


Tools for Sustainable Change: How Spatial Decision-Support Tools Support Transformative Urban Regeneration

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ABSTRACT

This research focuses on the ability of spatial decision-support tools (SDST) to transform urban regeneration processes through collaborative planning between authorities and communities. This article presents what was learned from the implementation of two SDST within planning authorities in Aotearoa, New Zealand. The first tool, Envision, enables the identification of suitable areas for urban regeneration; the second, ESP, focuses on the environmental and socio-economic assessment of regeneration scenarios at the neighbourhood scale. We use empirical observations from the implementation of these SDST in diverse planning authorities, to analyse the influence of local specificities and appropriate collaboration models for the development and adoption of the tools for decision-making and community engagement. We provide recommendations for future development and implementation of SDST to reinforce collaborative planning and local governance within urban regeneration processes.

KEYWORDS

Spatial Decision-Support Tools, Urban Planning, Urban Regeneration

1. INTRODUCTION

The increasing need for climate change adaptation and urban sustainability has encouraged governments to review planning agendas and strategies focused on social, environmental and economic urban regeneration, while tackling local needs such as housing and transport (Baker, Peterson, Brown, & McAlpine, 2012; Siders, 2017). Current planning tools and processes need to be re-evaluated to assess their suitability to address urban planning shifts. The big global challenges that need to be considered add pressure to planning, policymaking, and decision-making (Aylett, 2014), which already face challenges in the form of complex and diverse priorities at multiple scales. In this context, we argue that sustainable change is necessary in planning, toward evidence-based, multi-scale, and collaborative urban regeneration addressing local planning needs, and simultaneously tackling global planning pressures.

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This research aims to examine whether, and if so how, spatial decision-support tools (SDST) can encourage sustainable changes in urban planning, by supporting collaborative planning. To achieve this, we discuss the implementation of two research based SDST in several planning authorities in New Zealand. The first tool, Envision, enables the identification of suitable areas for urban regeneration, while the second, Envision Scenario Planner (ESP), supports the environmental and socio-economic assessment of regeneration scenarios. This research examines the suitability of SDST and implementation methodologies to strengthen planning processes and outcomes, while recognising the relevance of local and global issues to achieve sustainable changes in urban planning. Empirical observations on planning stakeholders' engagement provide the basis for this. Finally, we provide recommendations for future development and implementation of SDST to reinforce collaborative planning and local governance within urban regeneration processes.

We start by reviewing relevant research and raise some key questions. Section 2 reviews the three bodies of literature that contribute to the theoretical framework: 1) Emergent urbanism asserting the importance of urban regeneration for sustainable change; 2) collaborative planning supporting the need for collaborative tools; and 3) socio-technical interactions explaining some of the challenges of implementing SDST in urban planning. Section 3 explains the research methodology, including the SDST, case study authorities and implementation methods. Section 4 presents the results and section 5 then discusses the research findings, providing recommendations for future SDST implementation and methodologies to encourage sustainable change in urban planning.

1.1. Research Background

Urban planning paradigms around the globe face a number of significant challenges addressing impacts of current global phenomena including: the increase of urban populations, and the effects of greenhouse gas emissions, climate change, acute social inequalities, food insecurity, and political, religious and ethnic tensions. In many cities, planning authorities are now being challenged to focus on the wellbeing of communities as an outcome of environmental, social and political tensions (Papa, Galderisi, Majello, & Saretta, 2015). Socially and environmentally sustainable urbanisation is yet to be achieved in heavily car-dependent societies with urban sprawl consuming peri-urban land, and ongoing socio-economic disparities amongst communities (Calthorpe, 2011). Homelessness, socio-economic vulnerabilities, deteriorating infrastructure, and public safety are some of the key challenges faced by planners globally, which have been exacerbated by climate change and related hazards in the past few decades (Elsheshtawy, 2004; Euchner & McGovern, 2004). Planning systems and processes have yet to address such arising challenges in a systematic manner (100RC Network, 2019).

In the context of the cities of Aotearoa New Zealand, the main planning challenges include increased housing demand and affordability, and the need to mitigate undesirable environmental consequences of suburbanisation such as the loss of fertile soils in peri-urban areas and CO₂ emissions (Howden-Chapman, Early, & Ombler, 2017). Some local governments have initiated debates with organisations and communities to plan for adaptation while addressing local planning priorities. For instance, Christchurch and Wellington City Councils (both members of the 100 Resilient Cities Network), are actively pursuing more resilient social, environmental, and physical outcomes. The complexity of such planning challenges is manifold due to population growth and poor housing quality and its impacts on communities' health and wellbeing (Early, Howden-Chapman, & Russell, 2015; Falconer, 2015). Most urban centres in New Zealand have experienced significant urban sprawl, ongoing car dependency and socio-spatial segregations; transitioning toward sustainable urban regeneration poses significant strains to current planning practices.

Despite such pressures, some planning stakeholders are sceptical about urban regeneration and intensification of mid-suburban areas, due not only to a scarcity of accessible evidence and but also a lack of best practice guidelines and exemplars. This can exacerbate the status quo 'business as usual' low density development. Alongside, there has been variable and generally limited investment in public transport in New Zealand, leaving suburban and peri-urban communities heavily dependent on

privately owned motorised vehicles, encouraging the proliferation of highways and shopping malls and subsequent socio-spatial enclaves of segregation (Early et al., 2015; Falconer, 2015; Howden-Chapman et al., 2017). Such outcomes have contributed to the marginalisation of groups who cannot afford to live near amenities or the mobility costs to relevant social infrastructure. Market-led approaches to urban development have been dominant in the past few decades; and private interests have often been privileged at the expense of the collective, public welfare (Grimes, Lutchman, & Robinson, 2015). Consequently, housing affordability and liveable neighbourhoods are particularly difficult to achieve in the New Zealand urban planning context.

Despite the complexity of these urban planning challenges, the implementation of suitable SDST in New Zealand's urban planning policy and practice receives relatively little attention. In some cases central government endorses some tools to support planning decision-making processes, but their suitability to encourage procedural change is debateable due to their strong alignment with the status quo (see Schindler & Dionisio, n.d.). Despite the existence of participatory mechanisms mandating local authorities to engage with communities, participatory planning in New Zealand is yet to advance beyond consultation (Menon & Gavin, 2006). Community engagement and public participation are often understood as important planning steps, but their critical role to strengthen outcomes through collaboration between planning stakeholders for the integration of local knowledge, and co-production processes, is yet to be fully understood.

1.2. Research Questions

Current planning challenges in New Zealand and globally, highlight the need for research on urban regeneration, collaborative planning and socio-technical interactions in the application of SDST, to foster sustainable change in urban planning while articulating the needs of local communities (Joseph, 2013). Our main research questions are:

1. How can SDST encourage sustainable change while supporting collaborative planning in urban regeneration?
2. How can SDST and their implementation support sustainable urban planning, while simultaneously recognising local planning needs and global issues?
3. What are the key recommendations for the development and implementation of SDST, aiming at sustainable changes in planning for urban regeneration?

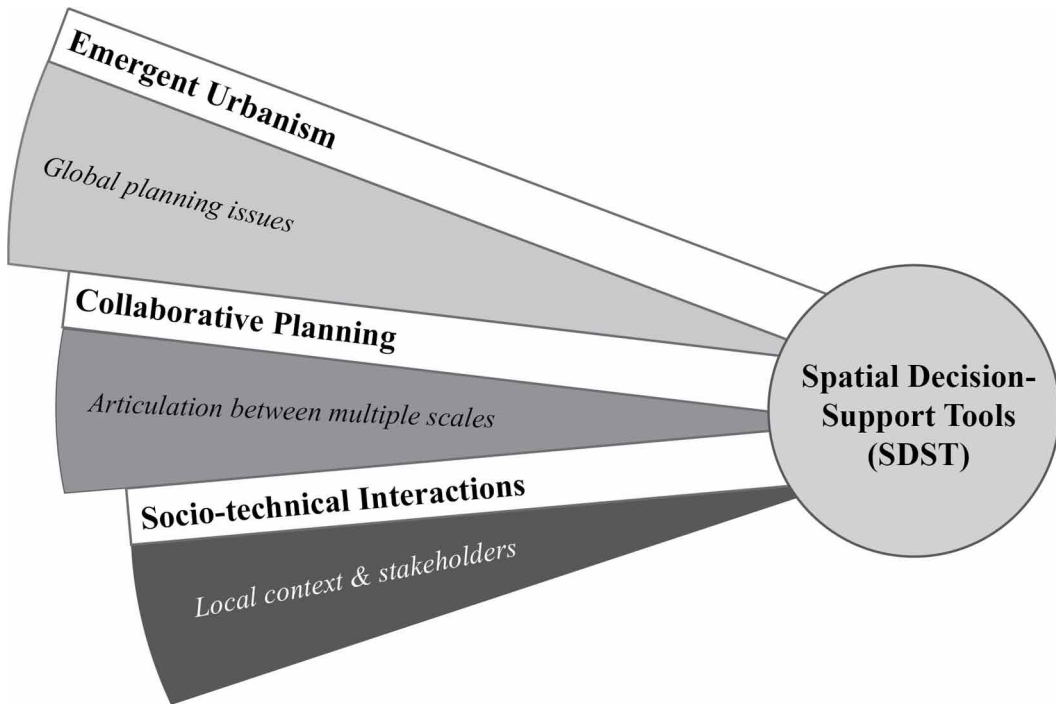
2. LITERATURE REVIEW

Three bodies of literature have informed this research and its theoretical framework (Figure 1). Emergent urbanism is the first body of literature, describing sustainable changes in urban planning while arguing for urban regeneration. This literature suggests that advanced planning outcomes require transformative planning methodologies. The second body focuses on collaborative planning, raising awareness of some shortfalls of participatory mechanisms in fostering collaboration between stakeholders. Finally, the third body focuses on socio-technical interactions, explaining the complexities of relationships between planners and SDST, raising awareness of the need for appropriate implementation of technological solutions. We propose a theoretical framework that links these three bodies of literature.

2.1. Emergent Urbanism: Paradigm Shift Toward Urban Regeneration

The influence of urbanisation on climate change and the need for transformative adaptation has been explored in urban studies, including some of the transnational challenges (Revi et al., 2014; Seto & Reenberg, 2014; Watts, Adger, & Agnolucci, 2015). The intense use of motorised vehicles is a major source of CO₂ emissions, exacerbating the greenhouse effect and contributing to global warming.

Figure 1. The relation between the reviewed bodies of literature and SDST



Industry and transport sectors remain heavily reliant on fossil fuels, stressing the urgency of urban environments to transition to renewal energy systems (Calthorpe, 2011; Newman & Kenworthy, 2015). Many planning systems in American and Australasian cities, however, continue to unwittingly encourage *Greenfield* development, which not only encourages motor vehicle use but also consumes peri-urban land that is crucial for environmental provision, regulation, recreation and natural ecosystems' support (Brandt, Tress, & Tress, 2000; Rouse & Bunster-Ossa, 2013). Addressing some of these issues, emergent urbanism focuses on effective solutions for adapting urban environments (Calthorpe, 2011). In complex urban systems literature, the need for multi-scale approaches has been recognised, with several frameworks supporting the articulation of global, national, regional and local priorities (Batty, 2013; Bettencourt, 2013; Webb et al., 2018) in order to holistically attain adaptation.

Urban regeneration offers the potential for improved sustainability, through interventions capable of meeting global, regional and local priorities (Bay & Lehmann, 2017) and understanding urban environments as complex systems. Joseph (2013) alludes to self-invention, frugality, and active citizenship as key adaptation capabilities to balance built and natural realms. Urban regeneration offers cities the opportunity to reinvent their socio-economic, cultural and physical conditions, while valuing urban land as a vital resource (Donnison, 1993; Hausner, 1993; Lichfield, 1992). Community engagement is also fundamental for urban regeneration (Roberts & Sykes, 2000), to ensure that local culture and identity are embedded in the transformation of neighbourhoods and cities (Zukin, 1995).

Newton et al. (2012) define greyfields as mid-suburban areas facing socio-economic and physical deterioration, offering opportunities for urban regeneration. The authors argue that local community needs, such as social infrastructure, should be addressed at the neighbourhood scale, while encouraging urban liveability through community engagement processes in regeneration (Newton, 2010; Newton et al., 2012). Trubka et al. (2010) examined the high costs of suburban growth, supporting transit-oriented development with evidence on costs and benefits of urban regeneration along mass transit investments (McIntosh, 2015).

Research on processes and tools aiming to facilitate sustainable urban regeneration has also been explored, including the development of SDST suitable for regeneration processes (see Dionisio, et al., 2016; Glackin et al., 2016; Kingham et al., 2016). The implementation of research-based SDST to support multiple-stakeholder engagement in urban regeneration has been the basis for the review of engagement methodologies in urban planning (see Glackin & Dionisio, 2016; and Dionisio & Kingham 2017).

Nevertheless, the suitability of planning tools and processes to address the intersection of global pressures and local planning needs, remains unexplored in current literature. Through the analysis of use cases, this research aims to contribute to this literature.

2.2. Participatory and Collaborative Planning: The Need for Collaborative Planning Tools

Public participation had its origin in the 1960s and 1970s, aiming to increase transparency and inclusiveness of planning processes (see Arnstein, 1969; Damer & Hague, 1971; Reynolds, 1969). Many urban planning systems have evolved to enable collaboration processes to support planning decisions (Bronwill & Carpenter, 2007; Laurian, 2009). The understanding that planning and policy are practical processes that should be accessible to public inquiry (Darke & Pocock, 1995; Fischer & Forester, 1993) encouraged the latter in their proposal for public participation debates to lead policy analysis and planning. Arguably, the role of planners should move from solely expert-led planning to engagement of communities in planning processes (Forester, 1999).

Aiming to articulate multiple perspectives in planning, consensus-building was introduced in the mid-1990s, with application guidelines (Innes, 1995, 1996; Innes & Booher, 2000, 2004). Consensus-building can support multiple parties to overcome divergences (see Margerum, 2011). In alternative to top-down decision-making, collaborative planning focusses on governance for urban transformation and management (Healey, 2003; Innes & Booher, 2000). In this advanced model, the basis for participation is to realise community engagement toward genuine forms of collaboration (Healey, 1998).

Collaborative planning includes methods such as co-design, co-creation, and collaborative platforms. In urban planning, co-design methods have been the most popular enabling stakeholders to develop connections during decision-making processes, which can benefit planning outcomes aiming at socio-economic inclusivity (Sanders & Stappers, 2014). Co-design can combine a wide range of non-expert and expert contributions, in which communities' contribution is recognised as relevant for improved outcomes. Collaborative planning methods have known advantages such as shared risk management, while developing learning processes (Crowe, Foley, & Collier, 2016; Somerville & Nino, 2007). The need for authentic engagement in urban planning has encouraged the adoption of co-design methods, such as charrettes, forums, and campaigns involving the public.

There have been a few studies focused on SDST to support collaborative planning in urban regeneration processes. Glackin and Dionisio (2016) discuss the implementation of co-design to facilitate community engagement in urban regeneration, while suggesting the need for authentic collaborative models between planning stakeholders, whereas Dionisio and Kingham (2017) propose an engagement framework aiming to support authorities to collaborate with other planning stakeholders.

Literature on collaborative planning provide an important basis for this research, supporting the need of collaborative methods to enable genuine partnerships in regeneration processes. This literature also raises awareness on the emergence of methods such as co-design, offering the opportunities for more inclusive, equitable, and transparent decisions in urban planning. However, there is still a need for research on the applications of SDST (Glackin & Dionisio, 2016), while examining the potential to articulate multi-scaled perspectives and priorities. This research aims to make a contribution in this gap.

2.3. The Influence of Socio-Technical Interactions on Urban Planning

Rational planning models have been extensively adapted in the past few decades. These models often include the delineation of objectives, evaluation of outcomes, and participatory mechanisms to incorporate communities' views in planning (Lane, 2005). These approaches have encouraged evidence-based practice in planning (Krizek et al., 2009) and complex system models with algorithmic, modelling, and predicting approaches (Batty, 2008; White, Uljee, & Engelen, 2012) which have extended the array of available evidence to support decision-making in urban planning.

Yet, there are challenges associated with the implementation of technologies into urban planning practices as the theory of socio-technical interactions explains (Clarke et al., 2006). Socio-technical interactions include the communication and exchange between planning end-users, and technologies such as planning support systems (PSS) and SDST. In urban planning practice, planners often use the same (S)DST to achieve diverse outcomes or use differently multiple tools to achieve common objectives. The interactions between planning stakeholders and SDST influence planning processes and outcomes (Vatrapu, 2009). For instance, SDST can support communication between planners adding technological inter-subjectivity to planning outcomes. Planners can control the data inputted to tools and might interpret results differently, adding user subjectivity to planning outcomes (Clarke et al., 2006; Vatrapu, 2009). Interactions between planners and technologies can enhance the connections among planning stakeholders, improving processes and outcomes, whereas solely expert-led planning approaches might hinder such connections.

Button (2006) stresses the importance of trust to mediate dependability interactions between technology users and computational systems in urban planning, while discussing the psychological, cultural, and organisational embeddedness of trust. Other research examines the relevance of standardisation to facilitate socio-technical interactions, influencing trust and dependability of technology (see Hardstone et al., 2006). Aiming to address some of these issues, engagement methodologies have focused on incorporating the views of end-users in the development of SDST and ground the relevance, consistency and applicability of planning tools within planning paradigms, while preventing potential misuses of tools (Reed, 2007; Uran & Janssen, 2003). Xu et al. (2018) support this by highlighting the relevance of trust and communication between teams developing SDST and planning end-users.

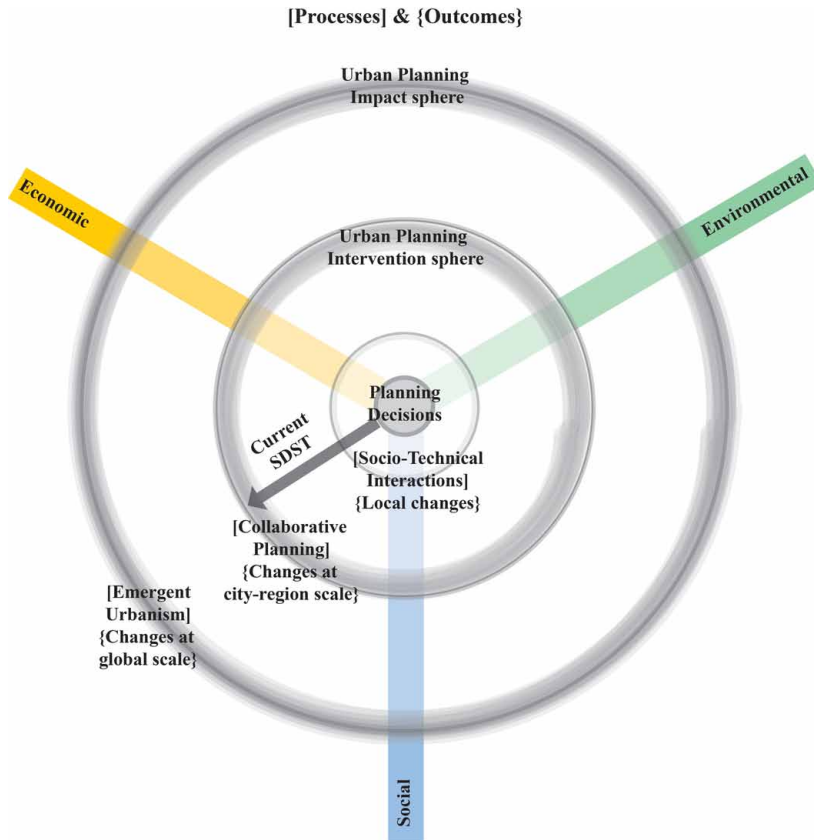
Few research studies on planning tools have critically connected with the socio-technical interactions literature (e.g. Vonk & Geertman, 2008; Vonk et al., 2005; Williamson & McFarland, 2015; Williamson & Parolin, 2012), exploring the relevance of local context within socio-technical systems to mediate the interactions between planning stakeholders and (S)DST (Schindler & Dionisio, n.d.). Although this literature raises awareness of the need for methodologies to overcome potential socio-technical subjectivities in the implementation of SDST, research focused on implementation methodologies to address local and global planning challenges remains scarce. It is in this gap that our paper is aiming to contribute.

2.4. Theoretical Framework

Based on this literature, we propose a theoretical framework positioning SDST relatively to planning processes and outcomes (Figure 2). We hypothesise that sustainable regeneration encompasses changes to planning outcomes and processes, through collaborative mechanisms, in which the interactions between planning stakeholders and SDST enable planning outcomes to reach the various scales and sectors within the planning impact sphere.

In planning processes, current SDST are mostly focused on the intervention sphere of urban planning (Figure 2, intermediate circle), while bridging socio-technical interactions between decision-makers and tools, and engagement between diverse planning stakeholders. Current tools are mostly sectorial, addressing either social, economic or environmental issues (intercutting lines). In contrast, we hypothesise that SDST which enable cross-sector collaboration will have greater potential to

Figure 2. Theoretical framework – Spheres of urban planning [processes], and {outcomes}



foster sustainable change. Such tools can encourage a cross-sectorial mediation to address potential socio-technical subjectivities and interconnect various scales. The articulation between local and global planning pressures requires multi-scaled, cross-sector collaborative planning processes, and the tools used to support such processes should reflect this.

In planning outcomes, the application of current SDST tools falls short in establishing multi-scale, cross-sector collaboration to interconnect local and global scales. This means that planning outcomes that only consider local needs, might soon become out-dated or inadequate, given the disconnect with the wider context of change. However, tools capable of fostering change, establish the connection between communities and global outcomes, through multi-scaled and inclusive planning processes. This framework provides a structure to analyse SDST, through the observation of processes and outcomes enhanced by the tools and their capacity to support sustainable changes in urban planning.

3. METHODOLOGY

The adopted methodology comprises three parts: i) two case study SDST focused on urban regeneration in the wider context of existing SDST (Section 3.1); ii) five case studies in New Zealand where the SDST were implemented to observe and assess the resulting planning outcomes (Section 3.2); and iii) partnership models adopted to implement the SDST in each case study (Section 3.3).

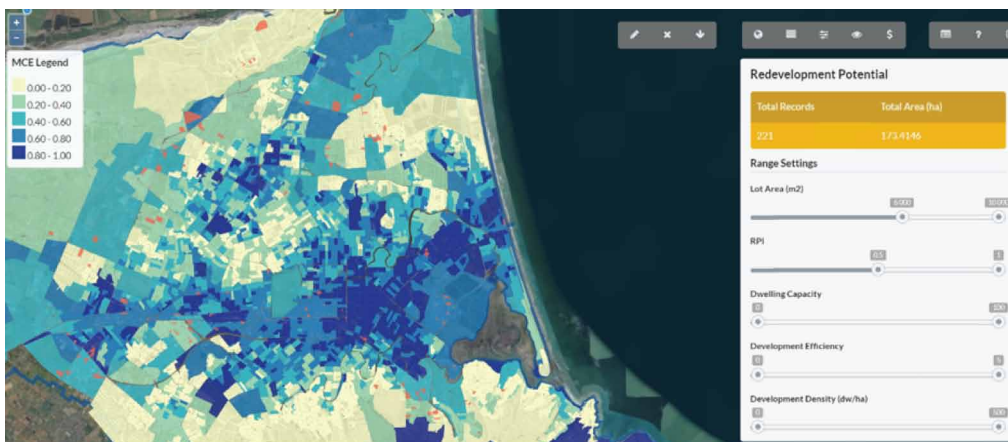
3.1. Case Study SDST

Planning tools in New Zealand are highly dependent on the current planning context, including the systems in which spatial data is generated and used, and the priorities of planning stakeholders. The spatial data ecosystem is fragmented, with diverse providers and stakeholders generating and using multi-levelled data without mandatory standards (Schindler et al., 2018). The most commonly used tools are either commercially sourced or endorsed by central government, and there are a limited number of planning tools incorporating local needs. For instance, the Development Feasibility Tool (DFT) is a tool endorsed by New Zealand's Ministry of Business, Innovation and Employment (MBIE), and is widely used within local governments. This non-spatial decision-support tool enables feasibility assessments of urban development based on estimated economic costs and benefits of new developments sourced from developers and consultancies. Other current planning tools often focus on sectorial approaches to planning decision-making; planning experts have detailed spatial datasets and complex models to assess urban development scenarios, while community engagement often involves post-its over maps. The articulation of diverse perspectives is difficult to attain while making it technically relevant for planners. Such gap was the basis for the emergence of Public Participatory Geographical Information Systems (PPGIS), which has been gradually adopted in planning authorities internationally, including New Zealand. Maptionnaire™ is a commercial PPGIS tool, aiming to enable collaborative planning, providing a platform for the visualisation of expert relevant data and diverse perspectives in urban planning (Kahila-Tani et al., 2019).

To address some of the limitations of current planning tools, two case study SDST (Envision and Envision Scenario Planner) were developed considering the Australian and New Zealand planning contexts (see Glackin et al., 2016; Newton et al., 2012). Later, the tools were revised to address the specific priorities of New Zealand planning stakeholders. Both aim to support socio-economic and environmental regeneration of mid-suburban areas and urban intensification for community development through collaborative planning (Dionisio et al., 2016; Newton et al., 2012).

Envision is a web-based tool, publicly available to planning authorities to engage with multiple stakeholders in the identification of areas suitable for urban regeneration. Envision aims to support planning stakeholders to define relevant urban and demographic factors for specific urban regeneration strategies. For instance, areas where young people live, near schools, medical centres, parks, supermarkets, bus routes and cycle lanes may be relevant for urban regeneration targeting housing affordability for young families. Planning stakeholders can collaborate to find where to regenerate in alignment with local planning strategies, priorities and community values (Figure 3).

Figure 3. Envision: Co-produced maps for the identification of areas with potential for regeneration (specific case of Tūmanako Centre, OHU)



Envision integrates a spatial dataset at cadastral scale, mostly built from publicly available data, and its interface targets a wide range of users including non-experts. The versatility of the tool aimed to support cross-sector engagement, between planning authorities, local communities, businesses, organisations and developers, to building consensus in engagement processes. Distances to key social amenities and urban infrastructure, several prediction redevelopment indicators, and demographic data have been integrated in the tool to enable multi-criteria analyses. The ability to exclude areas exposed to natural hazards (i.e. liquefaction, sea level rise, flooding, erosion and rock fall) from the results was particularly relevant for New Zealand planning stakeholders.

The second case study SDST, ESP (Envision Scenario Planner), is also a web based SDST, publicly and freely available in New Zealand. It was created for the assessment of regeneration scenarios through visualisation and impact assessments. With ESP, multiple planning stakeholders can build consensus on trade-offs of environmental, social and economic impacts, while targeting specific outcomes. It allows the subdivision and amalgamation of land parcels, and includes a library of building typologies, open spaces, and pathways. These are available in diverse building standards, enabling users to develop diverse regeneration scenarios. Data associated with these objects comprises construction costs, and environmental impacts such as embodied and sequestered CO₂, energy and water use and associated operational costs (Glackin et al., 2016), which can also be customised.

Social outcomes are also considered in ESP; for instance, residential typologies consider the number of residents and commercial and institutional typologies consider the prospective number of jobs created; ESP also calculates the average open space area per inhabitant. Generally, most social outcomes of urban regeneration are difficult to measure and compare across scenarios. Visualisation, however, increases ESP's capability to include non-experts in engagement processes, while detailed quantitative assessment reports increase planning experts' confidence in the tool. With the aim of increasing ESP's potential for collaborative planning, an interface was developed for the comparison of up to three regeneration scenarios for the same area, with visualisation and assessment reports (Glackin et al., 2016; Schindler & Dionisio, n.d.). With ESP, planning communities can collaborate to examine *how* to best regenerate neighbourhoods, considering local environmental and socio-economic priorities.

Both case study SDST, Envision and ESP, were developed and revised according to stakeholder feedback, enabling the incorporation of various perspectives across the components, interfaces, and algorithms of the tools. However, as research developed SDST they aim to align with current local needs, while contesting the status quo of urban planning. These SDST can enable and structure collaborative planning amongst multiple stakeholders, with a focus on consensus building and co-design scenarios. To examine their capacity to foster sustainable change, the two-case study SDST were implemented in the case study authorities.

3.2. Case Study Authorities

Aotearoa New Zealand offers some advantages to developing research focused on collaboration across the urban planning sector. Firstly, cities in New Zealand are currently undergoing significant change. About 72% of the population lives in urban centres (Statistics NZ, 2017), and substantial urbanisation is underway in major centres due to population increase. Secondly, the urban planning community is contained and stakeholders are familiar to each other's agendas and priorities, fostering an ideal environment for collaboration (Margerum, 2011). Additionally, New Zealand's institutional landscape embodies two constitutionally recognised cultural identities, representing indigenous and western perspectives, while forming a bicultural nation in which planning decision-making can benefit greatly from the cross-pollination between these two socio-cultural streams.

To cover the wider spectrum of planning agendas across the urban planning sector and to better understand how different contexts may influence the potential of tools to achieve sustainable change in planning, the case studies include two central government authorities, two local governments, and one grassroots organisation. Regenerate Christchurch¹ and Ōtākaro Limited² are central government

planning authorities with jurisdiction in Christchurch and have both been created to plan and implement the Christchurch rebuild after the 2010/11 Canterbury Earthquake sequence. Nelson City Council (NCC) and Christchurch City Council (CCC) are two local government authorities, which face distinct urban planning complexities, yet with similar challenges such as urban intensification and the need for socio-economic regeneration of inner-city areas. The Office for Holistic Urbanism (OHU) is a grassroots property development organisation, which engages with community groups in urban regeneration processes.

The research team partnered with planning teams in the five case study organisations to observe and assess the use of the two-case study SDST within current planning workflows and processes. These partnerships aimed to support the planning teams at the case studies to understand the SDST and incorporate them into current planning exercises, so that the research team could further observe the SDST's capacity to enhance sustainable changes in planning processes.

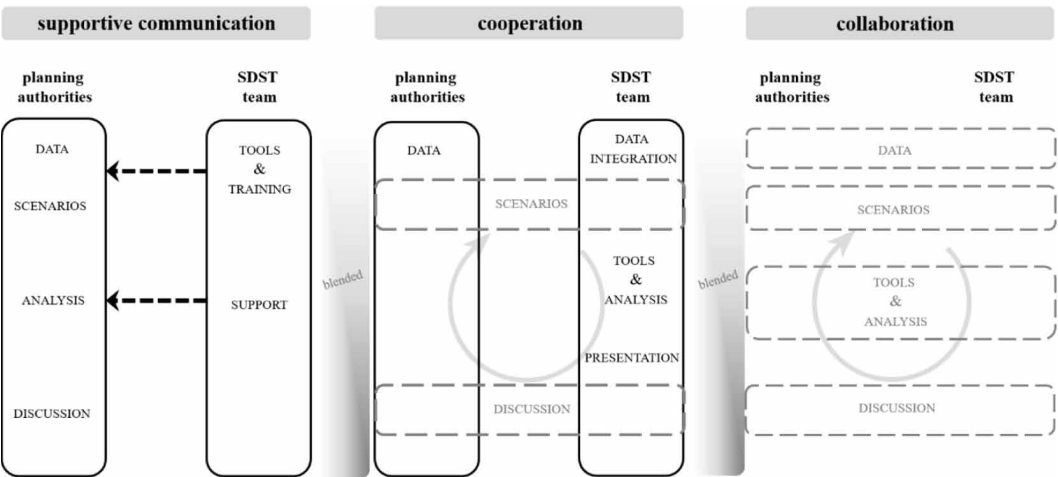
3.3. Partnership Models

To address the diverse needs of the stakeholders in each case study, three partnership models were used to implement the SDST and evaluate their capacity to foster sustainable change in planning. The partnership between the research team (who developed the SDST) and the users (i.e. case studies' planning stakeholders) took the form of 'supportive communication', 'cooperation', or 'collaboration' (Figure 4), and some blended versions of these models, depending on stakeholders' needs, expectations, organisational structure, as well as available time and staff resources at each case study organisation (Patel, Pettitt, & Wilson, 2011).

3.3.1. Supportive Communication Model

In the first partnership model, 'supportive communication' (Figure 4, left), training and support is provided to users when necessary. This scheme is suitable for planning authorities with well-defined criteria to develop regeneration scenarios, and limited resources for deeper forms of collaboration (Patel et al., 2011; Wilson, 2006). Stakeholders can develop knowledge about the SDST to meet their planning goals, guiding the definition and modelling of scenarios, while understanding the relevance of the inputs fed into the SDST. Stakeholders develop the know-how for future use of the SDST, while managing the allocation of time and resources. This model requires the least coordination, allowing users with flexibility to experiment with the SDST.

Figure 4. Partnership models adopted to implement the SDST in the case study authorities



3.3.2. Cooperation Model

The focus of the cooperation model (Figure 4, centre) is set on jointly discussing the regeneration scenarios and interpreting the outcomes. Like the supportive communication model, this model includes data preparation and integration into the SDST. Workshops are key to adapt the criteria of the regeneration strategies, scenarios and outcomes, leading to an iterative process. This model allows for debate on potential regeneration scenarios and their assessments can help tailoring the SDST to user needs. The main benefit of this model is the reduced need for technical resources, while stakeholders can have the opportunity to share insights with the research team (Voss & Bornemann, 2011; Weiseth, Munkvold, Tvedte, & Larsen, 2006) to improve the SDST. Stakeholders benefit from the insights of the SDST and can build the capacity to develop the functional and technical know-how for the implementation of the SDST. This model requires allocation of resources (time and staff) for implementation.

3.3.3. Collaboration Model

Collaboration mode (Figure 4, right) is the most interactive model, enabling rich conversations and learning environments. The research team and stakeholders collaborate throughout the implementation stages of the SDST, including engagement actions with communities and the wider public. This model is suitable to planning stakeholders who have the capacity to commit to a long-term integration of the SDST in their practices and knowledge transition (Patel et al., 2011). Planning stakeholders can use the SDST as a learning process to foster their understanding of underlying trade-offs. Collaboration equips stakeholders with the understanding of how to best implement the SDST to meet specific planning needs, while reflecting on current planning practices and processes, and potential ways to make sustainable changes.

4. RESULTS

Envision and ESP have been implemented in the case study authorities through partnership models adjusted to each authority's planning needs and priorities. The varied range of organisational, planning, and implementation contexts of the case studies provided the opportunity to examine the diverse conditions influencing the SDST's capacity to enhance sustainable changes. The following sections describe the case study authorities, outlining the aims for the implementation of Envision and/or ESP and the adopted partnership model(s). We examine changes in planning as structured by the theoretical framework (Figure 2).

4.1. Central Planning Authorities

The engagement with Regenerate Christchurch was initiated in January 2017, aiming to support the assessment of regeneration scenarios for the city centre, and assist a decision-making process with the local business community. A blended model of cooperation and collaboration was adopted for about twelve months, structuring the collaborative work between 3 members of the Regenerate Christchurch's Strategic and Planning team and the research team. The team manager endorsed the use of ESP given its suitability for the assessment of regeneration scenarios, and presentation of relevant evidence to engage with the local community in further planning stages. The collaborative partnership aimed to assess the environmental, social and economic impacts of three regeneration scenarios in comparison to the current situation: business as usual, green city, and compact city (Figure 5).

The evidence produced through ESP was presented at non-expert level to widen the potential for collaborative planning between Regenerate Christchurch and the local business community. The implementation of ESP supported a collaborative planning process, toward consensus building between the planning stakeholders. The compact city was the chosen scenario due to its beneficial

Figure 5. Comparative assessment of environmental impacts of three regeneration scenarios for Central Christchurch (BAU, Green City, and Compact City – versus the current situation)

	Current Situation	Business as Usual	Green City	Compact City
Total number of Buildings	43	77	70	83
Total Built Footprint area (sqm)	77,284.96	108,744.56	102,640.46	114,848.66
Total GFA	223,805.48	336,966.14	299,871.98	374,060.29
Total Operating Energy (MJ/yr)	1,436,383,570.64	2,162,648,669.88	1,739,052,174.14	2,034,247,478.79
Total Embodied Carbon (Kg CO ₂ -e)	78,331,918.00	117,938,148.09	104,955,193.00	130,921,103.19
Total Operating Carbon (Kg CO ₂ -e/yr)	367,075,762.93	552,676,824.40	454,408,378.57	539,584,633.34
Total Potable Water Use (kL/yr)	2,529,001.92	3,807,717.35	3,044,732.79	3,547,729.57
Total Water Demand (kL/yr)	2,529,001.92	3,807,717.35	3,388,553.37	4,226,881.33
Cost - Total Operating (\$/yr)	98,096,952.55	127,004,880.58	115,548,142.19	132,568,438.26
Permeability Areas (Public Open Spaces) (sqm)	2,190,208.04	2,081,463.48	2,164,852.54	2,152,644.34
Impervious surfaces (Public Open Spaces) (sqm)	98,184.96	206,929.52	123,540.46	135,748.66

environmental, social and economic impacts, while allowing for an increase of buildings and gross floor area (GFA) comparatively to the business as usual scenario.

Ōtākaro Limited focuses on the delivery of Anchor Projects⁶ with diverse services and social amenities. The supportive partnership with Ōtākaro Limited started in March 2018 to provide technical support for the application of the SDST. The main objective was to assist a small team of planners at Ōtākaro Limited in identifying areas in central Christchurch with regeneration potential for mixed uses and affordable housing, to further inform strategic planning. For this, the six month partnership focused on the implementation of Envision. This partnership was sustained with limited communication due to the unavailability of key Ōtākaro Limited staff. The outcomes achieved through the implementation of Envision were a number of workshops to produce maps aiming to inform strategic planning activities.

4.2. Local Planning Authorities

The engagement with Nelson City Council (NCC) started in February 2018 and aimed to assess diverse urban intensification scenarios to support the planning team in urban intensification processes. A cooperative partnership model was adopted for approximately eight months to implement ESP within the planning team. This was led by a champion planner, who had recently been appointed at the council, which led to some communication challenges with the wider planning team. For the outcomes, ESP enabled the visualisation and assessment of urban intensification scenarios to support planners in strategic planning activities focused on affordable housing across the city. In terms of processes, the implementation of ESP supported internal debates amongst planning and management teams with focus on the suitability of current planning tools endorsed by central government, such as the DFT, to support decision-making on sustainable urban intensification.

The engagement with Christchurch City Council (CCC) took diverse forms, to address diverse planning needs emerging during the partnership, which continued for two and a half years. Challenges arose throughout this partnership due to structural changes across the council, conditioning the communication and shifting the planning priorities. At first, the engagement was initiated in March 2016 with planners of the Urban Regeneration team to identify areas across the city with the potential for council-led urban regeneration, and to assess scenarios focused on affordable and social housing. For this, a collaborative partnership was adopted to jointly define the criteria to apply in ESP.

This collaborative partnership was championed by two planners and lasted six months, resulting in the definition of assessment criteria relevant to the Urban Regeneration team and the production of maps and assessment reports that supported a number of critical planning steps. In addition, these

maps were used by the Urban Regeneration team to raise awareness among councillors on council-led regeneration opportunities with focus on social housing and social infrastructure across the city. This internal debate amongst planners and decision-makers supported the wider engagement across the council for to the revision of the social housing strategy. In the assessment of regeneration scenarios for affordable and social housing, ESP supported the comparative assessment of two scenarios in Carey Street. The scenarios featured a BAU and a socially and environmentally efficient scenario, enabling the Urban Regeneration team to validate decisions before the design stage.

A second engagement with the CCC occurred in December 2017, with councillors and locally elected representatives. After several workshops, the CCC endorsed Envision and ESP for a specific strategic planning exercise. A cooperative partnership was adopted, in which the council's sustainability advisor worked closely with the research team for about six months to define a specific planning exercise, including the identification of suitable areas for affordable housing targeting young families in central Christchurch. This exercise included the visualisation and assessment of regeneration scenarios in an area identified through Envision (Figure 6). For the outcomes, the SDST enabled a planning exercise relevant for the council, increasing council decision-makers' awareness of regeneration opportunities focused on affordable housing in the city centre.

In terms of processes, councillors endorsed Envision and ESP amongst urban and strategic planning teams, resulting in another planning exercise with the strategic planning team. The cooperation with the strategic planning team aimed at assessing regeneration scenarios in a brownfield site in South Christchurch. Affordable housing and urban intensification were the strategies for this area, and the assessment aimed to enable the comparison of three scenarios with distinct urban densities (30, 50, and 100 dw/ha). After approximately six months of cooperation with one of the team's planners, ESP enabled a comparative visualisation and assessment of social, economic, and environmental impacts of the three regeneration scenarios (Figure 7). This planning exercise enabled the strategic planning team to engage with other teams across the council for broader strategic planning involving transport, infrastructure, and community development teams.

4.3. Grassroots Organisation

OHU is a grassroots organisation which works in collaboration with community groups in planning and co-designing urban regeneration. This engagement started in early 2018 and resulted in a collaborative partnership, aiming at the exploration of urban regeneration in Christchurch. In March 2018, OHU held a community workshop focused on the development of a wellbeing centre, the Tūmanako Centre,

Figure 6. Envision: Identification of urban areas with regeneration potential focused on young families in central Christchurch (left); ESP: visualisation and assessment of a mix-use scenario with social amenities relevant to young families in a selected area, CCC, 2018



Figure 7. Visualisation of three regeneration scenarios with distinct urban densities in South Christchurch, (left: 30 dw/ha with no provision of social amenities, centre: 50dw/ha with essential social amenities; 100 dw/ha with diverse social amenities)



where Envision supported the identification of urban areas responsive to criteria relevant to the community. The outcomes of the collaboration were the co-production of several maps with and for the community partners (Figure 3). The implementation of Envision enhanced OHU’s collaborative planning capability by integrating the perspectives of the community in the co-definition of criteria for the identification of regeneration areas, and by fostering participation in decision-making.

4.4. Summary of Results

The following summary table of results highlights the changes achieved in each case study. With Regenerate Christchurch and OHU, the planning processes enhanced collaborative planning with outcomes at multiple scales. Conversely, in the cases studies where the implementation of the SDST faced limited collaborative capacity within the authorities, the planning processes supported by the

Table 1. Summary of results: Planning processes and planning outcomes achieved with the support of the SDST in each case study

Case studies	Planning [Processes]	Planning {Outcomes}
1. Regenerate Christchurch	[Collaborative planning]: Regenerate Christchurch and local business community shared decision-making on urban regeneration scenarios.	{City scale addressing local planning priorities and global planning issues}: ESP enabled the assessment of three urban regeneration scenarios for central Christchurch, presenting evidence at non-expert level.
2. Ōtākaro Ltd	[Socio-technical]: Ōtākaro Limited used the outcomes to inform further strategic planning activities.	{City scale addressing local planning priorities}: Envision supported the identification of areas with potential for regeneration focused on mixed uses and affordable housing.
3. Nelson City Council	[Socio-technical]: The outcomes supported internal debates on the unsuitability of current DST (i.e. DFT) to assist local planning authorities in promoting sustainable urban intensification.	{City scale addressing local planning priorities and global planning issue}: ESP enabled the visualisation and assessment of urban intensification scenarios focused on affordable housing.
4. Christchurch City Council	[Collaborative planning]: The outcomes supported planners to raise councillors’ awareness on regeneration opportunities, allowed planners to validate decisions, and to engage with other teams across council for further strategic planning.	{City scale addressing local planning priorities and regional planning issues}: Envision enabled the identification of urban areas in diverse exercises, mostly focused on affordable and social housing, and opportunities for council-led regeneration. ESP supported the visualisation and assessment of regeneration scenarios focused on affordable and social housing.
5. Office of Holistic Urbanism	[Collaborative planning]: Collaboration between OHU and the community in the definition of criteria relevant for the development of the centre.	{Local scale addressing regional planning needs and global issues}: Envision enabled the identification of urban areas suitable for the development of a wellbeing centre.

tools only achieved the socio-technical scale, and planning outcomes ranged from local to city scale. This suggests that planning processes are key for SDST to enable sustainable change in urban planning.

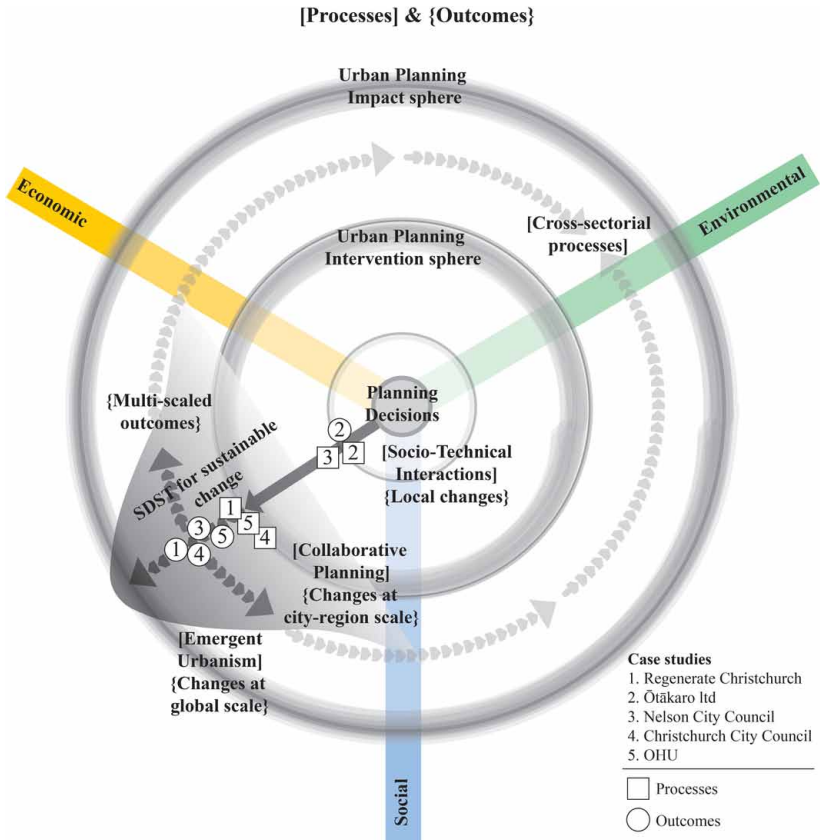
5. DISCUSSION

The case studies highlight that various collaborative partnership models to implement SDST can enhance planning authorities' ability to promote cross-sectorial, cross-scale and locally sensitive approaches to urban regeneration. This ability to transform planning processes has a positive impact on fostering sustainable change, as seen in the cases of Regenerate Christchurch and OHU, in which planners used the SDST to share decision-making with local communities. The case of CCC has also enabled planners to initiate intra-organisational, bottom-up processes raising political awareness on regeneration opportunities. Comparatively, the challenges faced in other case studies (Ōtākaro Ltd and NCC), highlight that supportive and cooperative partnerships to implement SDST have less impact on fostering sustainable change, since cross-sectorial processes and cross-scale outcomes were not equally enhanced.

We aimed to investigate how SDST can support sustainable change in urban regeneration. This research suggests that collaborative partnership models to implement SDST influenced the processes and outcomes, and the planning authorities' capacity to foster change comparatively to the current status quo in urban regeneration. Figure 8 illustrates the processes and outcomes achieved through the implementation of the SDST in each case study authority. For instance, in the case of Regenerate Christchurch, where ESP was endorsed by the team manager and adopted by planners to support engagement with the local business community, it was possible to enhance collaborative planning processes and achieve locally relevant planning outcomes, while addressing global planning issues such as climate change adaptation (see Figure 8:[1]). The first engagement phase with the CCC (collaborative partnership) also showed that SDST can support transformative planning processes, by enabling planners to take leadership in local regeneration opportunities to engage councilors. Such processes were enabled by the use of SDST and the collaborative partnerships guiding their implementation (Figure 8: [4]). Conversely, in planning authorities with constraints for collaboration, the implementation of the SDST had limitations in supporting sustainable changes in urban regeneration. The example of Ōtākaro Limited, NCC, and later CCC, with partnership models ranging from supportive to cooperative, demonstrated that when applied within the current planning status quo, SDST have a limited capacity to enhance transformative processes and outcomes. The ability of SDST to support sustainable change in urban regeneration is therefore influenced by the models adopted to implement the SDST, which have shown to shape the planning authorities' capacity to enhance collaborative planning processes with other planning stakeholders. As response to the first research question – how can SDST encourage sustainable change while supporting collaborative planning in urban regeneration? - Collaborative planning enhanced by local governance guiding the transformation of planning processes seems to be a central piece of the sustainability puzzle.

In response to the second research question – how can SDST and their implementation support sustainable urban planning processes and outcomes, while recognising local planning needs and global issues? - the findings show that the extent to which SDST can encourage sustainable changes is related to the planners' enhanced capacity to share decision-making with other stakeholders, and to initiate processes to raise decision-makers' awareness on urban regeneration opportunities. The cases of Regenerate Christchurch and OHU show that sustainable planning changes can be achieved using SDST to enhance collaborative planning. Both cases used the SDST to mediate engagement with local communities, achieving planning outcomes which simultaneously address local planning needs and global planning issues. This suggests that SDST can encourage sustainable changes through the enhancement of cross-sector processes and cross-scale outcomes, in alignment with current research arguing that sustainable change is achievable by, firstly, responding to local needs, while simultaneously tackling wider scales of planning through cross-scale and cross-sector regenerative

Figure 8. Theoretical framework – Situating the implementation of the case study SDST in each of the 5 case study planning authorities, within the spheres of urban planning [processes], and [outcomes]



intervention (Mang & Reed, 2012). The ability of the SDST to strengthen regenerative planning is influenced by the adopted partnership models and their capacity to respond dynamically to specific organisational structures and local priorities of planning authorities. For sustainable change to be holistically achieved, local context must be appropriately integrated in SDST as discussed by Schindler et al. (2020), ensuring that specific needs and paradigms are addressed, while recognising the specificities of organisational cultures. This finding suggests that locally sensitive supply - demand approaches must be considered in the development, implementation and assessment of SDST to ensure the enhancement of planning processes and outcomes toward sustainable change. This implies that local governance approaches may be valuable in mediating the supply and demand of SDST and their implementation.

Addressing the third research question - the development and implementation of SDST aiming at sustainable changes in planning for urban regeneration - should focus on cross-sectorial, intra and inter-organisational collaborative partnerships to enable transformative processes supporting the integration of local contexts in the development of SDST. Planning authorities should, therefore, recognise the importance of developing and implementing SDST as part of collaborative planning processes, to ensure that such processes are interconnected with local governance structures. Locally sensitive supply-demand approaches to develop and implement SDST should also be recognised as a potential way to enhance collaborative planning, due to its capacity to influence sustainable change (considering both processes and outcomes). Further research needs to be developed to

enhance planning stakeholders' awareness of the need to integrate local governance on SDST development and implementation processes as key pathway toward locally-sensitive sustainable change. Additionally, the development and implementation of future SDST should also consider multiple planning needs and capacities across authorities, including expert and non-expert end-users, and across diverse planning stages. To ensure the adaptability of SDST across diverse planning stages and for multiple end-users, co-design and collaboration are fundamental both in the development and implementation of such SDST.

6. CONCLUSION

This research focused on the implementation of SDST among urban planning authorities and analysed the influence of collaboration models on enhancing the capacity of the tools to support sustainable changes in planning processes and outcomes. Overall, the case study SDST and the cross-sectorial approach used – which included planning teams at central government, local government and grass-roots levels – have shown that SDST can be used to enhance political awareness on urban regeneration opportunities and increase collaborative capacity. This contribution is relevant for scholarly knowledge, highlighting that SDST play an important role in interconnecting local governance and collaborative planning through cross-sectorial collaborative partnership models.

However, this research does have a few limitations. Firstly, feedback from the case study authorities could help contextualising the research findings, which was not possible to obtain due to significant personnel changes in the planning teams. Future research might expand the analysis by integrating end-user feedback on the SDST and their capacity to foster changes in planning processes and outcomes. Secondly, it focused on both the development and implementation of the SDST, with distinct engagement in the development stage across the case study authorities. This design enabled a closer involvement of some of the authorities in the development stages of Envision and ESP (CCC and Regenerate Christchurch), allowing for active feedback to inform the reiteration of the tools. However, these circumstances may have influenced the adoption of the tools because the research team was trusted in these planning authorities more than others, such as Ōtākaro Limited and NCC. Thirdly, the development, implementation and assessment of the SDST has been developed by the same researchers, raising the potential for positionality biases. Finally, the case study authorities present distinct capacity levels to engage with research and to develop partnership models for the implementation of SDST. In some case study authorities, urban planners face increasing institutional pressures to achieve specific outcomes, meaning that their workloads allow limited opportunities to engage with experimental initiatives such as research developed SDST. Future research should deepen the understanding of the influence of political, institutional and organisational factors in the adoption of SDST and their resulting capacity to enhance sustainable change in urban planning.

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ENDNOTES

¹ <https://www.regeneratechristchurch.nz/>

² <https://www.otakaroltd.co.nz/>

³ <http://www.nelson.govt.nz/>

⁴ <https://www.ccc.govt.nz/>

⁵ <https://ohu.nz/>

⁶ Anchor Projects were defined in the Central Christchurch Recovery Plan (adopted in 2012) to lead to a more compact and deliberately structured central city.

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