Urban Futures: Systemic or System Changing Interventions? A literature review using Meadows' Leverage Points as analytical framework

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Highlights

- Cities are a key implementation site across many of the Sustainable Development Goals.
- Understanding whether current interventions account for cities as complex systems is key.
- This requires a focus on processes as much as on outcomes to enable systemic change.
- The negotiation between trade-offs needs to account for underpinning worldviews and values.
- Addressing this entails going beyond technocratic skills to interrogate our agency as researchers.

Abstract

Urban-led change for sustainability is a key site of intervention in delivering the ambitions of the Sustainable Development Goals. Within this broad discourse, four umbrella concepts have emerged in recent decades: urban sustainability, urban transitions, urban transformation and urban resilience.

This literature review aims to offer a qualitative assessment of the types of interventions currently being advocated for in academic-led literature. Firstly, the paper presents an overview of the concepts and summarises current gaps; secondly, it uses Donella Meadows' Leverage Points as analytical framework to categorise and discuss interventions supported in the literature.

Our findings indicate that although the literature advocates for systemic change towards sustainability as an outcome of a large palette of urban interventions, less consideration is given to the means of achieving these. The findings highlight the need to focus on processes as much as on outcomes when advocating, devising or implementing interventions. This requires a process of understanding and negotiating trade-offs and the different worldviews and values that underpin them. Addressing this entails going beyond technocratic skills through cultivating reflexivity, effective communities of practice and new forms of organising for knowledge production, as well as interrogate our roles and agency as urban researchers.

1.0 Introduction

The urban-led change agenda has diffused from an academic call for new ways of researching and intervening in an increasingly interconnected and globalised urban condition (Brenner & Schmid, 2011; Brenner, 2013; Burdett & Sudjic, 2008; Burdett & Rode, 2018). This has been mirrored by an increased interest in the role of cities in achieving the goals of global policy frameworks such as the *New Urban Agenda*, the *Sendai Framework for Disaster Risk Reduction* or *SDG 11 Sustainable Cities and Communities*.

This agenda is formed of a broad church of concepts developed and applied by different communities of knowledge and practice. We focus on four key concepts that have emerged in relation to urban futures: urban sustainability, urban transitions, urban transformation and urban resilience. They have become 'catch-all phrases' that encompass the normative concerns of a variety of actors, from policy makers and academics to civil society organisations and activists (Béné et al., 2018; Chappin & Ligtvoet, 2014; Childers et al., 2014; Collier et al., 2013).

Our research scrutinises the types of interventions advocated across these four concepts through a review of academic-led literature. We respond to a current research gap in understanding whether current studies on urban-led change are conducted from an understanding of change processes not as solely technical, social or ecological, but as interventions in complex systems (Bai et al., 2016; Batty et al., 2006; Olazabal, 2017). To this end, we deploy Donella Meadows' *Leverage Points: Places to Intervene in a System* (Meadows, 1999) as analytical framework.

The review is structured as follows: we first provide a summative background of the four concepts; secondly, we set out the methodology and the reasoning behind the choice of analytical framework; thirdly, we analyse the findings; finally, we discuss implications for the four concepts, future research as well as the use of the Leverage Points as analytical framework.

2.0 Urban resilience, transitions, transformation, sustainability: brief context and research gaps

This section sets out to briefly describe the evolution of the four key concepts to their present-day usage, as well as highlight current gaps as identified in the literature reviewed. The two diagrams below visualise the key pivot points in the evolution of the terms (Figure 1) and their relative positions regarding socio-ecological systems (SES) or socio-technical systems (STS) (Figure 2).

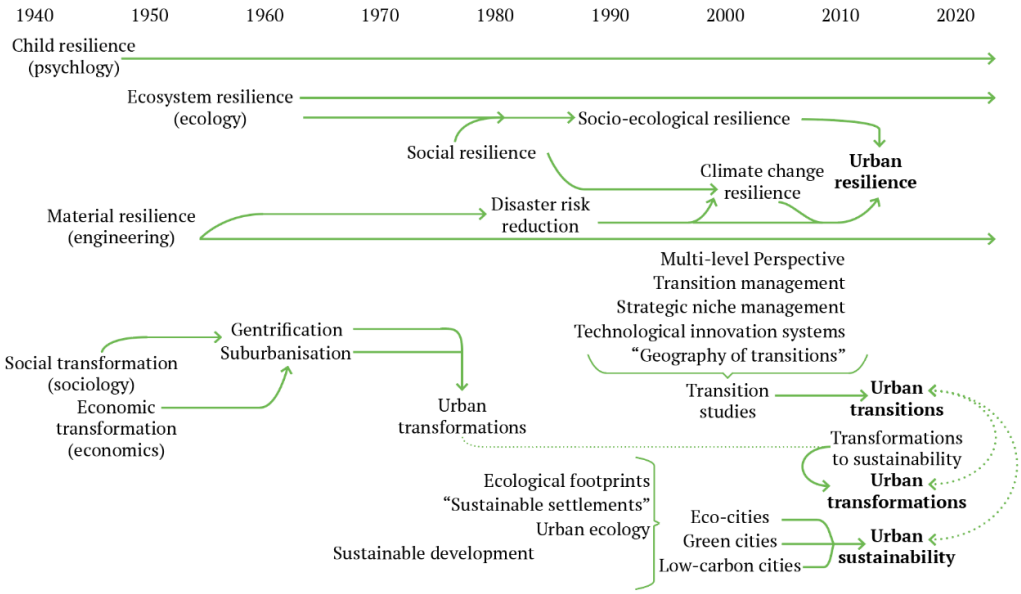


Figure 1. Evolution of the four key concepts, building on diagrams by Béné et al. (2018) and Markard, Raven, & Truffer (2012).

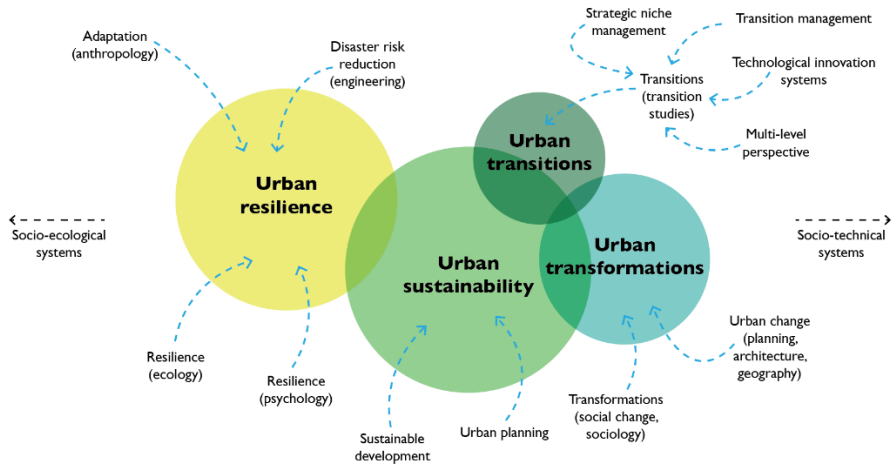


Figure 2. Mapping the relative positions of the four concepts regarding SES and STS, as identified in the literature.

Below we have summarised common definitional positions on the four concepts from the literature review. As exemplified in Figure 2 above, the concepts stem from different fields, while multiple definitions for the same term arise from different knowledge communities.

Table 1. Definitional positions in the literature.

	Definitional positions in literature
Urban sustainability	Resource management of urban regions through ways that guarantee the wellbeing of current and future generations, ensuring distributional equity. […] A normative concept, representing the vision for society. (Elmqvist et al., 2019)
Urban resilience	The ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity. […] A contested normative vision that cities strive to attain (Meerow & Newell, 2016). The capacity of an urban system to absorb disturbance, reorganise, maintain essentially the same functions and feedbacks over time and continue to develop along a particular trajectory. […] Fundamentally non-normative and an attribute of the system (Elmqvist et al., 2019).
Urban transitions	The process of multiple actors partaking in sociotechnical change through innovation, adaption, and adoption usually towards sustainable modes of urban production and consumption (Ehnert, Frantzeskaki, et al., 2018; Frantzeskaki et al., 2016).
Urban transformation	A shift from one state of an urban system to another that entails radical changes (Elmqvist et al., 2019). The process and the outcome of changing the systemic configuration of urban areas, mostly studied with a view to its sustainability performance or achievements (Wolfram et al., 2016).

2.1 Urban resilience

Urban resilience can be seen as a "mobilising metaphor" (Béné et al., 2018, p. 121) that can foster a multidisciplinary dialogue between traditionally disparate communities such as disaster risk reduction, community development, ecology or urban planning. The term's meaning has developed from a clear academic concept (resilience as a non-normative property of a system or sub-system as defined by Elmqvist et al., 2019) towards 'fuzzy' and 'increasingly vague' (Meerow et al., 2016) definitions that seek to address the normative dimensions of resilience for whom, of what and for when (Meerow & Newell, 2016; Bahadur & Thornton, 2015; Chelleri et al., 2015; K. Brown, 2014; Vale, 2014).

While the academic discourse is putting forward theoretical advances in the conceptualisation of urban resilience, there is growing concern that in practice the term is being co-opted as a mechanism for implementing policies that support business-as-usual (Kaika, 2017; DeVerteuil & Golubchikov, 2016; Bahadur & Thornton, 2015; Brown, Dayal, & Rumbaitis Del Rio, 2012). Addressing the research gap between academic and practice-led applications of the concept would thus require tackling social and environmental justice issues related to a normative reading of urban resilience, tightly coupled with urban governance and decision-making processes (Coaffee et al., 2018).

2.2 Urban transitions

Urban transitions, transformations and sustainability have a considerable shared history; although in many cases the terms are used interchangeably, urban sustainability is seen as the broadest 'umbrella term'. Although semantically both 'transition' and 'transformation' are indicative of both the process of and the outcome of enabling new system configurations, the terms appear to "delineate particular epistemic communities rather than a substantive difference in meaning" (Wolfram et al., 2016, p. 19). A bibliometric analysis of 'transformation' and 'transition' reveals high indices of co-authorship and cross-referencing among the literature (Chappin & Ligtvoet, 2014), which denotes a concerted effort to consolidate the fields of scholarship.

The term 'transitions' has been defined as "long-term, multidimensional, and fundamental transformation processes through which established sociotechnical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012, p. 956). Given the focus of transition studies on socio-technical regimes as predominantly domain-oriented (such as energy, mobility or food transitions), the urban transitions discourse first emerged in the context of geographical dimensions of past and emerging transitions, identified as a 'geography of transitions' (Coenen et al.,

2012; Coenen & Truffer, 2012) such as the energy transition in Netherlands, or the mobility transitions in Amsterdam. Current research gaps in urban transitions focus on addressing drivers of uneven effects in urban transition processes, such as struggles over urban redevelopment, green gentrification, or the impact of 'smart' urban transitions (de Jong et al., 2015; Hakansson, 2018; Roy, 2009, 2016).

2.3 Urban transformation

Urban transformation in the context of sustainability is seen as a broader term than transition, having been defined as "the process and the outcome of changing the systemic configuration of urban areas, and is mostly studied with a view to its sustainability performance or achievements" (Wolfram & Frantzeskaki, 2016, p. 19). In the context of sustainability, the term urban transformation is often accompanied by its qualifier *to sustainability*. This reading of the term stems from socio-ecological systems (SES), from which it developed perspectives on energy and material use that frame transformation as a succession of "sociometabolic regimes" (Brand & Wissen, 2017, p. 3).

However, at the scale of urban there is still confusion as to what transformations stand for, as there is a considerable historical body of empirical studies on urban transformation in relation to socio-political changes (for example in relation to migration, gentrification, suburbanisation; for a detailed literature review see Koch, Kabisch, & Krellenberg, 2018). Current research gaps in urban transformations focus around the lack of interrogation of structural barriers to change, such as the production-consumption systems, the goal of economic growth, or the impact of wider processes of globalisation (Brand & Wissen, 2017).

2.4 Urban sustainability

The broadest and fuzziest umbrella term (de Jong et al., 2015), the evolution of 'urban sustainability' has been closely linked to the development of the sustainable development discourse. Its lineage originally manifested through an ecological definition of strong sustainability (de Jong et al., 2015; Devolder & Block, 2015). In the context of urban sustainability, more narrow descriptors such as 'urban ecology', 'eco-city', 'low-carbon city' or 'green cities' focus on the development of zero-emissions and zero-waste closed loop urban design.

The focus on resource use and vulnerability in relation to the economic dimensions of cities (Campbell, 1996) has seen a growing focus on 'ecological footprints' and the relationship between cities and the carrying capacity of the hinterland (Romero-Lankao et al., 2016). Over time, the socio-ecological approach in practice has been reduced to a weak understanding of sustainability that doesn't challenge the economic growth imperative (Romero-Lankao et al., 2016).

The interconnected impact of cities on global processes and phenomena has been illustrated since the 1990s through studies that demonstrate the links between the 'transfer of environmental burdens', global inequality and local consumption footprints (Rees & Wackernagel, 1996; Wackernagel & Rees, 1998). However, the urban sustainability discourse has been advocating the compatibility between the global trend of moving towards service economies and increased value chain efficiencies with making progress on social inequality (de Jong et al., 2015) and "finding solutions for the urban poor" (*Urban Poor | UNFCCC*, n.d.). Current research gaps in urban sustainability highlight the need to investigate the impact of urban sustainability initiatives (such as green gentrification) as well as the impact that 'sustainable' cities impose on global flows of production and consumption.

2.5 Summary

In this section we set out to provide a summative background for the four concepts and identify key research gaps as currently laid out in the literature. We undertook this upfront to help contextualise how the concepts gained traction and to help inform the methodology of the literature review.

We have chosen not to expand on the concepts' definition beyond the summary found in Table 1 – for extended definitional reviews please see Elmqvist et al. (2019) and Meerow & Newell (2016). The

summary is intended to serve as guiderail to help navigate what at times are terms used interchangeably and that can lead to considerable confusion.

Building on this overview, the next section sets out the literature review methodology and expands on the choice of analytical framework.

3.0 Literature review methodology

The qualitative literature review covers the years 1970 - 2019 and was drawn from Web of Science UK. The keyword search for 'urban transitions' or 'urban transformations' or 'urban sustainability' or 'urban resilience' retrieved 1745 results. The resulting titles and abstracts were then narrowed based on mostly cited papers (with over 15 citations minimum), as well as whether the title and abstract addressed the keyword directly, which led to a shortlist of 34 papers. Through snowballing from the papers' references we selected papers that were highlighted by the authors as highly relevant (marked with * in the bibliography). In total, we analysed 68 papers (for a full list please see Appendix 1).

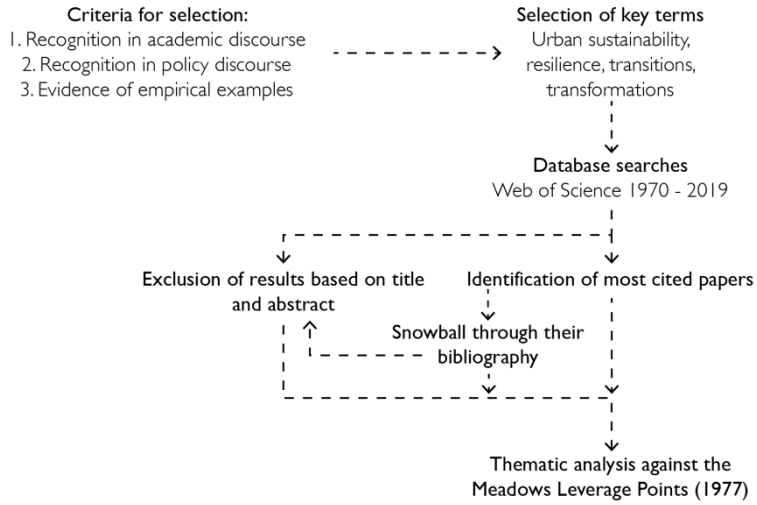


Figure 3. Literature review methodology

3.1 Analytical framework

The field of systems thinking provides approaches towards a holistic understanding of natural and social systems behaviour and the emerging properties arising from their interrelations over time. One such framework was put forward by Donella Meadows in her essay *Leverage Points: Places to Intervene in a System*, further revisited in 1999. The essay puts forward a hypothesis that there are "are places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything" (Meadows, 1999, p. 1).

The Leverage Points, illustrated in Figure 2, have seen a growing interest in recent years from researchers and practitioners alike (O'Brien, 2018; Abson et al., 2017; Nguyen & Bosch, 2013; Proust et al., 2012). Abson et al. (2017) developed a detailed discussion of the potential of deeper leverage points to frame and inform interventions towards sustainability, while Fischer and Riechers (2019, p. 115) have highlighted that a leverage points approach can "bridge causal and teleological explanations of system change – that is, change is seen to arise from variables influencing one another, but also from how human intent shapes the trajectory of a system".

The Leverage Points can be grouped into four main analytical categories:

- **Parameters** encompass constants, numbers (such as taxes or incentives), buffer sizes (such as physical capacities of disaster mitigation strategies), as well as material stocks and flows (such as physical infrastructure, or transport and logistics networks);
- **Feedback loops** encompass positive and negative feedback loops, as well as the relative delays compared to the pace of change (for example delays between the identified need for infrastructural change compared to the length of time necessary for implementation);
- **System structure** encompasses information flows (such as who has and who has not access to what information), the rules of the system and the capacity for self-organising system

structure (for example the capacity to design for and with emergence, experimentation and learning);

- **Mental models** encompass the goal of the system, the mindset or paradigm out of which the system arises, and lastly, the power to transcend paradigms through recognising them as such.

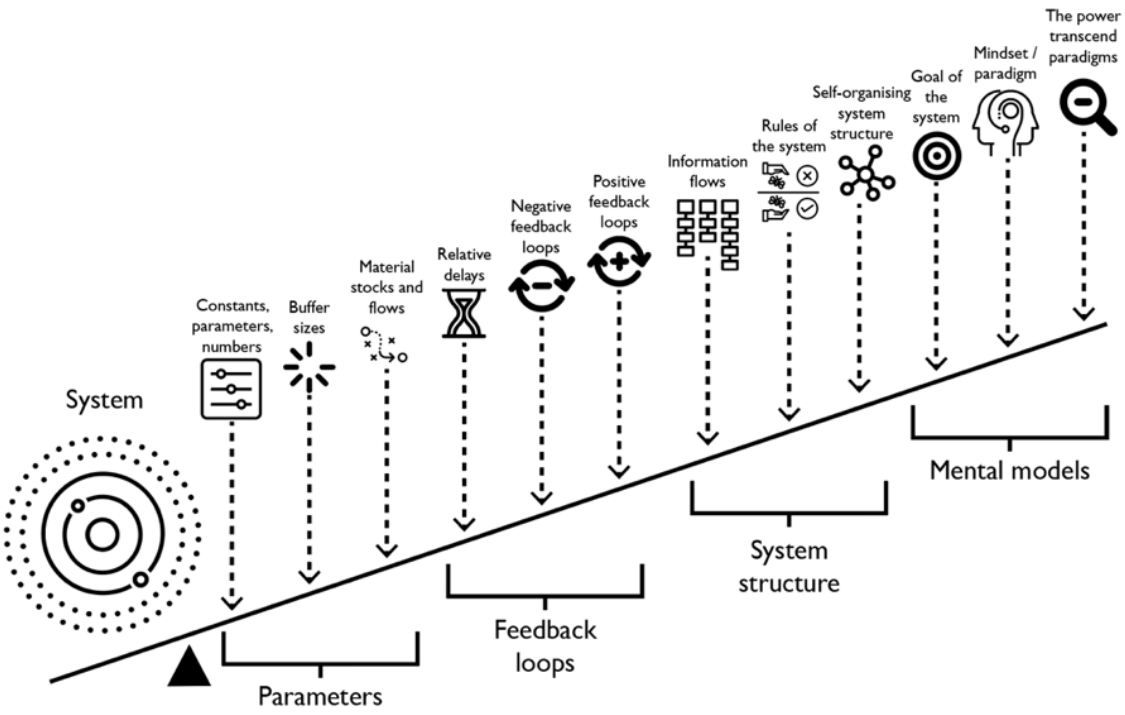


Figure 4. Meadow's Leverage Points (1999) in increasing order of their effectiveness, building on Fischer and Riechers (2019). As Fischer and Riechers note, interventions in 'deeper' leverage points (such as system structure or mental models) can potentially have more transformative impact, yet are more difficult to devise, implement and measure, while 'shallower' leverage points have more incremental impact.

The present literature review uses the Leverage Points as analytical framework to map the types of interventions areas identified within current positions across the four key concepts (urban sustainability, resilience, transformation and transitions). Key words from the original text were deployed as in vivo codes for lexical analysis. For example, the leverage point 'rules of the system' is described in the original text through the keywords *rules of the system, system rules, change the rules, social norms, change the norms, normative*, which were then used in the lexical search. Further exclusions were made through checking whether the resulting paragraph of each search return addressed interventions specifically. For example, if a paragraph that contained the key lexical search "social norms" didn't directly use it in the context of interventions being advocated for, then it was excluded. For the full keywords list and sample quotes, please see Appendix 2.

4.0 Research findings

The aim of this section is to discuss the types of leverage points that are being advocated for across the literature. The leverage points are interdependent, rather than independent, sites for intervention. In other words, their relationships are co-constructed – 'shallower' leverage points influence 'deeper' leverage points and vice versa. Figure 5 was visualised in MaxQDA depicts the co-occurrence (>2) between the different codes in the literature reviewed. The thickness of the line indicates the number of co-occurring codes, while the colours depict the clusters of co-occurrences.

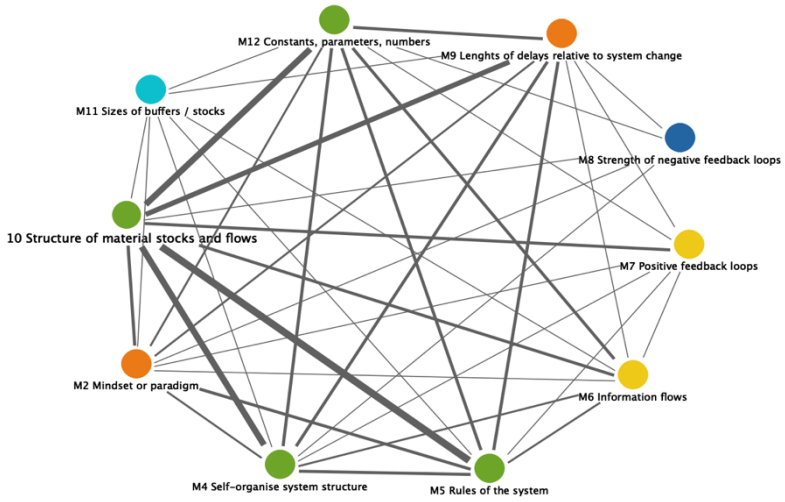


Figure 5. Codes co-occurrence across the literature (MaxQDA).

The interdependence between the different leverage points is mirrored in the results. The structure of material stocks and flows is the highest occurring code (perhaps obvious given the very tangible aspects of physical from), which is strongly connected to constants, parameters and numbers (such as targets and policy parameters), self-organising system structure (through levers such as governance and decision-making structures), as well as the rules of the system (nodding to a long scholarly history of interrogating the roles of power and agency as co-constituted by infrastructure and metabolic flows). In terms of predominance, parameters are first (97 instances), followed by feedback loops (54), system structure (53) and mental models (9).

Key words for three of the leverage points (the sizes of buffers relative to flows, the goal of the system and the power to transcend paradigms,) did not return any results after the lexical search. This could potentially be explained through the system dynamics jargon of the former (as key words for the lexical search were extracted from the original text only) or the philosophical intangibility of the latter.

The following sections discuss key themes that emerged for each of the four leverage categories. For an extended table of the literature mapped on the Meadows Leverage Points, the numbers of initial and final codes, as well as exemplary quotes from the literature, please see Appendix 2.

4.1 Parameters

Target setting: SDGs as driving vision

The literature welcomes the formulation of a standalone Sustainable Development Goal dedicated to cities (SDG11 Sustainable Cities and Human Settlements) as a significant step forward for goals and target setting, while acknowledging the difficulties in translating the high-level visions into actionable and measurable, yet transformative targets (McPhearson et al., 2016). Connecting to the SDGs, a number of associated frameworks for target setting (such as the New Urban Agenda, the Covenant of Mayors or 100Resilient Cities) seek to support the urban change agenda. Krellenberg, Koch, & Kabisch (2016) point out that although political will for target setting is present, the implementation of the frameworks mentioned above focuses predominantly on techno-efficiency (such as energy reduction and energy efficiency of building stocks or transport), while neglecting the need for behavioural change in urban lifestyles. The targets and indicators that are currently set in place in cities across the world will guide implementation over the coming decade, however an unaddressed bias towards "quantitative indicators and parametrisation, [that] often use arbitrary indicators and associated weighting to create an amalgam of several core indicators" (Coaffee et al.,

2018, p. 406) poses barriers for target setting as a systemic process for implementation. Examples of alternative processes include methods for translating participatory visioning into urban implementation targets, such as "causal loop diagramming, influence matrixes, participatory modelling, systems mapping, and trade-off assessment activities and tools into participatory visioning" (McPhearson et al., 2016, p. 4).

Potential for parameters in market stimulation

Constants, numbers and parameters are associated in the literature with the potential leverage of incentive mechanisms for change, such as "policy architectures, financial streams and political incentives for responding to shocks and stresses" (Bahadur & Thornton, 2015, p. 208), "payment for ecosystem services" (Ernstson et al., 2010, p. 540), stimulating innovative technologies through "niche developments in 'protective spaces'" (Fastenrath & Braun, 2018, p. 3), or through using public procurement to create incentives for SMEs to implement environmental measures (Burch et al., 2016). However, as Tyler and Moench (2012) note, although agent behaviour can be differentiated and incentivised through parameters, the means for change are sometimes outside their sphere of control which can constrain the effectiveness of parameters as leverage points. For example, the difficulty of negotiating "the trade-offs between investments that yield immediate benefits and those that address longer-term impacts" (Brown et al., 2012, p. 551) such as higher costs per unit further entrenches existing inequities, while adding regular maintenance and renovation cycles to current models impacts profitability (Haldrup & Snallfot, 2014).

The promise of 'green' infrastructure

Material flows and stocks such as infrastructure development and maintenance are highlighted as a key intervention sites with transformative potential. As Ahern (2011) notes, the magnitude of infrastructural investment foreseen for this century offers an unprecedented opportunity for rethinking the process of urbanisation through 'green infrastructure' that is 'sustainable and resilient'.

Such 'good' infrastructural development has the potential to pre-emptively account for resilience and adaptability to climate change, while creating the conditions for ecological restoration. However, as Béné et al. (2018) note in their literature review of urban resilience, 'good' infrastructure requires well-governed cities – a key factor which conditions the effectiveness of infrastructure as a leverage point. As Hodson, Geels, & McMeekin (2017, p. 2) further caution, "selectivity [nb. of sustainable infrastructural innovation] is mediated through context-specific governance and institutional arrangements, drawing on contested knowledge of and interpretations of 'sustainability'".

Due to current demand for infrastructural development and its implicit permanence, green infrastructure as identified in the literature (Ahern, 2011; Collier et al., 2013; Kaika, 2017; Moloney & Horne, 2015) needs to addresses issues such as decentralisation and diversity of supply and consumption patterns (Ryan, 2013), technological lock-ins and existing poor quality infrastructure (Sanchez et al., 2018), as well as physical and socio-economic accessibility (Sharifi et al., 2017; Tyler & Moench, 2012).

In the words of Donella Meadows,

> *"Physical structure is crucial in a system, but rarely a leverage point, because changing it is rarely quick or simple. The leverage point is in proper design in the first place" (Meadows, 1999, p. 7).*

4.2 Feedback loops

Time horizons: Designing with and for different paces of change

The importance of working with and for different time horizons and paces of change surfaced as a key recurring theme concerning feedback loops. The literature points to the importance of building both short-term responsive capacities and longer-term transformational ones, while being aware of the feedback loops being set in place which might strengthen the former but weaken the latter (Coaffee et al., 2018; DeVerteuil & Golubchikov, 2016; Gorissen et al., 2018; Masnavi et al., 2019; Mendizabal et al., 2018; Rogov & Rozenblat, 2018; Sanchez et al., 2018). The tendency to discount the future further adds to tensions surrounding the temporal focus of change initiatives (Sanchez et

al., 2018), which can mean that concepts which should be aligned on outcomes (such as resilience and sustainability) can seek to implement contradictory, or even competing measures (Zhang & Li, 2018). For example, sustainability interventions often focus on eco-efficiency (Meerow & Newell, 2016), while resilience thinking promotes functional redundancy (Korhonen & Seager, 2008). The potential contradiction becomes apparent in the case of 'smart cities' that advocate for increased energy and material efficiency and interconnectivity as being more 'sustainable', although their "inflexibility and extreme hypercoherence" (Redman, 2014, p. 8) has been argued against by resilience theorists.

Potential for learning feedback loops

Different paces of change are observed at both actor and domain level, dynamics that point to uneven processes driven by the 'projectification of funding' (Borgström et al., 2016; Ehnert, Kern, et al., 2018), where interventions that often require long-term commitment of funding and human resource are shoehorned into short-term projects according to external funding timelines and political cycles. A lack of integration and feedback for learning across urban domains within cities, as well as in between cities is also noted in the literature. Ehnert, Kern, et al. (2018) emphasise the need to explore the feedback loops between initiatives (such as urban transitions projects) and multi-level governance contexts, while Moglia et al. (2018) advocate for embedding early warning signals (such as community concern) as well as ongoing observation and reflection to proactively anticipate potential unintended consequences and avoid maladaptation. This highlights the potential of designing with and for these different dynamics and creating intentional feedback loops to enable the socialisation of learning (Moloney & Horne, 2015; Nagorny-Koring & Nochta, 2018).

4.3 System structure

Decision-making beyond consultation

As currently marginalised groups are predominantly excluded from urban decision-making processes often concerning them, the literature highlights the potential for participatory approaches for both gathering input in visioning processes, as well as in evolving decision-making processes beyond current consultation practice (McPhearson et al., 2016; Tyler & Moench, 2012). This highlights the potential of information flows in aiding more inclusive and empowering decision-making processes (such as participatory budgeting or policy co-design), which will require and understanding of information and data beyond the conflation of smart cities with information and communication technologies (ICT) (de Jong et al., 2015), or of technological smart cities with sustainable cities (Kaika, 2017).

Evolving forms of governance

Closely linked to the previous theme, governance is regarded as a key site of intervention, with new hybrid forms of governance such as urban adaptive management (Béné et al., 2018; Leichenko, 2011), multi-level governance (Ehnert, Kern, et al., 2018), decentralisation and polycentricity (Bahadur & Thornton, 2015), panarchy (Ernstson et al., 2010; Moglia et al., 2018; Pelling & Manuel-Navarrete, 2011) or experimentation as a form of transition governance (Frantzeskaki et al., 2018). Although the terms might take different forms in practice, they share a number of core principles such as "self-organisation, adaptive learning and diversity in processes, institutions and culture" (Krellenberg et al., 2016, p. 53). However, as Schiller (2016, p. 4278) notes, self-organisation "does not automatically bring about social networks in which individual actors change their behaviours from unsustainable to sustainable life styles". This latter point alludes to a wider gap between academic and practice-led positions on what is needed to evolve urban governance.

4.4 Mental models

Inquiring into 'normativity'

Across the literature there is a shared understanding of the need for a normative dimension of the four key topics (Béné et al., 2018; Burch et al., 2016; Collier et al., 2013; Ernst et al., 2016; Meerow et al., 2016; Romero-Lankao et al., 2016; Tyler & Moench, 2012). While Burch et al. (2016) note that the focus of transition governance is actively pursuing a normative agenda, Devolder & Block (2015,

p. 3269) highlight that the mere popularity of a normative ideal does not guarantee that "increased pressure on dominant unsustainable systems will occur". Furthermore, the literature points to a implementation gap between the 'transformative turn' of the sustainability discourse, while the current empirical cases do not reflect it (Koch et al., 2018).

The literature presents this as an opportunity to deepen the practice of translating normative ideals into practical considerations through asking intentional questions such as for whom, what, where, and why. This process would provide a framework for debating the values that can make interventions just and desirable. Iwaniec, Cook, Barbosa, & Grimm (2019, p. 5) point that this process needs to be followed up by "engaging marginalised and vulnerable stakeholders to enhance equity, well-being, and livelihood; avoiding the degradation of social-environmental conditions; reducing unintended consequences that diminish options for the future; and addressing the resulting trade-offs". This final point is echoed by Meerow et al.'s (2016) concern towards the tendency to adopt normativity with the assumption of 'universally positive' outcomes that do not take into consideration the uneven distribution of winners and losers in any given change process. As Pizzo (2015, p. 134) notes, "the shift from an analytical perspective to a normative one is not straightforward".

Nested approaches to change

Across the literature, mentions of the need for a deeper paradigm shift are sparsely present (Gorissen et al., 2018; Kaika, 2017; Koch et al., 2018). Scenario-driven research points out that there are multiple socio-political configurations which would enable 'acceptable' outcomes in urban change for sustainability (Moglia et al., 2018), including ones compatible with the current market logics. However, espousing transformative change language (in line with the New Urban Agenda call for a paradigm shift) while enacting "old methodological tools (e.g. indicators), techno-managerial solutions (e.g. smart cities), and institutional frameworks of an ecological modernisation paradigm" (Kaika, 2017, p. 89) implies that as practitioners and academics we are complicit in perpetuating mental models underpinning an extractive system built on inequality and inequity (Roy, 2016; Gibson-Graham, 1997). To paraphrase, everyone is advocating for change, yet few are recognising that *we* need to change.

As Salat (2017, p. 107) notes, "organisation at system level emerges from the feedback loops that characterise the system as a whole", which points to the nested nature of urban change processes and the roles of actors to acknowledge and act according to their position in the system. Interventions in mental models have the potential for deep transformation, however, they are the hardest to devise and most elusive to monitor and asses.

5.0 Discussion and conclusions

The research findings from section 3 indicate that although academic-led literature advocates for systemic change towards sustainability as an outcome of a diverse palette of urban interventions, less consideration is given to the means and enablers for achieving these. To reflect on the findings, we first discuss the implications across the four concepts (5.1). We then proceed to discuss the implications for future research (5.2) and the implications for the use of Leverage Points as analytical framework (5.3); finally, we draw conclusions (5.4).

5.1 Implications for the four key concepts: urban resilience, transitions, transformation, sustainability

Our analysis depicts that the literature reviewed is predominantly concerned with interventions in parameters, which in turn focus on the potential of SDGs as driving visions for target setting, the potential for market stimulation, as well as the promise of green infrastructure. Feedback loops (through the potential of designing with/for different time horizons and learning feedback loops) and system structure (through evolving decision-making as well as forms of organising) come second in proportion and are nearly equally represented in the literature. Lastly, mental models are sparsely present, with themes emerging around the need to inquire into what we mean by 'normativity', as well as the need to actively reflect on the deeper paradigm underpinning events, patterns and behaviour.

Across the four key concepts, a dynamic that becomes apparent is the relationship between process and outcome. On one hand, the interventions that fall in the parameters category predominantly advocate for deploying existing mechanisms (such as market incentives, target setting processes or green infrastructure) in order to achieve system changing outcomes. On the other hand, the interventions that fall in the other three categories (feedback loops, system structure, mental models) predominantly advocate for either rethinking existing or developing new processes as prerequisite for achieving system changing outcomes.

While the two perspectives are closely entangled, the disproportionate focus on parameters across the literature poses the risk of supporting long-term target setting or infrastructural decisions that are not systemic, thus falling short of acknowledging and interrogating the dominant worldview, values and paradigms underpinning them.

For example, Goh illustrates this in the case of Jakarta's approach to flood management, which has been based on studies that focused primarily on "biophysical indicators, methods and metrics of subsidence"(Goh, 2019, p. 251). However, in the process of developing and implementing adaptation measures, different worldviews clash: on the one hand, a positivist worldview regards "dynamic biophysical ecologies" as something that can be "tested objectively" and "actively intervened in" (Goh, 2019, p. 252); on the other hand, a constructivist worldview seeks to understand the underlying conditions and social values influencing uneven urban development processes. In the case of Jakarta, these lead to further marginalisation of the city's poorest inhabitants through the displacement resulted from the demolition of *kampung* settlements to make way for flood protection measures. As Goh argues, the solutions are "not necessarily infrastructural" as "*kampung* activists advocate for more participation in decision making" (Goh, 2019, p. 264).

This is one of many examples of conflicting worldviews, values and paradigms that shape urban interventions. It highlights the need to focus on processes as much as on outcomes and cautions against solely focusing on parameters while disregarding the feedback loops, system structure and mental models that are legitimised. Across the four concepts, advocating for and deciding where to intervene in the context of urban challenges, limited resources and imperfect information requires a process of understanding and negotiating trade-offs. Following Rittel & Webber (1973), when intervening in complex systems characterised by 'wicked' problems, there are no good or bad interventions, but better or worse ones.

5.2 Implications for future research

As our study has focused on the types of interventions advocated for in academic-led literature, future research is needed to contextualise this alongside the types of interventions advocated for by practitioners, as well as the types of interventions currently being implemented. This would help depict and analyse how and where different or even competing priorities occur. For example, a global review of current intervention priorities in urban governance depicts a mismatch between the top challenges as identified in academic literature (citizen participation, institutional shortcomings and government capability) and the responses of urban managers (insufficient public budgets, politicisation of local issues, interdependence of policy issues) (Cruz et al., 2019). Across the four conceptual domains there is a need to investigate academic – practice gaps to understand how they occur, as well as devise experimental research to explore how we might bridge them.

Secondly, future research across the four key concepts needs to engage with the methodological (as well as epistemological) implications of researching 'cities' as complex systems. Designing research from this stance means we need to devise appropriate methods for understanding complexity, interdependencies and trade-offs in urban change, as well as approaches for surfacing and interrogating dominant assumptions about how change happens. This bears consequences for us as researchers, as it requires us to interrogate our own roles and agency in influencing change through the research we undertake. Addressing this requires going beyond technocratic skills through cultivating reflexivity, effective communities of practice and new forms of organising for knowledge production.

5.3 Implications for the use of Leverage Points

Our paper hopes to add to an emerging body of work that applies Donella Meadows' Leverage Points as a framework to devise, monitor or understand interventions in complex systems. The Leverage Points can be seen as a "methodological boundary object" (Fischer & Riechers, 2019, p. 118) that can enable inter- and transdisciplinary research and collaboration. To do so, further research is required to test and extend the use of the framework beyond academic audiences, with urban practitioners and policy makers.

Although the language of the Leverage Points could lead to an assumption that 'pulling' specific levers could trigger change in others, causal inference in complex systems is a less straightforward endeavour. Therefore, further research is required to better understand the best use cases and limitations of using the Leverage Points as framework, as well as exploring the relationship between devising interventions and monitoring and evaluating their impact in complex systems.

5.4 Conclusions: towards systemic *and* system changing urban futures

We studied the types of interventions advocated for in academic-led literature across four key concepts that have emerged under the umbrella of urban-led change for sustainability: urban sustainability, urban transitions, urban transformation and urban resilience.

In our research, we responded to a gap in knowledge as to whether current urban studies are conducted from an understanding of change as both the process and outcome of intervening in complex systems. We deployed Donella Meadows' *Leverage Points: Places to Intervene in a System* (Meadows, 1999) as analytical framework to categorise the types of interventions being advocated for.

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7.0 Appendix

7.1 Reviewed literature

Focus of the paper	Citation
Urban sustainability	Childers et al., 2014; Koch et al., 2018; Martínez-Bravo et al., 2019; Vojnovic, 2014;
Urban resilience	Bahadur & Thornton, 2015; Béné et al., 2018; Brown et al., 2012; Chelleri, 2012; Chelleri et al., 2015; Coaffee & Clarke, 2015; Coaffee et al., 2018; Connolly, 2018; DeVerteuil & Golubchikov, 2016; Grabowski et al., 2019; Kaika, 2017; Leichenko, 2011; Masnavi et al., 2019; Meerow et al., 2016; Mehmood, 2016; Nunes et al., 2019; Pizzo, 2015; Rogov & Rozenblat, 2018; Sanchez et al., 2018; Sharifi et al., 2017; Tyler & Moench, 2012; Vale, 2014; Wang et al., 2018; X Sanchez et al., 2018;
Urban transitions	Bulkeley et al., 2016; Collier et al., 2013; Devolder & Block, 2015; Ehnert, Frantzeskaki, et al., 2018; Ehnert, Kern, et al., 2018; Ernstson et al., 2010; Fastenrath & Braun, 2018; Fragkias & Boone, 2016; Frantzeskaki et al., 2018; Frantzeskaki & Rok, 2018; Gorissen et al., 2018; Haldrup & Snallfot, 2014; Hodson et al., 2017; Nagorny-Koring & Nochta, 2018; Olazabal & Pascual, 2015; Schiller, 2016; von Wirth et al., 2019;
Urban transformation	De Flander & Brugmann, 2017; Ernst et al., 2016; Iwaniec et al., 2019; Krellenberg et al., 2016; McCormick et al., 2013; McPhearson et al., 2016; Moglia et al., 2018; Romero-Lankao et al., 2016; Salat, 2017; Wolfram et al., 2016; Zhang et al., 2018;
Multiple concepts	Ahern, 2011; Chappin & Ligtvoet, 2014; Collier et al., 2016; de Jong et al., 2015; Elmqvist et al., 2019; Mendizabal et al., 2018; Moloney & Horne, 2015; Pelling & Manuel-Navarrete, 2011; Romero-Lankao & Gnatz, 2013; Ryan, 2013; Siri, 2016; Zhang & Li, 2018

7.2 Mapping the literature on Meadows' Leverage Points

Leverage Points (Meadows, 1999)	Citations	Examples
12. Constants, parameters, numbers (such as subsidies, taxes, standards). Key words: constants, variable, parameter, percentage, incentive, target Number of initial codes from lexical search: 193 Number of final codes after qualitative exclusion: 54	(Ahern, 2011; Bahadur & Thornton, 2015; A. Brown et al., 2012; Bulkeley et al., 2016; Burch et al., 2016; Coaffee et al., 2018; Ehnert, Kern, et al., 2018; Ernstson et al., 2010; Fastenrath & Braun, 2018; Fragkias & Boone, 2016; Haldrup & Snallfot, 2014; Hodson et al., 2017; Kaika, 2017; Mendizabal et al., 2018; Moloney & Horne, 2015; Schiller, 2016; Tyler & Moench, 2012; Vojnovic, 2014; Zhang et al., 2018)	"Deliberative arenas such as these (nb. Water User Associations) are potentially potent in addressing broader social, ecological, and economic dynamics in the region, including incentives for development of a functional model for "payment for ecosystem services." (Ernstson et al., 2010)
11. The sizes of buffers and other stabilizing stocks, relative to their flows. Key words: buffers, stocks Number of initial codes from lexical search: 0 Number of final codes after qualitative exclusion: 0	n/a	n/a
10. The structure of material stocks and flows (such as transport networks, population, age structures).	Ahern, 2011; Béné et al., 2018; A. Brown et al., 2012; Bulkeley et al., 2016; Chelleri, 2012; Collier et al., 2013; De Flander & Brugmann, 2017; de Jong et al., 2015; Ernst	"Achieving a resilient sustainability will depend on significant innovations. In the 21st century, much of the infrastructure of the developed world will be replaced or rebuilt, and even more infrastructure will be needed to service the rapidly expanding cities of the developing

Key words: material stocks, material flows, infrastructure Number of initial codes from lexical search: 628 Number of final codes after qualitative exclusion: 42	et al., 2016; Gorissen et al., 2018; Hodson et al., 2017; Kaika, 2017; Koch et al., 2018; Krellenberg et al., 2016; Masnavi et al., 2019; McCormick et al., 2013; Mehmood, 2016; Moloney & Horne, 2015; Nagorny-Koring & Nochta, 2018; Ryan, 2013; Sanchez et al., 2018; Schiller, 2016; Sharifi et al., 2017; Tyler & Moench, 2012; von Wirth et al., 2019; Wolfram et al., 2016; Zhang et al., 2018)	world. Ironically, when viewed as an opportunity, the magnitude of global infrastructure (re)development represents an unprecedented opportunity to redirect and (re)conceive the process of urbanization from one that is inherently destructive to one that is sustainable and resilient in specific terms." (Ahern, 2011)
9. The lengths of delays, relative to the rate of system change. Key words: delays, pace of change, short-term, long-term, rate of change Number of initial codes from lexical search: 102 Number of final codes after qualitative exclusion: 36	(Béné et al., 2018; A. Brown et al., 2012; Coaffee et al., 2018; DeVerteuil & Golubchikov, 2016; Ehnert, Frantzeskaki, et al., 2018; Ehnert, Kern, et al., 2018; Frantzeskaki et al., 2018; Gorissen et al., 2018; Masnavi et al., 2019; Meerow et al., 2016; Mendizabal et al., 2018; Moloney & Horne, 2015; Nagorny-Koring & Nochta, 2018; Pizzo, 2015; Rogov & Rozenblat, 2018; Romero-Lankao et al., 2016; Sanchez et al., 2018; Sharifi et al., 2017; von Wirth et al., 2019)	"Thinking through 'resilience for when' entails deciding whether the focus is on short-term disruptions (i.e., storms) or long-term stressors (i.e., climate change) and translating the phrases "rapidly return" or "quickly transform" in the definition to a particular setting." (Meerow et al., 2016) "The extent to which these place-based and regional scale initiatives can or will drive broad scale urban regime change […is] constrained by short-term funding grants and the dynamic and unstable policy context that supports their work." (Moloney & Horne, 2015) "The Tis [nb. Transition initiatives] struggled especially with the so-called "projectification of funding" (Borgström et al., 2016), because short-term, project-based funding schemes created high uncertainty for them." (Ehnert, Kern, et al., 2018)
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against. Key words: negative feedback loops, rebound, preventative Number of initial codes from lexical search: 2 Number of final codes after qualitative exclusion: 2	(Coaffee et al., 2018; Schiller, 2016)	"Oliveira, Andrade, and Makse (2014) find super-linear scaling in US cities indicating increasing urban inefficiencies: doubling the population of US-cities results in an average increase of 146% in CO2 emissions, rather than the expected efficiency gains from economies of scale in infrastructure. Indeed, we seem to be witnessing strong rebound effects in US-cities." (Schiller, 2016)
7. The gain around driving positive feedback loops. Key words: self-reinforcing, positive feedback loop, perverse incentives, positive loop, success to the successful Number of initial codes from lexical search: 42 Number of final codes after qualitative exclusion: 15	(De Flander & Brugmann, 2017; Ehnert, Kern, et al., 2018; Ernstson et al., 2010; Iwaniec et al., 2019; Leichenko, 2011; McPhearson et al., 2016; Moglia et al., 2018; Nagorny-Koring & Nochta, 2018; Pelling & Manuel-Navarrete, 2011; Salat, 2017; Siri, 2016; von Wirth et al., 2019)	"*Additional work is needed in order to identify ways that efforts to promote urban resilience to climate change can take into account the unintended consequences of these actions, both across space and at different analytical scales, in order to ensure that these efforts do not reinforce existing inequalities or create new ones." (Leichenko, 2011)* "[…] it is argued that cities, if they can better anticipate pressures and their emerging unintended consequences, may be able to avoid unintended consequences (reactive transformation) if reorganisation occurs in an orderly rather than a reactive fashion (proactive transformation) and if they avoid maladaptation when they do respond." (Moglia et al., 2018)
6. The structure of information flows (who does and does not have access to information). Key words: information flows, access to information, access to	(Bulkeley et al., 2016; de Jong et al., 2015; Leichenko, 2011; McPhearson et al., 2016; Tyler & Moench, 2012)	"Households, enterprises, community organizations and other decision-making agents should have ready access to credible and meaningful information to enable judgments about risk and vulnerability, and to assess adaptation options." (Tyler & Moench, 2012) "Disaffected groups do not have ownership over their future visions and examples such as the

knowledge, transparency Number of initial codes from lexical search: 55 Number of final codes after qualitative exclusion: 6		#BlackLivesMatter movement, which has a focus on raising awareness of the lack of empowerment and capacity, underline the importance of participatory approaches and gathering 'bottom-up' inputs to create shared visions for transforming communities. There remains incredible opportunity to elicit and create consensus around shared visions, especially through participatory processes." (McPhearson et al., 2016)
5. The rules of the system Key words: rules of the system, system rules, change the rules, social norms, change the norms, normative Number of initial codes from lexical search: 155 Number of final codes after qualitative exclusion: 26	(Ahern, 2011; Bahadur & Thornton, 2015; Béné et al., 2018; Burch et al., 2016; Collier et al., 2016; Devolder & Block, 2015; Ehnert, Kern, et al., 2018; Ernst et al., 2016; Iwaniec et al., 2019; Koch et al., 2018; Krellenberg et al., 2016; Meerow et al., 2016; Moglia et al., 2018; Pizzo, 2015; Romero-Lankao et al., 2016; Tyler & Moench, 2012)	"Transitioning is a unidirectional process of mainstreaming sustainability within normative societal behaviour, which communities hope will build resilience, reduce our dependence on distant resources and lead to the transformation towards more sustainable living as an end product." (Collier et al., 2016) "We argue that strong urban debates on these initiatives and on urban sustainability are required to facilitate and stimulate urban systems towards a more socially just and environmentally sustainable future. When we say "urban debates" we mean substantive talks and detailed discussions about the type of cities we want to live in and about a shared understanding of sustainable urban projects and how they affect urban systems." (Devolder & Block, 2015)
4. The power to add, change, evolve, or self-organize system structure. Key words: new structures, new behaviours, forms of organising, autopoiesis, self-organisation, self-evolve Number of initial codes from lexical search: 110 Number of final codes after qualitative exclusion: 22	(Béné et al., 2018; Coaffee et al., 2018; DeVerteuil & Golubchikov, 2016; Ernstson et al., 2010; Frantzeskaki et al., 2018; Hodson et al., 2017; Krellenberg et al., 2016; Leichenko, 2011; Masnavi et al., 2019; Mehmood, 2016; Pelling & Manuel-Navarrete, 2011; Rogov & Rozenblat, 2018; Salat, 2017; Sanchez et al., 2018; Schiller, 2016; Sharifi et al., 2017; Zhang et al., 2018)	"This discursive shift to a participatory society results in a challenging deadlock: in areas where the level of self-organization among local communities is perceived as the lowest, the demand for self-organization to tackle multiple systemic problems becomes the highest (i.e., the more extensive and complex the challenges, the higher the demanded for self-organization and self-resolving capacities)." (Frantzeskaki et al., 2018)
3. The goals of the system. Key words: goals of the system, system purpose, system outcome, renewed goal, new goal Number of initial codes from lexical search: 0 Number of final codes after qualitative exclusion: 0	n/a	
2. The mindset or paradigm out of which the system — its goals, structure, rules, delays, parameters — arises. Key words: mindset change, paradigm change, mindset shift, assumptions, societal paradigm, beliefs, new paradigm Number of initial codes from lexical search: 45	(Béné et al., 2018; Chelleri, 2012; Gorissen et al., 2018; Kaika, 2017; Koch et al., 2018; Moglia et al., 2018)	"[…] shifting towards cleantech solutions and infrastructures will be a vital part of the transition, but these can only work if the social structures, social contracts and the value creation arrangements that surround them have co-evolved as well. This means that society needs to rethink the ideas upon which old systems were founded, the mental models encompassing assumptions, beliefs and values that keep the old system in place." (Gorissen et al., 2018)

Number of final codes after qualitative exclusion: 9	
1.The power to transcend paradigms. Key words: beyond paradigms, transcend paradigms, all models are wrong Number of initial codes from lexical search: 0 Number of final codes after qualitative exclusion: 0	n/a