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## Original Research Paper

# Planning roles in infrastructure system transitions: A review of research bridging socio-technical transitions and planning



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## ABSTRACT

Human settlements, particularly cities and their surrounding regions, are sites of infrastructural intensity and agglomeration, presenting challenges and opportunities for sustainable development. Both strategic spatial planning and sustainable transitions examine the interrelationships of urban, regional and infrastructural sustainability. Interdisciplinary interactions between planning and transitions in these contexts require further examination. This integrative literature review examines 30 journal articles with the aim of identifying the roles planning plays in sustainable infrastructure system transitions. Research examining local and regional infrastructure and urban transitions highlights the relational and contingent roles planning plays in place-based contexts. The review distils and discusses seven roles played by planning in sustainable transitions. Examining these roles provides insight into equipping planning, as a spatial and integrated policy process, for engaging with socio-technical transitions in complex policy processes.

## 1. Introduction

Human settlements are sites of infrastructural intensity and agglomeration presenting both challenges and opportunities for sustainable development and addressing climate change. These infrastructures and systems not only provide utility and services, they also influence social dynamics and practices. In many cities and regions, the development of infrastructure systems is guided by planning for strategic, sustainability and spatial direction in the medium to long term. Sustainable transitions research is examining prospects for reconfiguring infrastructure systems inclusive of institutional and socio-technical interdependencies. While urban (McCormick et al., 2013; Wittmayer et al., 2015), governance (Hodson et al., 2012; Smith et al., 2005; Tukker and Butter, 2007) and spatial contexts (Coenen et al., 2012; Hansen and Coenen, 2014; Truffer and Coenen, 2012) are a growing focus of sustainable transitions research, the interfaces and boundaries of strategic spatial planning and sustainable transitions have not been widely researched.

This integrative literature review examines 30 journal articles to identify the roles of metropolitan and regional scale strategic spatial planning in sustainable transitions with reference to infrastructure systems. This aim acknowledges that planning and transitions are not oppositional or exclusive, but fulfil differing relational roles within a policy mix for sustainable development at multiple spatial scales. The aim also acknowledges that the interface and bridging of urban planning and sustainable transitions is an emerging theoretical and research focus (Doyon et al., 2018; Malekpour et al., 2016) and that transitions methods offer spatial planning an approach to transformative and non-linear change (de Roo et al., 2012). Sustainable transitions are long-term processes of transformation predicated on radical structural, societal and systemic change that is ‘inherently sustainable’ and co-evolutionary (Loorbach and Shiroyama, 2016). Transitions occur through both incremental and multi-dimensional momentum including learning,

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experiment and system innovations that trigger whole-of-system evolution (Geels et al., 2004; Kemp and Loorbach, 2005; Smith et al., 2005). Where planning tends to affirm stability, spatial management and incremental precautionary change (Birkeland, 2008; Malekpour et al., 2015; Steele and Ruming, 2012), sustainable transitions steers towards windows of opportunity for radical socio-technical alternatives and innovation over time (Loorbach and Shiroyama, 2016). Urban and regional environments are complex and multi-scalar; planning is not only situated within these contexts, it also shapes them (de Roo et al., 2012). This article first introduces interrelationships between infrastructure systems, sustainable transitions and strategic spatial planning. The findings of the literature review are presented through discussion of seven roles identified for strategic spatial planning in infrastructure systems and sustainable transitions. The identification of these roles examines interactions between planning and transitions. They are instructive for identifying further research and cultivating reflexivity in planning as a long term spatial policy making process that is critical for developing socio-technical systems in tandem with human settlements.

## 2. Infrastructure systems at the interface of sustainable transitions and planning

Infrastructure systems support cities and regions by providing services and access to services. They shape those environments and are shaped by them in complex webs of meaning, socio-technical relations and power. Infrastructure systems are understood as socio-technological constructs that are woven into human lives, settlements and societies (Guy et al., 2012; McFarlane and Rutherford, 2008; Markard, 2011). In examining the interrelationship between infrastructure systems, socio-technological systems and infrastructure, Frantzeskaki and Loorbach (2010) define infrastructure systems, or infrasystems, as a type of socio-technological system or large technical system. Infrastructure systems are comprised of combined hardware and software, including material, institutional and social elements and relations. The hardware or material elements of the system are understood as infrastructure. Such large systems are agglomerations of cultural, social, technological and organisational infrastructures, investments and processes.

Urban and regional infrastructure systems – including energy, transport, communications and waste – enable settlements to function, and are comprised of resource and social flows. Their socio-ecological and spatial impacts accrue from materiality and construction practices combined with social practices, resources and technologies comprising the system (Hodson et al., 2012). Population centres, particularly cities, are sites of infrastructural intensity and access, in which sustainability can be undermined by poorly integrated, path dependent or locked in, and resource intensive infrastructure systems (Moss et al., 2001; Low et al., 2005). Urban and regional development patterns have co-evolved with infrastructural development historically (Dodson, 2009; Monstadt, 2009). As existing infrastructures, like roads and power stations, represent significant investments and are long-lived, decision-making can favour optimisation or modernisation rather than transition (Monstadt, 2009; Maassen, 2012; Moss et al., 2001).

Planning is a central policy response to sustainability challenges (Gleeson, 2003, 2012; Meadowcroft, 2000) that promotes spatial and infrastructural sustainability. Examining the planning relationship to sustainable transitions is relevant for understanding transition policy and governance dynamics in cities and regions. As a diverse field of theory and practice, it is a strategic and high-level policy for guiding decisions across levels of government, stakeholder interests, socio-technical systems and geographic scales (Counsell and Haughton, 2003; Searle and Bunker, 2010). Planning is one element of policy systems responding to technological development, often unable to achieve vision priorities (Hodson and Marvin, 2010). Theoretical developments in collaborative and communicative planning (Albrechts et al., 2003; Healey, 2007a) and complex adaptive systems and non-linear approaches (de Roo et al., 2012; Hillier, 2007) are not readily adopted in practice (Malekpour et al., 2015). Urban and regional planning tends to be a government-led policy process affirming sustainable development, ecological protection, settlement pattern and growth management, and infrastructure coordination (Albrechts, 2012; Davidson and Arman, 2014; Searle and Bunker, 2010). Propositions for renewed roles and aspirations for planning also emerge from research (Albrechts, 2008; Gleeson, 2012), implying learning and exploration in response to changing conditions rather than perpetuation of reactive and precautionary planning cultures (Birkeland, 2008; Malekpour et al., 2015).

Infrastructure systems are sites of political and policy contestation and convergence for both planning and sustainable transitions (McFarlane and Rutherford, 2008). Strategic spatial planning is embedded in the governance and policy systems that can reproduce unsustainable development patterns (Cowell and Owens, 2006; Loorbach and Shiroyama, 2016). Both strategic spatial planning and sustainable transitions adopt a long term outlook that is articulated in policy contexts to promote sustainable development. Both address infrastructure systems as large scale systems that are obdurate and resist change (Hodson et al., 2012; Monstadt, 2009). The introduction of transitions in policy mixes necessitates interrogating how planning and transitions are bridged for sustainable urban and regional futures, and how the transition dynamics of socio-technical systems are addressed. Examining the interface of sustainable transitions and planning and their convergence on infrastructure can enable greater reflexivity in planning and its role in infrastructure transitions (Grin et al., 2010).

## 3. Methodology

The examination of roles is constructivist and involves an interpretative approach examining how planning performs and is performed in transitions contexts (Bevir and Rhodes, 2010; Poulsen, 2007). Roles are negotiated, interpreted and acted out contextually, often for reproducing social structures and institutions. This integrative review undertakes a thematic analysis of articles examining infrastructure systems in planning and sustainable transitions. An integrative literature review is an appropriate approach as the topic is emerging and requires enhanced understanding (Torraco, 2005; Webster and Watson, 2002). A literature search of three databases, Scopus, Web of Science and Science Direct, identified articles that examined sustainable transitions and urban and regional planning focusing on infrastructure systems. Searches were conducted using the terms spatial planning, urban planning,

**Table 1**

Keywords and themes for coding of roles of planning in sustainable transitions.

Role	Keywords and concepts for interpretive coding
Legacy	History, stability, government, conventions, national, regional and local planning systems, incumbency
Obstacle	Hindrance, reactive, lagging, inertia, lock-in
Limitation	Insufficient, partial, hierarchical, disconnections, should/could
Management	Urban management, coordinating stakeholders, relation to governance, managerialism, incrementalism
Facilitation	Partner, collaborator, integration, vision, conflict, negotiation, relationship/s
Leverage Point	Political tool, intervention, knowledge creation, system relations
Opportunity	Strategic work, learning, reflexivity, windows of opportunity, experiment, niche

regional planning, socio-technical transition and sustainable transition in combination. A total of 225 documents, not accounting for duplicates, were found. The search results were refined using additional terms, specifically socio-technical systems and infrastructure, and terms associated with planning and sustainable transitions, such as scale, system innovation, regime and niche. This resulted in 30 papers for review, indicating that literature and research examining the relationship between planning and sustainable transitions is underway and that specific examination of the interface of planning and transitions is developing.

The articles were examined to identify the roles planning plays in sustainable transitions. This involved thematically coding and categorising areas or practices that examined, identified or proposed a role for planning in sustainable transitions initiatives (Saldana, 2009). The examination was a response to the question “what role is planning playing in relation to infrastructure systems and sustainable transitions?” The analysis resulted in a list of seven roles distilled from coded articles and grouped into categories based on key concepts and themes, reflecting role as indicating ‘what is done with planning’ and ‘how planning is done’ in infrastructure transitions (Flyvbjerg, 2004) (Table 1).

#### 4. Findings and discussion

The roles of planning in sustainable transitions are not static or singular, with planning playing multiple, often related, roles in differing contexts and over time. Seven roles were identified: legacy, obstacle, management, facilitation, leverage point, opportunity and limitation. These roles are not intended as a typology or as a spectrum, but as a means for demonstrating strategic spatial planning as a plural and differentiated policy and political practice that responds to and resists transitional pressures. The roles articulate how planning hinders and assists transitional dynamics, and provide insight into how projected changes in infrastructure systems can require alternative planning processes, problem solving and learning. The combined significance of these roles is that they move beyond a simple categorisation of hindering and assisting transitions by examining ‘how’ and by inflecting broader systemic or institutional tendencies as integral to the roles in context.

Many papers applied the multi-level perspective (MLP) to analyse urban and regional socio-technical dynamics and sustainable transitions. The MLP is an analytical framework for examining socio-technical systems and innovations across the three levels of landscape (exogenous pressures), regime (stable and mainstream systems) and niche (sites of radical innovation). Transitions, as radical changes in regimes, occur when exogenous landscape pressures destabilise the regime and create windows of opportunity for niche innovations to catalyse transitions (Geels and Schot, 2007; Rip and Kemp, 1998). Each of the planning roles identified includes consideration of multi-level dynamics, experiments and/or niche-regime dynamics. These framings are central to transitions analysis and understanding the role of planning in system reconfigurations.

##### 4.1. Legacy

Legacy acknowledges the historic and institutional dimensions of planning and policy in relation to socio-technical systems and in cities and regions. It also acknowledges that infrastructures and urban forms exert presence or obduracy in planning and policy. In decision and policy making, preference is given to established and existing investments through incremental gains to optimise, extend asset life or affirm the infrastructure regime rather than pursue radical system changes (Hernández-Palacio, 2017; Malekpour et al., 2015). Path dependent socio-technical regimes exclude the emergence of innovations and reconfigurations, such as teleworking (Hynes, 2016). Planning has adopted sustainable development precepts, such as sustainable transport, but these are not sufficient to build momentum for niche practices or address the legacy of unsustainable infrastructure systems (Geels, 2012). Planning, historically bound to a rationality paradigm, demonstrates cultural and historical inertia and planning processes fail to respond to mounting systemic pressures (Malekpour et al., 2015). In relation to low carbon urban experiments, Moloney and Horne (2015) find that planning priorities, such as development of carbon intensive infrastructure and spatial structure in the Australian context, are historically constructed and protected by planning and government. Development trajectories maintain entrenched paths concurrently with peripheral sustainability experiments that cannot displace the regime (Hernández-Palacio, 2017; Moloney and Horne, 2015). The legacy issues scale from planning discourse and practice to the lived materiality of cities and regions to reinforce lock-in.

Planning legacies also arise from critical junctures (Kingdon, 1995), as occurred in Freiburg, Germany, where the introduction of community and collaborative planning resulted in district scale integrated housing and energy efficiency. An earlier governance innovation or learning created alternative planning, organisational and infrastructure opportunities and pathways (Späth and Rohracher, 2015; Williams, 2016; Pineda and Jørgensen, 2016). The institutional and historic dimensions of planning influence the

success of experiments in the urban environment, particularly where new modes of governance emerge. The legacy of an alternative pathway opened other opportunities for planning, niche-regimes and transitions at the local level.

#### 4.2. Obstacle

Policy and spatial processes which are regime-bound can obstruct and resist sustainable transitions. Planners acknowledge the obstacles they face as indicative of institutional impediments and static development models (Filion et al., 2015). Incremental and hierarchical modes of planning, including planning instruments that are unchanged for decades, can inhibit sustainable development and sustainable transitions as well as infrastructure experiments and learning diffusion (Berkhout et al., 2010; Bai et al., 2010; Eames et al., 2013; Hernández-Palacio, 2017; Moloney and Horne, 2015). Institutional and incumbent resistance can also hinder urban innovation (Bai et al., 2010; Hernández-Palacio, 2017; Murphy, 2015) and development of integrated infrastructure strategies or retrofit programs to counter carbon and infrastructure lock-in (Malekpour et al., 2015). Planning presents institutional or regime barriers while negotiating fluid spatial and regime relations (Moloney and Horne, 2015; Hernández-Palacio, 2017; Berkhout et al., 2010). Disconnection between sustainability goals and conventional planning instruments can halt the momentum of niche projects which are contesting existing infrastructural relations.

#### 4.3. Limitation

Planning can impose and experience limitations in approaching sustainable transitions. Unlike obstacle, limitation implies threshold. In other roles where planning is found to support transitions, this is also expressed as limited and limiting. Those limitations can be the result of other contextual influences, although planning is involved in an iterative, incremental and historical relationship with its place and political context.

Four interrelated dimensions of limitation have been identified, raising considerations for experimentation or niche-regime interactions.

First, planning does not adequately address sustainable transitions and socio-technical systems challenges. In its current form, planning is not well equipped to anticipate and address changing technologies and their distribution (Spickermann et al., 2014; McPhearson et al., 2016). Rapid technological change can be problematic for planning given urban inertia, yet planning works with and in multi-segmented regimes where new technologies challenge socio-technical systems (Hynes, 2016; Næss and Vogel, 2012). Infrastructure systems can suffer from the regime effects of black boxing in planning (Hodson and Marvin, 2010; Moloney and Horne, 2015; Quitzau et al., 2012, 2013). Adil and Ko (2016) examine incorporation of decentralised energy systems finding planning unresponsive to their spatial and urban form and climate change mitigation implications. Despite policies for carbon emission reduction, new technologies and/or decentralised infrastructure systems, planning maintains existing regimes and infrastructure systems (Adil and Ko, 2016; Wächter et al., 2012) and promising sites of experimentation, such as special projects, can perpetuate 'non-transition' (Hernández-Palacio, 2017). In relation to teleworking, planning has reinforced path dependencies of work and transport regimes and marginalised teleworking as a matter for individual firms rather than infrastructural and spatial policy making (Hynes, 2016).

Second, a broad mix of policy instruments, including planning, applied in city and regional planning are not well integrated. Recent research indicates the importance of policy process and policy mix to sustainable transitions (Kern and Rogge, 2017; Kern et al., 2017; Rogge et al., 2017). Infrastructure systems require integrative problem solving and innovation as well as integrated planning and policy (Wächter et al., 2012; Pineda and Jørgensen, 2016). Radically different compositions of policy and organisation at multiple spatial scales are required to address spatial reorderings resulting from new technologies and transitions (Eames et al., 2013; Geels, 2012; Hernández-Palacio, 2017; Marletto, 2014; Moloney and Horne, 2015; Næss and Vogel, 2012; Spickermann et al., 2014; Switzer et al., 2013).

Third, planning is critiqued for its incremental, regime bound and path dependent tendencies (Eames et al., 2013; Geels, 2012; Hernández-Palacio, 2017), emphasising the need for innovation in planning and for meaningful connection between transitions and city-scale or regional policy-making (Eames et al., 2013; Quitzau et al., 2012; Pineda and Jørgensen, 2016). Planning plays a regime role particularly in supporting stability in uncertainty (Adil and Ko, 2016). The multi-segmented nature of urban regimes poses challenges for urban contexts as co-evolutionary processes account for systemic, multi-actor and multi-sector dynamics (Switzer et al., 2013). A static relationship between planning, policy and practice and path dependence cultivates incrementalism and the lack of an exploratory approach which inhibits sustainable infrastructure development (Malekpour et al., 2015; Truffer et al., 2010). Radical change in urban regimes has not resulted from the support of planning policy for sustainable development (Hernández-Palacio, 2017). Other parts of the planning system are targeted for regime destabilisation, including planner education (Switzer et al., 2013). These analyses advocate for alternative types of planning beyond current limits.

Fourth, many critiques of planning limitations include proposals for reflexive, exploratory, participatory and discursive tools, processes and paths. This would require change in planning processes and responsibilities as well as stakeholder relations (Adil and Ko, 2016; Malekpour et al., 2015; Truffer et al., 2010; Pineda and Jørgensen, 2016). Planning is revealed as often regime constrained, and unable to support radical change in its current iteration. Planning instruments have remained unchanged for several decades and reinforce regime rules (Eames et al., 2013; Hernández-Palacio, 2017), while the challenges of sustainable transitions and urban retrofit call for new approaches to land use and infrastructure. Malekpour et al. (2015, 74) propose that connections between planning and transitions require consideration of planning's incremental modality. Several papers test and introduce alternative and new tools and methods that address planning limitations. Some tools draw on established methods such as futuring, foresight,

visioning and backcasting (Marletto, 2014; Spickermann et al., 2014; Wächter et al., 2012), or involve tools designed for exploring relationships and problems to yield more solutions or opportunities. Truffer et al. (2010) trialled an exploratory foresight method and found that stakeholders assessed existing infrastructure configuration enhancements as less desirable than options addressing system alternatives, yet strategic planning practices tend to privilege existing configurations. While Turnheim et al. (2015) have not developed a new tool, they have examined existing tools to identify the attributes that new tools require in order to evaluate transitions pathways. The tools shape the reality and storylines in which actors deliberate and make decisions across disciplines. In introducing new tools, transitions research highlights the need for greater flexibility and exploration in policy and planning processes than is presently exercised.

#### 4.4. Management

Planning is embedded in the institutional frameworks of urban and regional management, through which urban resource, infrastructure and population needs are coordinated and integrated. Planning systems vary across jurisdictions, although globalised planning discourses that prioritise urbanism and environmental management through hierarchical and rational arrangements are prevalent (Birkeland, 2008). Over several decades, planning and planning culture have experienced shifts in practice from managerialist to entrepreneurial and strategic policy approaches; all approaches are evident in contemporary planning (Albrechts, 2012, 2006; Counsell and Haughton, 2006). Managerialism has also been shaped by market-oriented reforms and corporatisation in public management, such as economic rationalism and neo-liberalism. Planning can be bound to managerialist practices, in which controlled and blueprint-based incremental advances towards fixed futures and marketisation can inhibit sustainability (Birkeland, 2008; Malekpour et al., 2015; Kemp and Martens, 2007; Balducci et al., 2011). This is evident in the reviewed articles including in relation to shocks and system learning (Castán Broto and Dewberry, 2016). Comparative case studies of two Spanish towns reveal that where a dominant economic or management regime is not questioned and vested political and corporate interests preside, both innovation and resilience are inhibited (Castán Broto and Dewberry, 2016). A managerialist approach can affirm path dependence and limit reflexivity and social learning in addressing system change and sustainability goals, even as reforms for public participation and improved methods are introduced. India's Jawaharlal Nehru National Urban Renewal Mission is expanding and disseminating learnings about integrated planning, community engagement and project management through top-down regulatory and policy reform. Policy broadens innovations across socio-technical systems and levels of government for urban and infrastructural management; this reflects globalised planning paradigms and assimilative policy transfer, demonstrating managerial responses to uncertainty, but does not necessarily support regime change (Balducci et al., 2011; Roy, 2005).

Cities have political and policy authority to shape grassroots niches. In Seoul, South Korea, Wolfram (2016a) found a legacy of spatial and social segregation and inequality resulting from decades of top-down planning. Although Wolfram identifies potential for experiments to join up and scale across neighbourhoods, the experiments remained localised. The city is adapting the planning process, but these have not translated as policy or system change, suggesting that hierarchical planning is path dependent and unresponsive to radical transition pathways (Low and Astle, 2009). New modes of public management and governance are evident in communicative and collaborative forms of planning (Healey, 2007b). These are not necessarily indicative of transition management, which is a governance, guidance and implementation framework for sustainable transitions (Loorbach, 2010; Loorbach and Shiroyama, 2016), but may be indicative of emerging hybrid and networked governance and policy relations (Keast et al., 2006) or democratic response to plural interests (Osborne, 2006). Urban management predicated on planning is in flux with windows of opportunity opening for renegotiating planning cultures, practices and structures as new modes of governance and policy making emerge. The managerialism that has shaped planning cultures and organisations over several waves of reform may allow for regime fluidity, but does not readily enable reflexivity and regime change.

#### 4.5. Facilitation

Facilitation involves enabling and engaging diverse stakeholder, intermediary and policy interests to negotiate conflicts and collaboration and create vision. Planning is enacted in a strategic way reflecting movement from government to governance, from hierarchical to a relational modality, and from managing uncertainty to 'probing the future' or 'engaging in the development of the futures-to-come' (Pierre and Peters, 2005; Skelcher, 2012; Friedmann et al., 2004; de Roo et al., 2012). In their case studies of Spanish towns experiencing economic shocks, Castán Broto and Dewberry (2016) found that planning facilitated alternative uses for underutilised or abandoned infrastructures and spaces through multi-stakeholder problem-solving and social learning. In the case of Freiburg, Germany, a facilitative role developed through community and collaborative planning for energy (Späth and Rohracher, 2015). This role diverged from usual municipal processes which tended to affirm existing infrastructure configurations. A facilitative role is also demonstrated where planning enables protected spaces for socio-technical innovation. The cluster strategy, as an economic and innovation development strategy, has implications for planning in relation to policy mix, infrastructure and land use. A regional sustainable energy cluster in Massachusetts, USA can protect niches and connect between niche and regime dynamics so that new technologies can be addressed in regional and infrastructure planning and policy (McCauley and Stephens, 2012). Where a cluster is a new form of organisation or intermediary (Hodson and Marvin, 2010), planning facilitates a policy response within complex governance relations (Jessop, 2000; Sørensen and Torfing, 2016).

Planning both facilitates stakeholders and co-production, and the development of experiments and niches within planning. In Egedal, Denmark, planners were constrained by the planning framework in achieving desired energy targets yet exploited the planning process to integrate energy efficient technology in a development project (Quitzaau et al., 2012). This required an alternative

practice of and space for planning - niche planning - to achieve a change in planning culture and practice from passive to active. Niche planning affirmed the transformative potential of planning in addressing integrated infrastructure and land use in a special project. Without such strategic intervention or protection, experiments and innovations can flounder in urban contexts. Williams (2016) found that experiments have produced limited changes in the regime, such as more collaborative or integrative planning and new benchmarks, or catalysed similar initiatives. Planning can facilitate experiments, although these are not constitutive of regime change, potentially indicating regime resistance that inhibits momentum or system learning (Bosman et al., 2014). They can result in the development of niche-regimes where innovation in the regime occurs but the regime remains fundamentally unchanged. Diverse ways of enacting planning and purposively engaging with transitions are needed for this facilitative role to be transformative.

#### 4.6. Leverage point

The concept of leverage points (Abson et al., 2017; Meadows et al., 1972) has currency in sustainable transitions where “a small shift in one thing can produce big changes in everything” (Meadows, 1999). McCormick et al. (2013) propose that planning and governance are critical leverage points for transformative change in cities. This asserts new approaches to planning to support sustainable transitions including more effective strategic planning, integration of policy instruments and stakeholder collaboration.

Planning can be leveraged for innovation and sustainable development and this can involve performing and enacting planning differently, particularly by government and policy makers (Quitza et al., 2012). Bai et al.’s (2010) examination of innovative urban practices in Asia found that urban planning and policy play a central role in up-scaling and broadening sustainability practices. Local government, as an actor in socio-technical systems and governance, can use planning to support sustainability experiments (Bai et al., 2010; Castán Broto and Dewberry, 2016). The agency of government actors is also reflected in practices where planners leverage the planning process to introduce sustainable infrastructures in urban development (Quitza et al., 2012). While these reforms are not evidence of transitions, they may provide opportunities for transition orientation in planning and regulatory systems.

Changes in socio-technical systems may be indicative of reconfiguring and fluid regimes, niche-regimes or emergent and imminent pathways for more sustainable urban and infrastructure systems (Malekpour et al., 2015; Williams, 2016). In case studies of Trondheim, Norway (Hernández-Palacio, 2017) and the Copenhagen Metro, Denmark (Pineda and Jørgensen, 2016) adaptations of the planning process to create protected spaces enabled changes in infrastructure systems although did not translate into transition pathways. In these examples, governments and policy makers, including planners, can exercise discretion in asserting performing or conforming planning processes. Enactments of planning connected to changing modes of governance and organisation are better equipped for challenging and complex strategic planning and integrated infrastructure (McCormick et al., 2013).

#### 4.7. Opportunity

In sustainable transitions, windows of opportunity are necessary for catalysing transition pathways. Windows of opportunity are created through system and multi-level dynamics, particularly landscape pressures, which invite or necessitate innovation (Geels, 2002). These windows allow niche innovations to breakthrough and diffuse into a destabilising system. The opportunities presented by and for planning have resulted in demonstration projects, reconfigurations and adaptations arising from learning, evincing that planning is a field in which experiments can occur, but that policy windows or windows of opportunity also require other contextual and systemic politics and processes (Kingdon, 1995).

Planning has provided and responded to opportunities in three main ways.

First, planning provides and protects space for experiments and innovation, including reconfiguration of planning processes in infrastructure systems and other urban regimes (Kivimaa et al., 2017; Moloney and Horne, 2015; Pineda and Jørgensen, 2016). Wolfram (2016b) elaborates transformative capacity as a systemic property relating scale, power and agency, and this aligns to Quitza et al.’s (2012) formulation of ‘transformative strategic work’ which shaped niche planning through purposive crossover between planning and sustainable transitions. The ability to enable experiments does not scale to system change without other systemic relations including place-based and reflexive interactions (Moloney and Horne, 2015; Williams, 2016). Reflexive system realignment and building capacities, such as transformative capacity (Wolfram, 2016b), underpins strategic change in urban environments through leadership, learning and place-based conditions (Castán Broto and Dewberry, 2016; Quitza et al., 2012). While experiments have produced changes in the regime, such as collaborative or integrative planning, they do not always transform the regime (Kivimaa et al., 2017). Innovation in planning included processes of collaboration and exploration as well as the development of new planning frameworks. Opportunities for new ways of performing planning open but seem to remain as threshold or localised events that do not breakthrough, scale or broaden. This suggests the planning in its current form may be unlikely to flow with transitions pathways, despite other capacities for innovation.

The second area for opportunity arising from planning supports regime fluidity and system learning. As a regime actor, planning can focus on endogenous regime adjustments and other incumbent regime actors to maintain or change regime dynamics. Quitza et al. (2013) found that the Municipality of Egedal, as an incumbent regime actor, resisted the national planning regime through an alternative performance of planning and policy focusing on vision and targets. Greater transition orientation and actor resistance in planning, as endogenous challenges to the regime, achieved regime adjustments. In the urban context enacting planning otherwise enabled reorganisation of interconnected or multi-segmented infrastructural and spatial regimes. Continuing parallel investment in both sustainable and unsustainable land use and infrastructure systems is observed (Hernández-Palacio, 2017; Næss and Vogel, 2012). Normative sustainable development tropes, such as densification (Hernández-Palacio, 2017) and smart growth (Murphy, 2015), and their implications for integrated infrastructure systems are not commensurate with transitions. The result is regime

fluidity as many of the unsustainable and stable conditions of the regime, including infrastructure, are maintained (Berkhout et al., 2010).

Third, planning presents opportunities for and through a place-based approach to multi-scalar and multi-level relations. Planning is a policy field that enables learning and regime fluidity in relation to territorial, place-based and spatial policy and contexts. Murphy (2015) proposes planning as playing a role in learning about and improving place-based, multi-scalar and relational place-making processes for the development of transition strategies. Planning and regulation allow for diversity in the composition of the regimes and development in different parts of the multi-segmented regime. Næss and Vogel (2012) argue that more is achievable through the composition of existing multi-segmented regimes in places, understood as an ‘agreed mix’, as a long term process of shifting from one regime configuration to another. Planning can play a critical role in urban transitions with a long term perspective, learning and vision purposively aligned to transition opportunities and the contingencies of place.

## 5. Further research

The critical examination of the role of urban and regional planning in transitions has identified four areas for further research. First, the examination of roles has revealed the importance of planning histories and planning cultures in infrastructure transitions, and specifically experiments and niches, in places. If planning is to be conducive for sustainable transitions, particularly in infrastructure systems, further examinations of multi-level and spatial dynamics and conditions are required. Further research can elaborate culture, structures and practices of planning which engage with sustainable transitions, particularly through the spatial and relational dimensions of infrastructure systems.

Second, bridging strategic spatial planning and sustainable transitions offers scope for research examining the fuzziness and extensions of boundaries and interfaces. This includes enhanced development of a roles-based typology of planning drawn from transitions perspectives and methods. Research to interrogate planning assumptions and roles that undermine or inhibit transitions can redirect to system learning and policy innovation.

Third, this analysis has identified how new tools and practices support transitions in planning contexts. This indicates a need for developmental research in this field, particularly in enabling exploration and reflexivity in planning and policy making. Through such tools and practices, boundaries between research and practice can be bridged to enable planning practices that are immersed in and integrated with socio-technical transitions methods and pathways.

Finally, policy mixes and processes for sustainable transition require examination of the spatial, temporal and scalar implications of policy as well as how planning fits into these mixes. A developing body of literature exists about transitions and policy mixes is relevant to research about governance and politics in relation to infrastructure planning, emphasising consistency and coherence of the policy mix, promoting policy learning and applying a systems perspective for analysing policy mixes (Rogge and Reichardt, 2016; Kern and Rogge, 2017).

## 6. Conclusion

This integrative review has examined recent research to identify the roles played by strategic spatial planning in sustainable infrastructure transitions. This is important because planning can be a principal policy process and part of a policy mix guiding infrastructure system development, which can significantly shape the sustainability of cities and regions. Seven interrelated roles of planning were identified to express what planning does and what is being done with planning: legacy, obstacle, management, facilitation, leverage point, opportunity and limitation. These roles are useful for a more nuanced understanding how planning interacts with transitions as spatial processes unfolding over time. Planning is engaging with transitions perspectives, signalling that planning is being ‘transitionised’ (Wittmayer and Loorbach, 2016). The socio-technical transitions perspective affirms that new or alternative types of planning and planning systems are needed for infrastructure system transitions.

Despite indications that planning has enabled innovation, experiment and protected spaces, including alternative performances of planning, it imposes and experiences constraints in pursuing radical change in infrastructure systems. Having experienced significant shifts over the last century, planning remains limited by established incremental and managerial methods and reactive planning cultures indicative of regime constraints. Experiments and innovations have occurred, with some cases demonstrating regime fluidity and system learning in and with planning. When driven by sustainability visions and targets, practices of ‘doing something other with planning’ or ‘performing planning otherwise’ result in cultural and spatial shifts and negotiation. Planning theorists, such as Gleeson (2012), propose that planning has been successful at finding “new aspirations and rationales”. This searching requires reflexivity and exploration in planning and purposive engagement with sustainable transitions to address the uncertainties of systemic transformation in, and for, sustainable infrastructure systems and futures in cities and regions.

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