011: 2). Corpus-assisted discourse studies (CADS) (Baker et al. 2008; Partington, 2006; Partington et al., 2013) bring together primarily qualitative discourse analysis with essentially quantitative corpus linguistics in a complementary fashion (McEnery et al., 2006, p. 111). While discourse analysis emphasises the situated nature of language as shaped by the behaviour and attitudes of social actors, corpus-linguistic techniques can help to avoid some of the pitfalls of traditional discourse analysis:

The principles of representativeness, sampling and balance which underlie corpus building help to guard against cherry-picking, while corpus-driven techniques like keywords help us to avoid over-focussing on atypical aspects of our texts. Corpus techniques can thus reassure readers that our analysts are actually presenting a systematic analysis, rather than writing a covert polemic (Baker and McEnery, 2015, p. 4).

We use a CADS approach to analyse academic discourse on sustainable USD. To systematically uncover discursive patterns in our corpus and identify representative illustrations of those patterns, we use the classic corpus techniques of keywords, collocations and concordances. *Keywords* are words that are more salient in one corpus than in another corpus. They are seen as robust indicators of the dominant discourses in a corpus, i.e. what the corpus is “about” (Bondi and Scott, 2010). Keywords are identified by comparing the relative frequency of a lexical item in one corpus to its relative frequency in a “reference corpus” to identify words that are statistically over- or underrepresented. The reference corpus is often one of the freely accessible mega-corpora that are seen as representative of a notional “standard”, such as the British National Corpus (BNC), or a subset of the corpus under investigation in order to tease out discursive differences more precisely (Baker, 2004). We use both the BNC as well as subcorpora created by dividing our main corpus in various ways to answer our research questions.

While keywords provide an “entry point” to the data (Baker, 2004), *collocations* reveal more about the associated values and discourses. Collocations are sequences of words that occur in a corpus statistically significantly more frequently than would be expected if the words were arranged randomly. As preferred patterns of discourse in a given community of practice, collocations are lexical associations that have been reified through repeated use and can thus be seen as indicative of dominant ideologies (Stubbs, 1996; 2001).

Keyword and collocation analysis are essentially quantitative techniques that lead into an analysis of *concordances*, which highlight given lexical items and the surrounding words

in a text. Accessing every instance of a word in its original context allows the research to become more situated and qualitative, facilitating the selection of representative examples for illustrative purposes.

Finally, we combine this approach with frame analysis (Goffman, 1974), which is concerned with how an issue is defined and what effect this has on discussion of the issue, for example by drawing attention to particular aspects and obscuring others. The sociological notion of “frame” refers to the culturally determined constructs by which people make sense of reality. In this article, we consider the four pillars of the United Nations’ definition of sustainability (Figure 1) as frames in Goffman’s (1974) sense. We do not intend to pass judgement on the UN definition of sustainability but rather use it as a departure point from which to reflect on what is (or is not) currently assumed to constitute sustainable USD, and what dimensions may require further attention. Deductively mapping our keywords, collocations and concordances in relation to this definition provides insight into whether the discursive framing of sustainable USD is relatively balanced, or is skewed in favour of one or more of the pillars of sustainability.

Data and methods

The corpus

We created a corpus of academic discourse in the field of sustainable USD by searching two online academic databases, Scopus and Web of Science, based on title, abstract and keywords in June 2021¹. We extracted all articles published in English in the field of sustainability transitions focusing on at least one of the aforementioned UBIS: water and sanitation, waste collection and management, transport, energy or housing². To ensure the research is from within the field of sustainability transitions as opposed to merely using its language, research must utilise at least one of the key analytical frameworks associated with transitions studies, as identified by Markard et al. (2012). More specifically, only papers which utilise the Multi-Level Perspective, Strategic Niche Management and/or Transition Management were included. Studies using the Technological Innovation Systems framework were excluded due to its explicit focus on discrete technologies rather than broader patterns of transformation (Wieczorek, 2018). In this article, we are more interested in transformations relating to the organising principles of UBIS than a specific technological innovation.

The search yielded 202 results, which we then manually screened in order to exclude duplicates and papers that were not peer reviewed, did not focus explicitly on a basic

¹ The search string was as follows: (“sustainability transition” OR “sociotechnical” OR “socio-technical” OR “transform*”) AND (“multi-level perspective” OR “multilevel perspective” OR “transition management” OR “strategic niche management”) AND (“urban” OR “city” OR “cities”) AND (“waste” OR “water” OR “sanitation” OR “energy” OR “transport” OR “mobility” OR “housing”).

² Social services such as education, healthcare, childcare, urban planning and public safety are of course also fundamental to human development but are not included here.

infrastructure service or were not urban in scope. The main corpus comprises the remaining 107 articles,³ consisting of a total of 953,779 words, with an average of 8,913 words per article excluding references (see Table 1). Though the earliest record was published in 2003, three-quarters of the articles were published between 2015 and 2021, indicating the burgeoning current interest in, yet relative adolescence of, sustainability transitions in USD. All articles were converted to .txt files for further analysis, with the references removed to ensure that the lexis contained therein would not skew the results.

Table 1: Description of main corpus and subcorpora

	Number of texts	Number of words
Main corpus	107	953,779
Geographical subcorpora		
Global North	70	624,634
Global South	30	267,781
Other	7	61,364
Total	107	953,779
Sectoral subcorpora		
Energy	33	294,266
Housing	8	62,358
Transport	37	338,549
Waste	2	15,574
Water and sanitation	26	237,586
Other	1	5,446
Total	107	953,779

Notes: The category “other” refers to articles that did not identify a specific focus, either geographically or by sector.

In addition, we created several subcorpora, including for those articles primarily focused on the Global North (n=70) versus the Global South (n=30), excluding those without a specific focus country (n=7). For the purposes of this paper, the Global North includes countries classified by the United Nations as developed economies and economies in transition, while the Global South includes those classified as developing economies (UN DESA, 2021)⁴. Close to half of all studies (n=45) were conducted in Europe, perhaps reflecting the provenance of the most cited authors, many of whom come from or are based in the Netherlands, Scandinavia and the United Kingdom (Markard et al., 2012). Asia was the second most studied continent (n=18), yet two-thirds of studies in this region concerned China (n=12), with the rest of South and South-East Asia comparatively neglected. Africa and Latin America are similarly underrepresented in this review, with only two records from each,

³ A full list of the peer-reviewed articles that were included in the corpus is available via the 4TU.ResearchData repository (<https://doi.org/10.4121/20424645>).

⁴ The authors recognise that both the term and the concept of the Global South are contested. Increasingly, the term “Global South” is also understood as a way to conceptualize a deterritorialised political economy of the uneven processes of economic development generated by capitalism and colonialism.

though it is also important to note the English language limitation may affect this, with Latin American research in particular likely to be published in non-Anglophone journals. Still, this is in line with previous assertions that transitions processes in the Global South are a relatively new area of study (Oates, 2021; Wieczorek, 2018). The most studied countries were Australia (n=12), China (n=12), the United Kingdom (n=7) and Germany (n=6).

We also divided the articles into subcorpora based on the basic infrastructure service under investigation. All but one article focused on a single sector. Transport (n=37), energy (n=33) and water and sanitation (n=26) were the most common, between them accounting for more than 90% of all studies. Housing (n=8) and waste management and collection (n=2) were comparatively neglected. As such, the latter two were not included in the corpus-based discourse analysis since the associated subcorpora are not large enough to draw conclusions from, though given that transitions thinking is by definition a systemic perspective, the relative neglect of these sectors is in itself noteworthy.

Data analysis

All analyses were performed using AntConc (Anthony, 2020), a freely available corpus-analysis software tool. First, a keyword analysis was performed of the main corpus compared against the BNC. The top 100 most distinctive keywords were deductively coded using the four dimensions of the UN definition of sustainability: economic, environmental, social, and institutional. As we show below, in addition to these four frames, two further themes were inductively identified as being particularly noteworthy: (i) technical, and (ii) spatial and temporal context. We then calculated and extracted illustrative concordances of the most statistically significant collocates for each keyword. This quantitative coding process combined with a qualitative analysis of significant collocates allowed us to access dominant discourses and conceptions of sustainability within the transitions literature. Next, using the same method, we extracted keywords, collocations and concordances for each of the two regional and three sectoral subcorpora compared to the rest of the corpus to reveal discursive patterns and interpretations of sustainability distinctive to each geographical region and basic infrastructure service under investigation.

Results

Primary corpus findings

The first 100 most distinctive keywords are shown in Table 2, and with their coded associations in Figure 2. As noted, keywords are those that are statistically significantly overrepresented in one corpus compared to another. In our case, these keywords illustrate the “aboutness” of the sustainability-transitions corpus as compared to a corpus of general British English (the BNC).

Table 2: 100 most distinctive keywords in main corpus cf. BNC, listed alphabetically

Access	Electric*	Municipal	Sector
Activities	Environment*	National	Smart
Actor*	Experiment*	Network*	Social
Alternative	Future	People	Societal
Area*	Global	Perspective	Solar
Biogas	Governance	Place	Solutions
Bus	Government	Planning	Space
Business	Green	Policy*	Stakeholders
Capacity	Grid	Political	State
Car	Growth	Power	Strategy
Carbon	Group*	Practices	Structures
Challenges	Implementation	Pressure	Supply
Climate	Individual	Private	Support
Community*	Industry	Problems	Sustainable
Companies	Initiatives	Process*	System
Conditions	Innovation*	Production	Technical
Construction	Institution*	Project	Technology*
Current	Issues	Public	Time
Cycling	Knowledge	Regional	Users
Demand	Learning	Renewable	Vehicles
Development	Local	Resources	Vision
Dynamics	Management	Role	Years
Economic	Market	Scale	

Notes:

(i) Words removed from the lists of most distinctive keywords include: terms appearing in or closely related to the search string (e.g. multilevel, regime, service); words appearing frequently but only in one record (e.g. ropeway, jeepney); words clearly related to research (e.g. study, research); proper nouns (e.g. China, Curitiba); and function words, including articles, auxiliary verbs, conjunctions and prepositions.

(ii) Lexical items with the same base lemma are combined e.g. plurals (technology and technologies) and derivative forms/modifiers (democracy and democratic), indicated by *.

Institutional frame

The institutional frame included terms that can be associated with the political or social organisations involved in policy making or implementation (e.g. *actors, government, power⁵, role, stakeholders, state*), the ways in which their decision-making processes may be carried out (e.g. *management, perspective, results*) and the availability of information (e.g. *capacity, knowledge, learning*). Since transitions research is often critiqued for failing to adequately engage with issues of power and governance (Loorbach et al., 2011), it is notable that the institutional frame figures so prominently. Exploring the collocates⁶ of *governance* revealed that it is most frequently paired with *experiment* (and its associated lemmas, i.e. derivative forms), a phrase that appears a total of 218 times, for example in the following excerpts:

⁵ Power in this corpus could be used in two distinct ways: power relations between stakeholders, or power to generate energy. Checking its collocates showed that it was most frequently associated with the word *relations* and also often with the terms *politics* and *dynamics*, and so it is included here in relation to governance. However, it also appeared frequently with words such as *wind, combined* and *solar* to refer to power generation.

⁶ A collocate is a constituent component of a collocation, e.g. the collocation *governance experimentation* is made up of collocates *governance* and *experimentation*.

These findings further explicate the importance of well-designed and organised **governance experimentation**, for this allows the development of concurrent and embedded social learning situations, which together have the potential to create momentum for socio-technical system change (Bos et al., 2013, p. 410).

There is a need to better connect differentiated place-based processes of experimentation with the wider forms of **governance experimentation** that structures and conditions these differentiated urban responses (Hodson et al., 2017, p. 5)

The discourses surrounding governance and policy experimentation for transitions and its benefits in advancing social learning (e.g. Bos et al., 2013; Brown et al., 2013; Wutich et al., 2020) and supporting the accelerated diffusion of infrastructural reconfigurations (Hodson et al., 2017; McLean et al., 2016) are suggestive of a somewhat flexible approach to governing uncertain transition processes. Other lexical associations in the institutional frame are, however, more indicative of a techno-managerial approach (*implementation, management, planning, process, sector*), characterised by the deployment of a range of corporate-style strategic policy tools linked to governance and sustainability indicators (Guibrunet, 2021).

Economic frame

This techno-managerial approach is reflected, too, in the prevalence of keywords coded under the economic frame, particularly those related to the activities of the private sector (e.g. *market, business, company, economic, industry*). This corresponds to the increasingly widespread application of neoliberal policies aimed at the privatisation and financialisation of municipal services based on the assumption that private companies are more efficient than state agencies (Mazzucato, 2011). Indeed, the collocates of *market*, for example, show that much research is concerned with how fundamental change might be influenced by factors such as market *reforms*, the market *share* that innovations have or may be able to achieve, competition amongst (new) market *players*, and market and consumer *preferences*.

Tariff reforms are essential in order to create a more favorable **market** environment for RE [renewable energy] to make a business case (Mah et al., 2020, p. 19).

The rise of piped water was a catalyst that stimulated the diffusion of a range of hygienic products, such as water closets, baths, showers, washing machines, washing bowls. Although these products already existed before

piped water, their **market** share was greatly stimulated by piped water (Geels, 2005, p. 392)

All these countries have different strengths and weaknesses regarding their innovative ability, **market** structure, and consumer preferences, and a forthcoming technological shift would represent different opportunities and risks for each (Steinhilber et al., 2013, p. 537).

Environmental frame

The strong discursive focus on economic factors is tempered to an extent with environmental considerations through research related to building a green economy. The collocates for keyword *green* reveal that it is used primarily in two ways. Firstly, it refers to specific infrastructures related to the built environment (e.g. *building*, *construction* and *housing*).

Financial returns have been shown to drive the **green building** innovations and fundamentally improve building energy consumption of the structure in the long-term (Jiang and Payne, 2021, p. 2).

Secondly, it is also commonly associated with economic terms (e.g. *economy* and *growth*), suggesting a commitment to an urban transition that involves continued economic development whilst simultaneously reducing negative environmental externalities:

ULEV-policies since the 2010s represent a stronger climate change strategy, which are motivated by the hope of creating “**green growth**” potential for the UK car industry (Geels 2018, p. 99).

This ideology is increasingly critiqued for its failure to engage with discussions around whether fundamental transformation is possible within a capitalist system (Feola, 2020) and for its narrow interpretation of environmental challenges as climate change. The presence of other environmental keywords – such as *carbon* and *climate* – suggest that much research is specifically focused on the transition to low-carbon USD but pays less attention to a wider range of environmental issues such as biodiversity loss or land use change.

Social frame

Aspects relating to the social dimension of sustainability are similarly underrepresented. *Community*, *people*, *social* and *societal* are the most relevant keywords in this frame, though other terms may have a secondary connection to issues related to social sustainability and social justice (e.g. *power*, see also Footnote 5) or may be linked indirectly to social aspects of

sustainability transitions. For example, *cycling* is a mobility form which has wider societal benefits (Sudmant et al., 2020). The most statistically significant collocates for *societal* are *embedding* and *acceptance*, reflecting a concern with how to increase the uptake of specific technologies:

While there seems to be broad agreement that restrictions for private cars are inevitable to enable a real transition towards multimodal transport, many of the interviewed actors doubt that such measures will find the necessary political and societal acceptance (Schippl and Arnold, 2020, p. 12).

Additional frames

Two new themes, in addition to the four UN pillars of sustainability, have also been identified. Firstly, the prevalence of keywords relating to technology (e.g. *technical*, *technolog** and *smart*) may reveal something about how the transition to more sustainable USD is envisaged. The collocates for *smart* reveal that it is often associated with specific infrastructural technologies such as *meter* and *grid*, as well as with *city* (i.e. smart city). On the one hand, this is unsurprising in a literature focused on *sociotechnical* transitions. On the other hand, it corresponds with the notion that technologies and innovation, rather than concepts and guiding principles, form the most frequent starting point in addressing challenges to the delivery of basic infrastructure services (Hegger et al., 2007), whereby technical solutions underpin progress towards a more sustainable future (Clark et al., 2004). The excerpts below are illustrative of a discourse that suggests smart technologies may solve sustainability challenges:

Alongside the role out of **smart** grids and appliances, this future envisages widespread application of novel and disruptive materials and products (for example, vacuum panel insulation and phase change materials) to improve the energy performance of existing buildings (Dixon et al., 2018, p. 257).

The second newly identified frame concerns spatial and territorial configurations of USD and their temporal context. Some of the keywords are used primarily in describing case studies (*area*, *years*), while others remind us that urban infrastructure is grounded in place and time:

This highlights variable **place**-based capability to shape experimental processes and variable effects (Hodson et al., 2017, p. 9).

The inclusion of keywords from *local*, *municipal* and *regional* to *national* indicates that urban infrastructure is influenced by rules and regulations across spatial scales, and not just at the city level:

While **municipal** governments are constrained by federal and provincial definitions of e-bikes, they do have some authority to implement by-laws (Edge et al., 2020, p. 203).

The regime defining the energy sector is influenced by the relation between [...] policies and regulations (from **municipal**, **national**, supranational levels) (Bukovszki et al., 2020, p. 5).

Interim conclusions: Primary corpus

The coding of keywords from the primary corpus into different frames has shown that lexical items associated with institutional and economic factors appear most prominently. The environmental frame is less prevalent and where it is used, it is most frequently in relation to a green economy, suggesting environmentally sustainable UBIS are conceptualised within the economic growth model advanced by the existing capitalist system. Similarly, the social frame is less salient and is conceived less in terms of benefits to society and more with a view to establishing societal acceptance of initiatives and technologies. In addition to the four UN frames, we also identified a prevalent technological frame and a frame concerned with the spatial and temporal context of USD.

Connections are visualised in Figure 2, which shows for illustrative purposes how the keywords have been mapped onto the respective frames. It highlights for example where there are overlaps and reveals, in particular, a high degree of overlap between the economic, institutional and technological frames. It also shows the relative smallness of both the environmental and social frames.

Subcorpora findings

Dominant discourses per UBIS sector

As previously mentioned, more than 90% of the papers in the primary corpus focus on the sectors of energy, transport and water and sanitation. The distinctive keywords for these three subcorpora are shown in Table 3.

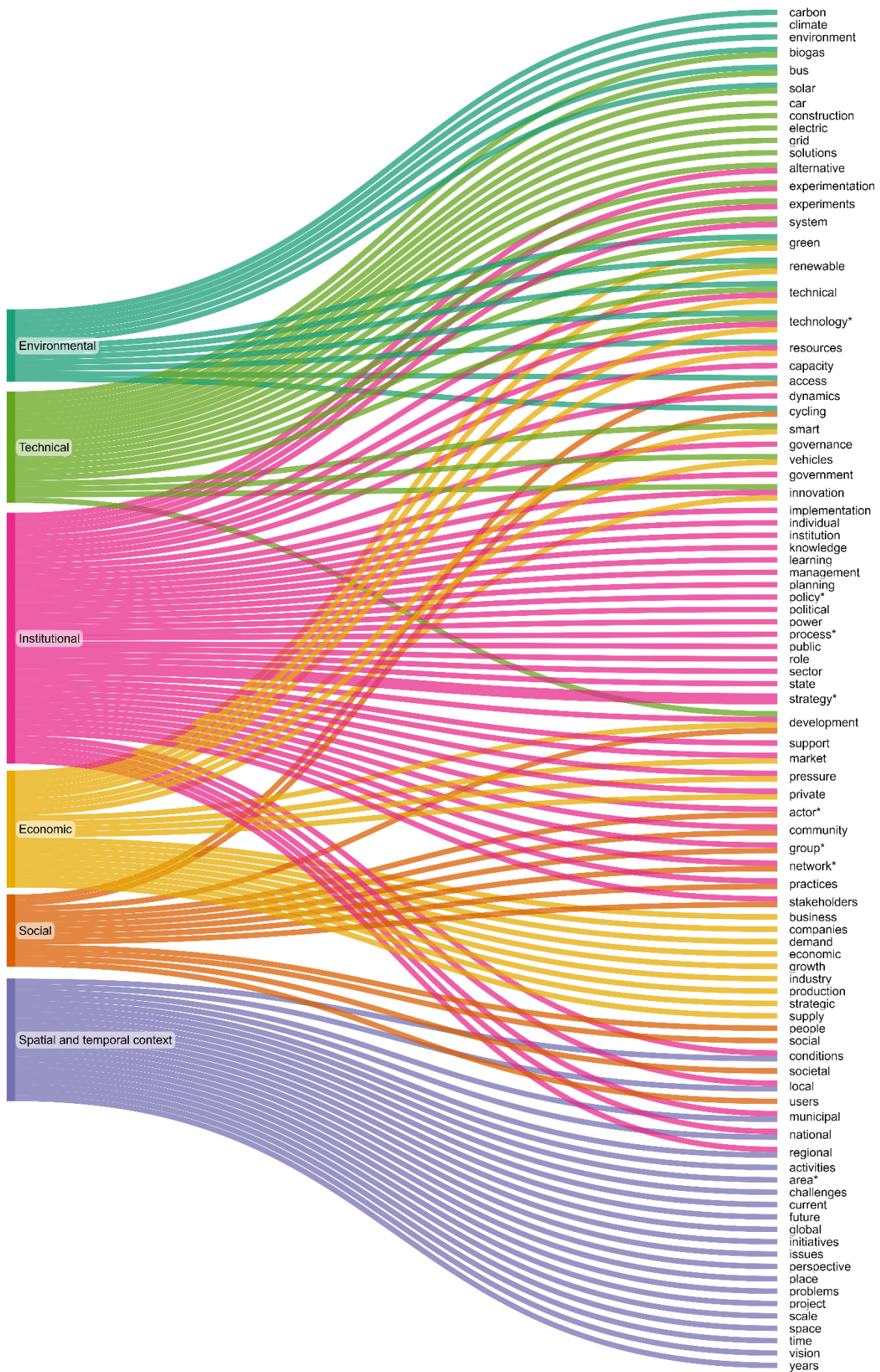


Figure 2: Associations between frames (left) and keywords (right). Data visualisation produced using sankeymatic.com.

Table 3: 50 most distinctive keywords per subcorpus based on UBIS, alphabetically

UBIS	Distinctive keywords
Energy	Affordances, biogas, biomass, carbon, CHP [combined heat and power], coal, community*, company, consumption, council, DH [district heating], district, eco, economy, electricity, electrification, EPC [energy performance contracting], experiments, food, fossil, gamma, garden, gas, generation, geothermal, grid*, heat, heating, industrial, intermediary*, lifecycle, local, meter, milieu, national, networks, nuclear, periphery, production, progression, PTA [public transport authority], PV [photovoltaics], renewable, resilience, smart, solar, storage, subsystems, SWH [solar water heater], wind
Transport	Auto, automakers, automated, automobil*, automotive, AV* [Automated Vehicle], bicycle*, bike*, bus, car*, carsharing, charging, congestion, constituencies, cycling, cyclists, drive, electric, epistemic, EV* [Electric Vehicle], fleet, future, justice, LEVs [Low Emission Vehicles], MaaS [Mobility as a Service], megacities, metro, modal, mode*, motorcycle, multimodal, parking, passenger, private, public, rail, road, route*, safety, sales, scooter*, sharing, taxi*, traffic, transit, travel, trip*, upscaling, vehicle*, walking
Water and sanitation (WASH)	Blue, brown, capacity, catchment, champions, change, contamination, democra*, desalination, drainage, drinking, drought, frontrunners, governance, groundwater, harbour, harvesting, hygiene*, initiative, institution*, IWRM [Integrated Water Resource Management], learning, management, monitoring, municipalities, navigational, NGO [Non-Governmental Organisation], organisational, piped, port, principles, process, rainwater, recycling, reuse, river, sanitation, science, sensitive, shadow [network], storm, stormwater, SUWM [Sustainable Urban Water Management], swimming, treatment, wastewater, waterway, WSUD [Water Sensitive Urban Design]

Notes: Lexical items with the same base lemma are combined e.g. plurals (technology and technologies) and derivative forms/modifiers (democracy and democratic), indicated by *.

In the energy subcorpus, the relative dearth of both social and institutional terminology, and the presence of a wide range of specifically technical terminology (*biogas, CHP, DH, PV, renewable, smart, solar, storage, SWH, wind*), suggests that the energy transition is principally envisaged as a technology-based switch from fossil fuels to renewables and low-carbon fuels:

Specific technologies and strategies for increasing resiliency include building microgrids on critical infrastructures, modernizing transmission and distribution through **smart grids**, installing powerlines underground in high wind areas, increasing battery storage and onsite backup generation, **combining heat and power** systems, and implementing stricter vegetation management (Ko et al., 2019, p. 10).

Similarly, the keywords in the transport subcorpus also show a clear trend towards the technical dimension of sustainability, e.g. *automated, AV, EV, LEV, and MaaS*. Again, technological fixes focusing on the physical aspects of infrastructure are prominent in this literature, in particular in relation to making cars greener:

As **EV's** emerge on the market, a physical infrastructure for recharging marks an essential feature for **EV** uptake. Here, strategies emphasize the rolling out of charging stations in advance (Held and Gerrits, 2019, p. 17).

Such technologies are intended to reduce emissions, but also to be profitable. As such, they often have costs attached, likely precluding access by some populations. Such business models may also continue to encourage excessive consumption. Further, private electric vehicles do not address traffic congestion, nor do they encourage urban planning to move away from sprawling cities designed with private car ownership in mind.

On the other hand, the keyword analysis also reveals attention for mobility modes that are linked to social and environmental benefits, including *cycling*, *multimodal*, *public* and *sharing*. Shared cycle schemes, for example, are low cost, compatible with existing transport infrastructure and familiar to most populations.

In the water and sanitation sector (WASH), institutional aspects are prominent. Particularly noteworthy are keywords *frontrunners* and *champions*, with many studies focused on specific good practices in water infrastructure transitions such as Integrated Water Resources Management (IWRM), Sustainable Urban Water Management (SUWM) and Water-sensitive Urban Design (WSUD). These frameworks are designed to coordinate the management of land and water resources in a given catchment area while maximising social welfare benefits and minimising negative ecological externalities.

Frontrunners possess the ability to utilise visions, integrate new concepts into policy narratives and nontechnical components to promote **SUWM** to highly influential leaders (Poustie et al. 2016, p. 136).

Although this is difficult to precisely quantify given the diffuse nature of urban **stormwater** pollution, the proliferation of **WSUD** schemes across Melbourne, the ongoing funding and increasingly stringent regulatory requirements all indicate a more effective transition overall (Werbelloff et al., 2017, p. 5855).

Ecological terminology relating to the environmental dimension of sustainability, such as *catchment*, *drought*, *rainwater* and *river*, also appear more prevalently here than in other UBIS subcorpora. This is likely because, perhaps more so than for any other UBIS, the provision of water is dependent on the functioning of natural ecosystems.

Dominant discourses based on geographical focus

In the North, where issues such as carbon lock-in are of key concern (Erickson and Tempest, 2015), there is a clear trend towards technology-related aspects, such as *biogas*, *MaaS*, *wood*, *desalination*, *AVs*, *nuclear* and *automated*, all of which can be linked to technically innovations designed to allow humanity to maintain our current lifestyles in a greener way. To a lesser but still notable extent, this is replicated in the South, through keywords like *electrification*, *EVs*, *green* and *hybrid*.

Table 4: 50 most distinctive key words per subcorpora based on geographical scope

Region	Distinctive keywords
Global North	Agenda, authorities, automated, AVs [Autonomous vehicles], biogas, blue, car-sharing, champions, council, decentralised, democra*, densification, desalination, diesel, district, electricity, experimental, experimentation, foresight, fossil, freight, initiative, institutionalization, intermediaries, learning, MaaS [Mobility as a Service], mayor, multimodal, municipal*, networks, nuclear, organisation*, parking, planning, professional, providers, public, radical, reconfiguration, resilience, scenario*, scooter, sectoral, sharing, solutions, stormwater, structuration, upscaling, wood.
Global South	Adoption, agencies, aid, bike, civil, compliant, contamination, cooperatives, cosmopolitan, cycling, delta, developers, distributive, donor, eco, electrification, enterprises, EVs [electric vehicles], firm*, foreign, formalization, government, green, hybrid* implementation, inadequate, income, inequalities, informal, injustice, justice, leapfrog*, manufacturers, megacities, ministry, modernization, motorcycle, NGO* [non-governmental organisation], peri, poor, power, protection, rationalization, residents, reuse, sanitation, subsidy, unsustainability.

Notes: Lexical items with the same base lemma are combined e.g. plurals (technology and technologies) and derivative forms/modifiers (democracy and democratic), indicated by *.

It is generally accepted that cleaner technologies will be ineffective without good governance. Both sets of keywords demonstrate a high incidence of keywords related to the institutional dimensions of sustainability. However, the specific institutional aspects highlighted for each region differ. In the North, there is a prevalence of keywords that seem to reflect high levels of formalised planning and state involvement, such as *authorities*, *council*, *institutionalisation*, *municipal**, *planning* and *professional*. In the South, certain institutional keywords suggest that a wider array of actors (should) have a role in transitions (e.g. *aid*, *cooperatives*, *donor*, *foreign*, *informal*, *NGO*), yet from a critical perspective, these keywords also draw attention to discourses of dependence. Further, keywords such as *formalization*, *modernization* and *rationalization* suggest that much transitions research focuses on how cities in the Global South can replicate the development pathways of high-income countries, although conversely the keyword *leapfrogging* also points to the opportunity for lower-income countries to skip less efficient, carbon-intensive phases of development:

Linking **leapfrogging** analysis with a socio-technical perspective implies that environmental problems associated with urbanization and industrialization may be avoided by **leapfrogging** to cleaner technologies from the outset (Yu and Gibbs, 2018, p. 4).

There also appears to be greater awareness in Global South-related texts of social issues arising in transition processes, such as *justice*, *inequalities*, and *injustice*, as well as greater attention for less technologically intensive aspects of UBIS such as *cycling* and *reuse* (of materials, waste and wastewater) that are linked to both social and environmental benefits beyond the mitigation of greenhouse gas emissions:

The refusal of the State to legitimize the operations of motorcycle taxis as a public transport conveyance is a case of recognition **injustice**, considering that motorcycle taxis have proven to be *viable mode of public transport* and therefore deserve recognition as such in the existing laws (Sunio, 2021, p. 12, emphasis in original).

Interim conclusions: Subcorpora

Keywords from the UBIS subcorpora revealed a strong preoccupation with technological solutions designed to make energy and transport infrastructure greener. The WASH sector, by contrast, encompassed institutional and environmental factors too, through the proliferation of keywords related to good practice frameworks and attention to the link between water provision and natural ecosystems respectively. In terms of the regional subcorpora, in the Global North we see an emphasis on technical innovations underpinned by formal, often state- or private-led planning, compared to USD transitions involving civil society and foreign participation in the Global South.

Discussion and conclusions

The foregoing corpus-based discourse analysis of 107 academic articles on sustainability transitions in UBIS endeavoured to provide insight into how sustainability transitions are envisaged in academic discourses in UBIS, how these manifest differently across infrastructure sectors and geographical regions, and what conceptual or empirical blind spots may warrant greater attention.

Conceptions of sustainability transitions

The UN definition of sustainability encompasses economic, environmental and social dimensions underpinned by institutional dimensions of sustainability (Figure 1). Our findings provide quantitative evidence to substantiate the claim that much research on sustainable

urban infrastructures neglects the environmental and social dimensions. Instead, transitions towards more sustainable USD are often discursively framed in institutional and economic terms, as well as in terms of an additional, technologically focused frame.

Advances in technology have the potential to create opportunities to develop more efficient infrastructure, for example by using renewable energy to power homes, buildings and motorised vehicles. Yet an overreliance on technology as a “silver bullet” can also lead to a host of practical and ethical dilemmas (Arcanjo, 2019; Sudmant et al., 2021). Technology itself can exacerbate existing inequalities and injustices within and between cities or create new ones (Diep et al., 2019; Sunio et al., 2021), and technological lock-ins and path-dependency can contribute to unsustainable consumption patterns, dependence on private cars, public budget overruns and financial crises (Markard et al., 2012; Savaget et al., 2019). Though our analyses revealed minority counter-discourses—for example, on the potential pitfalls of implementing smart technologies without also paying attention to good governance (e.g. Britton, 2019; Canitez, 2019; Pangbourne et al., 2020)—these were heavily outweighed by purely technology-focused discourses. At the same time, previous research suggests that technical solutions that neglect social aspects are likely to maintain existing power imbalances and ensure that large parts of society remain marginalised and discriminated against (Bosomworth et al., 2017; Singh, 2018).

Instead of a narrow conception of sustainability transitions as revolving around technology (or, for that matter, any of the four UN pillars of sustainability in isolation), transitions should be approached holistically and “emplaced” (Brown et al. 2013; Feola and Jaworska 2018). This implies that considerations of the spatial and temporal context of USD (our second newly identified discursal frame) must go beyond merely recognising local practices. Instead they must pay greater attention to how wider discourses and policies on UBIS transitions interact with such practices (Brown et al., 2013) and can support alternative and perhaps more experimental ways of organising USD, such as citizen-led, community-based or needs-driven service configurations (Monstadt and Schramm, 2017; Moretto et al., 2018; Oates, 2021), which are often associated with improved environmental sustainability (Ranzato and Moretto, 2018) as well as accessibility and equity of USD (Jaglin, 2014; McGranahan, 2013). Greater engagement with such arrangements could thus help to redress the neglect of the environmental and social dimensions in the sustainability transitions literature.

Sustainability transitions discourses per sector

The dominant techno-economic discourse was clearly apparent in research on both the energy and transport sectors. With the energy sector responsible for an estimated 35% of anthropogenic greenhouse gas emissions, making it the largest emitting sector, and transport responsible for 14% (IPCC, 2014), this discourse may reflect a predilection for large-scale

technical fixes designed to cut carbon emissions in line with multilateral global agreements. The techno-economic focus also revealed a preoccupation with USD models that, while green, also generate value, most often measured in monetary terms. This can disadvantage USD performed by small local enterprises, communities or individuals, which in comparison are considered risky investments (Van Welie and Romijn, 2018), and can (continue to) promote a cultural preference for consumption and private property ownership. In the transport subcorpus, for example, numerous studies explored the individual ownership of private autonomous and electric vehicles, which makes car- and bike-sharing schemes less viable (Geels, 2012) and reduces the incentive for states to invest in public transport improvements. By contrast, discourses in the water and sanitation sector paid comparably more attention to environmental and social aspects, though primarily in relation to specific good practice frameworks such as IWRM, SUWM and WSUD. Such practices are often promoted by states and multilateral agencies, and can still be considered part of a techno-managerial paradigm in their reliance on planning and engineering.

Sustainability transitions discourses per geographical region

Our findings provide quantitative evidence to substantiate assertions that research on sustainability transitions neglects the Global South in terms of volume, and also reinforces discourses of dependency on international development assistance and the associated enforced compliance with externally imposed rules and Northern norms. This echoes earlier research on dominant ideologies whereby innovation is expected to emerge in the Global North and “trickle down” to Southern countries (Coenen et al., 2012), despite increasing evidence that innovations in USD also emerge in Southern cities (Jaglin, 2014, Oates, 2021), which have a “unique but often overlooked capacity, to innovate and experiment for sustainability” (Nagendra et al., 2018). These findings tie in with existing calls for more and better theoretical and conceptual engagement with the urban areas of the Global South, including the need for a critical turn that pays greater attention for power relations, diverse worldviews and inclusivity (Feola, 2020; Van Welie and Romijn, 2018) and a focus on just transitions, whereby sustainability initiatives and interventions are explicitly viewed as an opportunity to reduce global inequities (Swilling and Annecke, 2012).

Methodological reflections

The methodological approach used here is novel in the sustainability transitions field and allowed us to tap into the abovementioned critical perspective: the strength of corpus-assisted discourse studies (CADS) lies in “questioning what is taken for granted, indicating problematic discursive practices [...] and challenging dominant ideologies and normative assumptions”

(Barakos and Unger, 2016: 3). At the same time, some limitations of this research should be acknowledged.

First, the size of our corpus, though considerable, precluded us from drilling down to the country level in our geographical analysis. Each subcorpus must remain large enough in terms of “tokens” (words) to ensure statistically valid results, hence our division into sustainability transitions discourses pertaining to the supra-regional Global North and South, despite the potential differences between countries within each region. This may be a revealing avenue for future research.

Second, due to word limitations we only report here on discursive differences across corpora, rather than similarities. Although this risks emphasising differences at the expense of shared discursal patterns, it allowed us to identify both the focal points and blind spots of research on sustainable USD differentiated by sector and region.

Finally, although a CADS approach helps to reduce the impartiality common to discourse analysis (Feola and Jaworska, 2018), the selection of concordances for qualitative analysis remains a subjective process (Baker and McEnery, 2015). Indeed, different researchers may well draw different conclusions from the same corpus. Nevertheless, the corpus-assisted techniques used here allowed us to draw conclusions from large samples of data, thereby adding validity to previous claims made in the field of transitions studies.

Concluding remarks

If research on sustainability transitions is to contribute to meeting international targets like those set out in the Sustainable Development Goals and the Paris Agreement, an integrated approach is required that treats the respective pillars of sustainability not in isolation from one another but as distinctive yet interrelated parts of the same system (Purvis et al., 2019). This study allowed us to investigate dominant academic discourses and conceptual gaps with a view to fostering a broader understanding of (transitions towards) sustainability. It is hoped that these findings draw attention to the need to systematically address all dimensions of sustainability in USD research, thereby informing possibilities for a more holistic and equitable response to global sustainability challenges.

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