EFFECTUAL URBAN GOVERNANCE:

THE EFFECTUATION OF CITIES FOR SYSTEMS CHANGE UNDER UNCERTAINTY

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Thesis submitted in fulfilment of the requirement for the degree of Doctor of Philosophy

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Abstract

Three key drivers create the imperative for a new approach to urban governance. Firstly, scientists around the world agree that global ecological systems are at risk of collapse if current development trajectories continue. Secondly, decision-makers are facing a heightened level of uncertainty, due to factors including climate risk, ecosystem changes and geopolitical tensions – and since 2020, the COVID-19 global pandemic. And thirdly, given these complexities, current models of forecasting and prediction for strategic decision-making are increasingly constrained and unreliable, particularly for informing urban infrastructure governance decisions with multi-decade legacies.

While urban infrastructure decision-makers find uncertainty challenging, for entrepreneurs uncertainty is the basis for opportunity. Entrepreneurs are agents of systems change, especially under conditions of heightened uncertainty. As a result, this thesis turns to the entrepreneurship domain to inform a new approach to urban governance, specifically the entrepreneurial decision-making logic of 'effectuation' developed by Saras Sarasvathy through her study of expert entrepreneurs' approaches to new venture creation.

Effectual urban governance includes establishing design principles, beginning with available means, establishing partnerships, and taking effectual action to iteratively increasing the structuration of innovations. In Part 1 - the thesis develops this model by reviewing and synthesizing the literature on sustainability transitions, urban governance, and entrepreneurship, with a historical analysis illustrating the role of entrepreneurship in industrial systems change. Building on a novel taxonomy of urban governance along the axes of uncertainty and systems change, the dynamic model of effectual urban governance combines entrepreneurship theory with sustainability transitions theory and is demonstrated through an illustrative civil infrastructure case study of the Willunga Basin Water Company informed by semi-structured research interviews.

Part 2 of the thesis justifies the applicability of this model through focus on four key elements of effectual urban governance with application to urban transport, elaborating the theoretical rationale for each element and providing insights from effectuation literature and supporting complementary academic theories and research conducted during this thesis. In doing so, the thesis makes theoretical and practical contributions to urban governance and the development of civil infrastructure in the 21st century.

At a time of heightened uncertainty, when global industrial and economic transformation to avert ecological collapse is imperative, this thesis begins a new conversation by demonstrating how adopting an entrepreneurial approach to civil infrastructure development can help government and civil actors proactively address the world's shared and complex challenges. Effectual urban governance is this approach.

Statement of Originality

I, Daniel James Conley, certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Signed: Date: March 31, 2023

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PART 1

CHAPTER 1

INTRODUCTION

1.1 CONTEXT

This thesis responds to three global challenges that have made their presence felt more strongly since the beginning of 2020 than at any other time in history. Firstly, the overwhelming majority of scientists around the world agree that global ecological systems are at risk of collapse if current development trajectories continue. This has stark implications for the natural world, global economic prosperity and societal wellbeing (Meadows et al., 1972; Bruntland Comission, 1987; Stern, 2006; Smith, Hargroves & Desha, 2010; Stern, 2015). This requires systemic industrial transformation – or what the sustainability transitions literature refers to as 'systems change' (Geels, 2002; McCormick et al., 2013; Trencher et al., 2014). Secondly, due to changing global ecosystems and geopolitical tensions, and with compounded intensity during the COVID-19 pandemic – decision-makers face heightened levels of uncertainty (Curry and Webster, 2011; IPCC, 2012; Mehta et al., 2019; Smales, 2021; Szczygielski et al., 2022). Strategic decision-making based on current models of forecasting and prediction involves much more risk in a world where the future is uncertain and conditions can change rapidly, and as such the planning literature is placing increasing emphasis on uncertainty and its impacts and implications (Albrechts 2010; Bertonili 2010; Van Woerkum et al. 2011; De Roo, Rauws 2012; Batty, 2013; Salet et al. 2013). Thirdly, effectively responding to the imperative for systems change in a time of heightened uncertainty requires collaborative governance approaches that bring stakeholders together, i.e. public/government, private and community to collaboratively solve society's complex challenges (Linnenluecke et al., 2017; May and Marvin, 2017).

These three global challenges establish the wider context for this thesis which responds to:

1. An imperative for systems change towards sustainable development;
2. A continuing heightened level of uncertainty; and
3. A need for transformative governance approaches.

1.1.1 An Imperative for Systems Change

For decades, it has been recognised that current global development trajectories are 'unsustainable' – risking the collapse of both ecological systems and economic systems of production, consumption and distribution, while destabilising institutions and risking future prosperity and quality of life (Meadows et al., 1972; Bruntland Comission, 1987).

However, today the world is approaching breaking point. Never has humanity faced such an imperative for systems change. As of 2022, 194 member states to the United Nations Framework Convention on Climate Change had ratified the Paris Climate Agreement, in clear recognition that addressing human-induced climate change is essential over the coming decades, and that failure to do so threatens not only environmental systems but the economy and society (Stern, 2006; 2015; Smith, Hargroves & Desha,

2010). However, the vast majority of countries are not on track to achieve the objectives that were set out in the Paris Agreement due to significant path dependency that exists from decades of economic growth underpinned by fossil fuels, with the national commitments themselves being broadly insufficient to reduce global greenhouse gas emissions by 50 percent by 2030 (Universal Ecological Fund, 2019). Figure 1-1 below shows the projected emissions trajectory associated with current national policies. It clearly identifies the increases in emissions since 1990 and depicts the steep reductions needed in emissions to keep climate change to within 2 degrees Celsius, and preferably lower than 1.5 degrees Celsius.

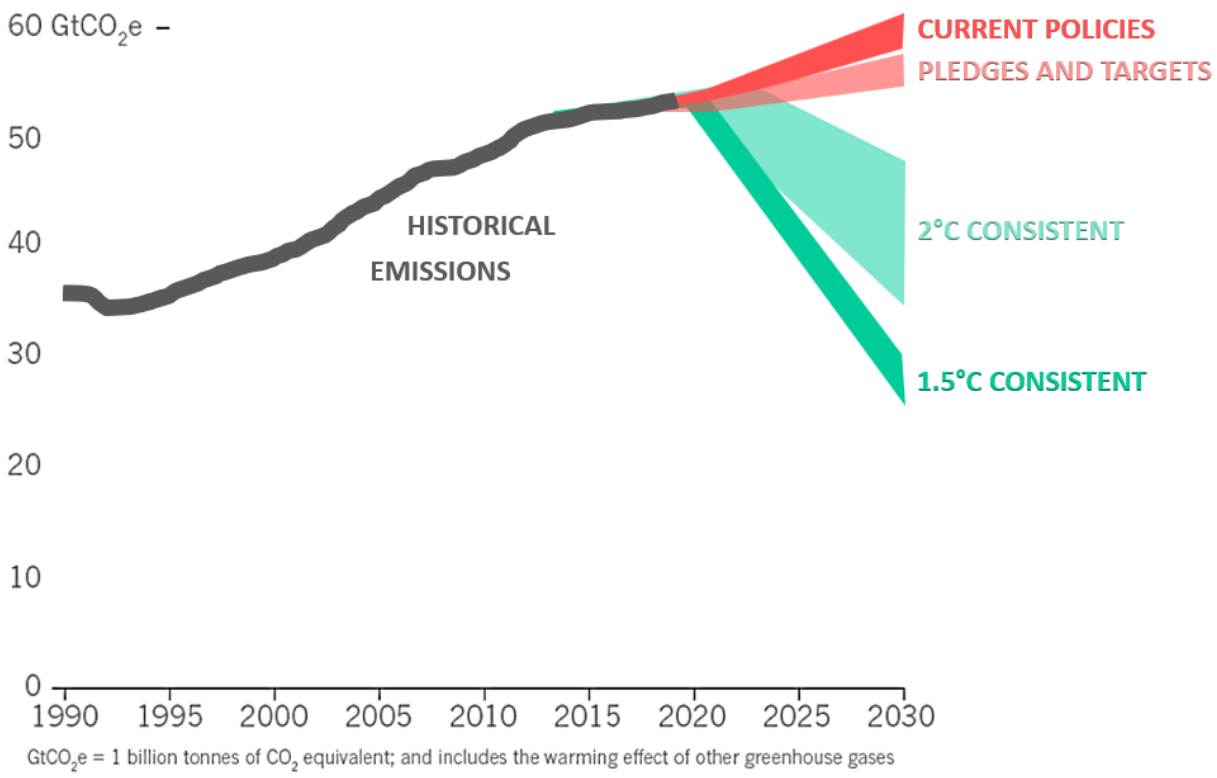


Figure 1-1: Current greenhouse gas emissions trajectories (Climate Action Tracker, 2019)

The fossil-based energy sources that have industrialised many parts of the world have contributed to an increased quality of life for billions of people. However, the science relating to climate change is clear and practically unanimous, with inaction threatening to undermine the economic progress and prosperity that has been achieved. In 2017, United Nations Framework Convention on Climate Change (UNFCCC) Executive Secretary Christiana Figueres and colleagues urged the world that if global emissions do not begin to decrease by 2020, the Paris Climate Agreement becomes almost unattainable (Figueres et al, 2017).

More broadly, achieving the United Nations Sustainable Development Goals (UN SDGs) will require transformation across industry and society (McCormick et al., 2013; Gaziulusoy et al., 2016, Voytenko

et al., 2016). The UN SDGs are 17 shared goals adopted by all United Nations member states in 2015, encompassing objectives relating to social, environmental and economic prosperity (United Nations, 2022). This transformation requires new technologies, new institutions, new social norms and new governance approaches (Geels, 2005). Such an undertaking is not straightforward and achieving this profound industrial and societal transformation will require creative, robust and audacious strategies at levels of government, industry, education and society (McCormick et al., 2013; Trencher et al., 2014). Such expansive transformation requires innovations that are 'directed to redesigning entire systems of practices and provisions, instead of individual products or processes' (Sterrenberg et al., 2013). Cities, as resource-intensive, built-environments are centres of transformation among these systems.

Cities are at the frontier of climate mitigation efforts given the built environment sector is the primary contributor to global greenhouse gas emissions. The world's cities comprise approximately 75 per cent of global primary energy use and 50-60 per cent of global greenhouse gas emissions (United Nations Human Settlements Programme, 2023). Between 2000 and 2030, the amount of urban land area is expected to triple to accommodate two-thirds of the predicted 9.7 billion people living on this planet by 2050 (Seto et al, 2012; United Nations, 2014; 2015). Cities therefore need to transform their systems to avoid ecological collapse and simultaneously respond to infrastructure challenges created by massive trends of population growth and urbanisation.

The cost of investing in infrastructure is vast. One estimate posits USD $57 trillion will be required to satisfy the basic needs of an increasingly urbanised population between 2013 and 2030; this is more than the entire value of global infrastructure in 2013 (McKinsey, 2013). In emerging economies throughout Asia, Africa and South America , the global 'Infrastructure Gap' between current investment amounts and the investment required to meet global needs is estimated to grow by over USD $1 trillion each year, as shown in Figure 1-2 below (OECD, 2015). This amount of investment cannot be met by governments alone, and as a result, governments and city authorities around the world are turning to the private sector to facilitate more private investment into public infrastructure through public-private partnerships (PPPs) (Marx 2019; Sergi et al., 2019). Governance is therefore no longer the responsibility of governments alone (Lambin et al., 2018).

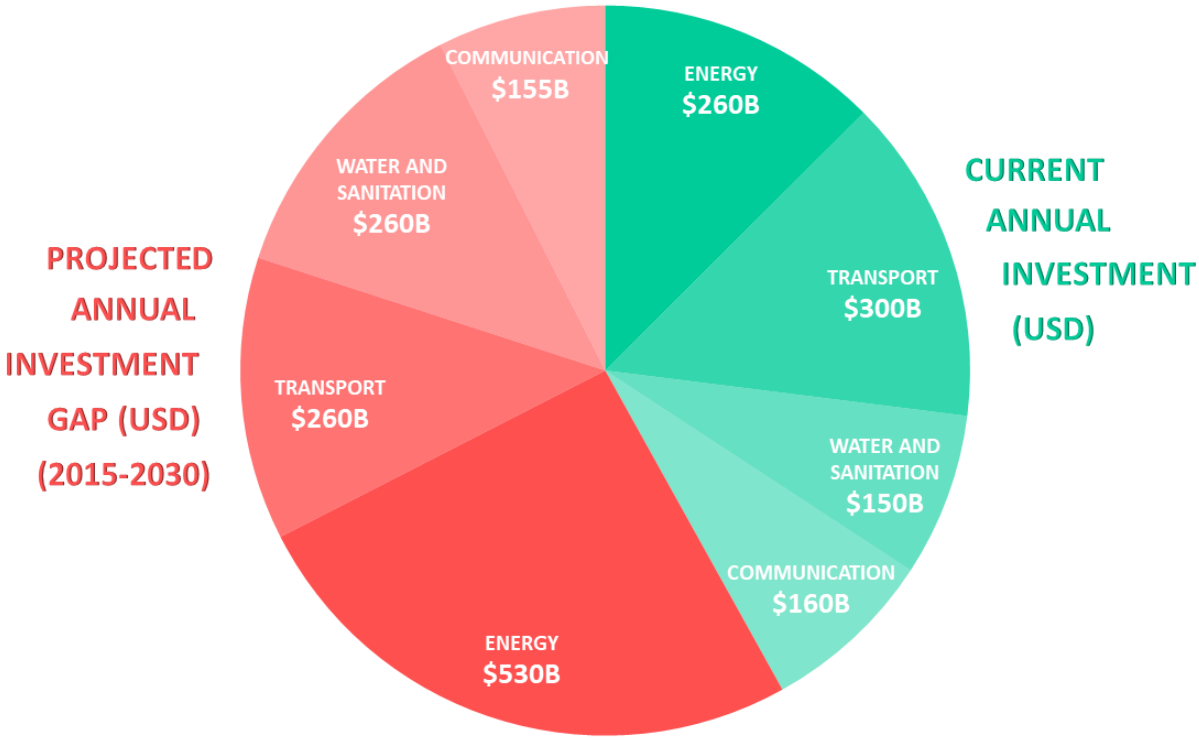


Figure 1-2: Infrastructure finance in developing countries and projected investment gaps (Organisation for Economic Co-Operation and Development (OECD), 2015)

Due to the complexity and interdependencies among urban stakeholders, governance requires operating with permeable boundaries between organisations in the public and private sectors (Stoker, 1995; Stoker, 1996). As a result, urban governance can no longer be understood as a 'top down' or 'command and control' model, as was prominent until the late half of the 20th Century (Healey et al., 1995).

Kearns and Paddison (2000) describe governance in an urban context as the following:

"Governance is about the capacity to get things done in the face of complexity, conflict and social change: organisations, notably but not only urban governments, empower themselves by blending their resources, skills and purposes with others. The capacity to get things done no longer lies (if it ever did) with government power and authority in one place."

Providing adequate infrastructure to meet the needs of growing populations is increasingly important if cities are to align their development trajectories with the Sustainable Development Goals. Transitions towards sustainability require both social and technical (or 'socio-technical') change, which has historically been observed to occur over the course of decades (Geels, 2002). Infrastructure decisions based on historical data using current models and projections come with increasing risk – as these models have entrenched unsustainable socio-technical characteristics (Jones, 2016). Continuing to

make decisions to invest in urban infrastructure using these outdated approaches further risks perpetuating a future where environmental and social issues are exacerbated.

1.1.2 A Heightened Level of Uncertainty

In 2020, the COVID-19 global pandemic shook the world and introduced a greater level of uncertainty about the future. For example, in Australia, levels of business confidence were lower than the 2008 global financial crisis and the early 1990s recession (see Figure 1-3 below). In times of such significant uncertainty, prediction and forecasting based on past conditions becomes less reliable as a basis for planning decisions.

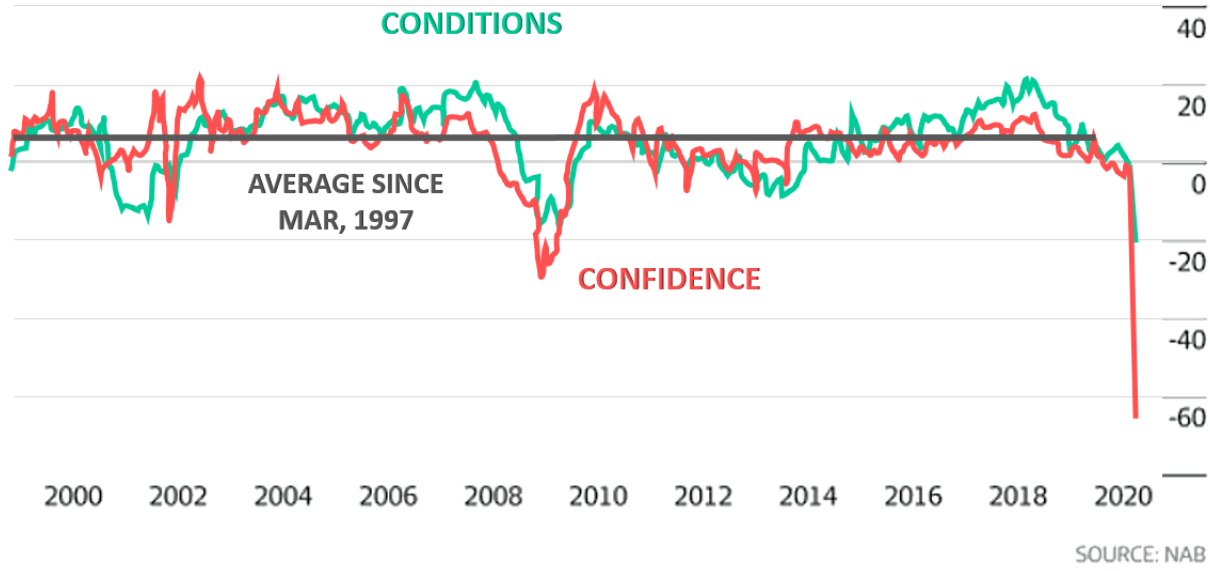


Figure 1-3: NAB Business Survey Confidence and Conditions, (Source: NAB Confidence Index)

Reminiscent of 'wartime urgency' responses, COVID-19 demanded the capacity to respond to crises in shorter timeframes than we thought possible at a systemic level.

"Before, we thought that change was long term and couldn't happen quickly. COVID-19 has short circuited that thinking. Now, we realise that systemic change can happen rapidly."

– Sandrine Dixon-Decleve, Co-President of the Club of Rome.

As occurred during the pandemic, governments and authorities, including urban decision makers and planners, are increasingly required to act in the face of uncertainty. However conventional planning and governance approaches tend to rely on prediction, stability and risk reduction; they are historically less receptive and responsive to uncertainty (Abbott, 2005; Albrechts 2010; Gunn & Hillier, 2014; Albrechts

& Balducci 2013; Rauws et al., 2014). This suggests that new transformative and collaborative approaches are required to more effectively plan for and respond to present and future challenges.

1.1.3 The Need for Transformative Governance Approaches

The need to induce systems change in short timeframes and amid increasing levels of uncertainty calls for 'transformation' rather than 'transition'. In their paper assessing Australia's progress towards achieving the SDG's using a detailed scenario-based modelling approach, as published in Nature Sustainability, Allen et al (2019) state:

"A focus on economic growth, social inclusion or green economy in isolation foregoes opportunities for greater gains. However, future uncertainty and cascading risks could undermine progress, and closing the gap to 100% SDG achievement will be very challenging. This will require a shift from 'transition' to 'transformation'."

– Allen et al (2019).

'Transformation' is used to describe whole-of-system change which can be global, national or local (Folke et al., 2010; Brand, 2014). While transition describes the long-term dynamic processes that can occur to achieve a sustainable society over time (Geels, 2002), transformation describes a more radical shift from the present to a future state (Allen et al., 2019). Arguably, new approaches that produce transformative outcomes are required rather than 'transitionary' approaches that play out over long periods of time.

New, flexible forms of governance are needed to align collective institutions through collaboration (Folke et al., 2002; Linnenluecke et al., 2017). In the public transport sector, the International Association for Public Transport (UITP) strongly emphasises the need to improve attention to passenger needs, as well as improve the efficiency of operations (Vuchic, 2014). Governance must also respond to the pressing challenges of the 21st Century – such as addressing the infrastructure gap while responding to climate change - which creates the context and imperative for such change. Urban infrastructure investments have long-lasting legacies, meaning decision-making can be contested – an example in the transport sector is whether to invest in high-capacity public transit, which in turn facilitates growth patterns reflecting greater density and mixed use; or invest in more highways to serve private vehicles, which facilitates greater urban sprawl. In both cases, governments look to attract private finance to address the current infrastructure gap.

Key questions therefore arise. For governments and urban stakeholders they include: How do governments tap into private investment to address the significant shortage of public funds for urban infrastructure? How can investment in infrastructure with lifespans of multiple decades be 'future-

proofed' when the future is so unpredictable and changing so rapidly? How do urban stakeholders come together to select and evaluate projects when competing interests are at odds with one another? How can decision makers find clarity in the face of complexity, particularly when user preferences and human habits are continually shifting? And recognising the dynamic nature of contemporary society, how can new technologies and processes aligned to sustainability be not only tested, but embedded and scaled across economies to accelerate sustainability? How can the 'public good' be preserved – so that projects and initiatives achieve optimal outcomes for the communities they seek to serve?

These questions underpin this research. Combining several research methods and multiple theoretical frameworks from multi-disciplinary research fields, this thesis presents a new framework for urban governance that responds to these challenges.

1.1.4 The Potential of the Effectual Urban Governance Model

The world is complex and the future is uncertain. This research proposes effectual urban governance as a new governance model that has the potential to firstly, provide new insights for urban participants across different sectors of society and the economy, and secondly, enable them to more effectively work together to solve our shared complex challenges. Drawing on the entrepreneurial decision-making logic of effectuation (Sarasvathy, 2009), effectual urban governance is posited as an approach that enables diverse stakeholders to co-create solutions. Inspired by the entrepreneurial new venture creation process, this thesis demonstrates the potential of this urban governance model, thereby moving the decision-making logic applied by entrepreneurs beyond the entrepreneurial domain. Part 1 of this thesis develops the underpinning theoretical insights that informed the development of the effectual urban governance model. Part 2 then demonstrates the principles and processes of applying the effectual urban governance model and demonstrates how some elements are already visible in urban systems; despite this approach not being a consolidated and recognised alternative to the conventional, prediction-based urban decision-making methodologies.

1.2 RESEARCH QUESTIONS

This thesis responds to the following research question:

'How can urban governance facilitate systems change for sustainable development under conditions of heightened uncertainty?'

The following sub-questions explored throughout the thesis are outlined below, as are the main tasks undertaken to respond to the research question:

Research Sub-Question 1: Are current mainstream models of urban governance suitable for responding to the imperative for systems change under conditions of heightened uncertainty?

- Articulate and define through a review of the literature the concepts and challenges of system change, uncertainty and urban governance. See Chapter 2, the Literature Review.

- Develop a novel framework of urban governance along the dimensions of Uncertainty and Systems Change to respond to the research question. The framework consists of a four-part urban governance typology comprised of Predictive Urban Governance; Adaptive Urban Governance; Visionary Urban Governance; and Transformative Urban Governance. See Chapter 4.

- Using the urban governance framework and the review of the literature, identify shortcomings of mainstream urban governance models to respond to the research question. See Chapter 4.

Responding to this research sub-question involved the following practical research activities:

Undertaking stakeholder workshops with practitioners from across transport departments of 14 Asian countries (Vietnam, Russia, Mongolia, India, Sri Lanka, Pakistan, Myanmar, Malaysia, Bangladesh, China, Cambodia, Indonesia, Iran, Thailand) to interrogate issues associated with existing and emerging urban governance models and any associated opportunities. (See UNCRD, 2018).

Engagement with urban governance practitioners (from public, private and community sectors) to explore challenges and opportunities associated with system change towards sustainability, and assess the effectiveness of current approaches.

Visit research site to conduct interviews, observe the application of technologies, and existing governance models and practices to inform a deeper understanding of the current 'state of play' globally. Key cities that have informed the research include: Dubai (United Arab Emirates); Amsterdam (The Netherlands); Bologna (Italy); Yibin (China) – See Appendix B; ZhuZhou (China); Shenzhen (China); Ulaanbaatar (Mongolia); and Hanoi (Vietnam).

Research sub-question 2: What role has entrepreneurial agency played in urban systems change throughout history?

- Apply multiple case study method (Yin, 2006) to review four past transformative technological advancements in short case study form, namely: the steam engine, railways, electricity and the automobile. See Chapter 3.

- Apply thematic analysis (Braun and Clarke, 2006) to codify the approaches to development and implementation of each technology. Cluster similar approaches across the four technological examples to refine the core approaches and group them into common themes. See Chapter 3.

- Summarise the findings from the historical case studies and identify insights for current day infrastructure transitions. This summary validates entrepreneurial agency as a pivotal contributor in systems change processes and justifies further work to identify the key principles of entrepreneurship applicable in broader urban governance contexts. See Chapter 3.

Research sub-question 3: Is the entrepreneurial decision-making logic of Effectuation a useful construct for transformative urban governance approaches in the context of contemporary civil infrastructure?

- Present a 'Dynamic Model of Effectual Urban Governance' that translates effectuation logic to an urban governance domain drawing on a subset theory of sustainability transitions - strategic niche management. See Chapter 4.

- Present the initiation and growth over 20 years of the Willunga Basin Reclaimed Water Pipeline as a civil infrastructure case study. Use the dynamic model of effectual urban governance to illustrate how stakeholders leveraged available resources, generated buy-in and created systems change for more effective water provisioning across the region. See Chapter 4.

Responding to this research sub-question involved the following practical research activities:

- Semi-structured research interviews with key stakeholders involved in the formation of the Willunga Basin Water Company and the provision of the pipeline. See Appendix A for further detail on interviews.

- PhD Research Program on 'Innovation and Sustainability Transitions' at Arctic University of Norway.

Research sub-question 4: How can effectuation inform urban governance and accelerate systems change to promote sustainable development under conditions of heightened uncertainty?

In Part 2, effectual urban governance is presented as a new governance model particularly suited to complexity and uncertainty, and to bringing together stakeholders to co-create infrastructure futures. Commitments, risks and rewards are shared between 'effectual stakeholders' while responding to local challenges and leveraging available resources.

The model has the following core components, with a chapter in Part 2 each detailing:

1. The guiding design principles of effectual urban governance (responding to landscape pressures, aligned to sustainability). See Chapter 5.

2. The actions based on available means (starting with available resources rather than pre-determined outcomes). See Chapter 6.

3. The formation of partnerships and stakeholder commitments based on opportunities for value creation (establishing partnerships and seeking effectual stakeholder commitments). See Chapter 7.

4. Taking effectual action to iteratively drive the socio-economic structuration of an innovation. See Chapter 8.

To illustrate effectual urban governance, in each of the above chapters, the model is applied to urban transport.

Responding to this research sub-question involved the following practical research activities:

Undertaking stakeholder workshops with practitioners from across transport departments of 14 Asian countries to interrogate issues associated with existing and emerging governance models and associated opportunities. See Chapter 7.

Visiting Yibin, China to study the Autonomous Rail Rapid Transit (ART) project to produce a detailed case study on the first commercially operating line in the world, hosted by Chinese Railway Rolling Stock Company (CRRC). See Chapter 8 and Appendix B for further detail.

1.3 RESEARCH METHODOLOGY

Meredith (1993) described the typical research cycle as iteratively moving between describing, explaining and testing with the goal of developing and refining theory. Conceptual frameworks are crucial in this process as they provide a link between phenomena (e.g. urban governance or entrepreneurship), and the theories that are capable of explaining, predicting and informing such phenomena (e.g. is entrepreneurship a product of an individual or an opportunity, or both). Although conceptual research is sometimes criticised for a perceived lack of rigour or evidence, as Lüdeke-Freund (2019) states, conceptual research 'is indispensable to capture new and insufficiently described phenomena, reduce complexity, consolidate and reflect upon available knowledge, and finally allow for systematic theorising (Whetten, 1989; 2009)'.

Research design is defined by Creswell (2009, p. 3) as 'the procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis'. The overarching research design of this thesis draws on existing literature in sustainability transitions, entrepreneurship/effectuation and broader fields. It also draws on insights from research case studies, interviews and practitioner workshops. As represented in Figure 1-4, the methodology is as follows:

1. Assess theory within the field of study to identify elements that respond to the research question, and to also identify current gaps and shortcomings of existing approaches and their application to urban infrastructure governance;

2. Explore and assess if existing academic theories from outside the direct field of study that are yet to be applied to this research problem but that potentially provide insights to inform the resolution of some of the issues in traditional approaches;

3. Investigate complementary and supporting theoretical and practical methods, models and empirical examples (including case studies) to enhance the proposed model by further articulating the contribution and resolving remaining issues to deliver a unique contribution to the academic literature; and

4. Aggregate the findings from across the existing literatures, established practices and the undertaken new research to propose a new urban governance model termed 'effectual urban governance'.

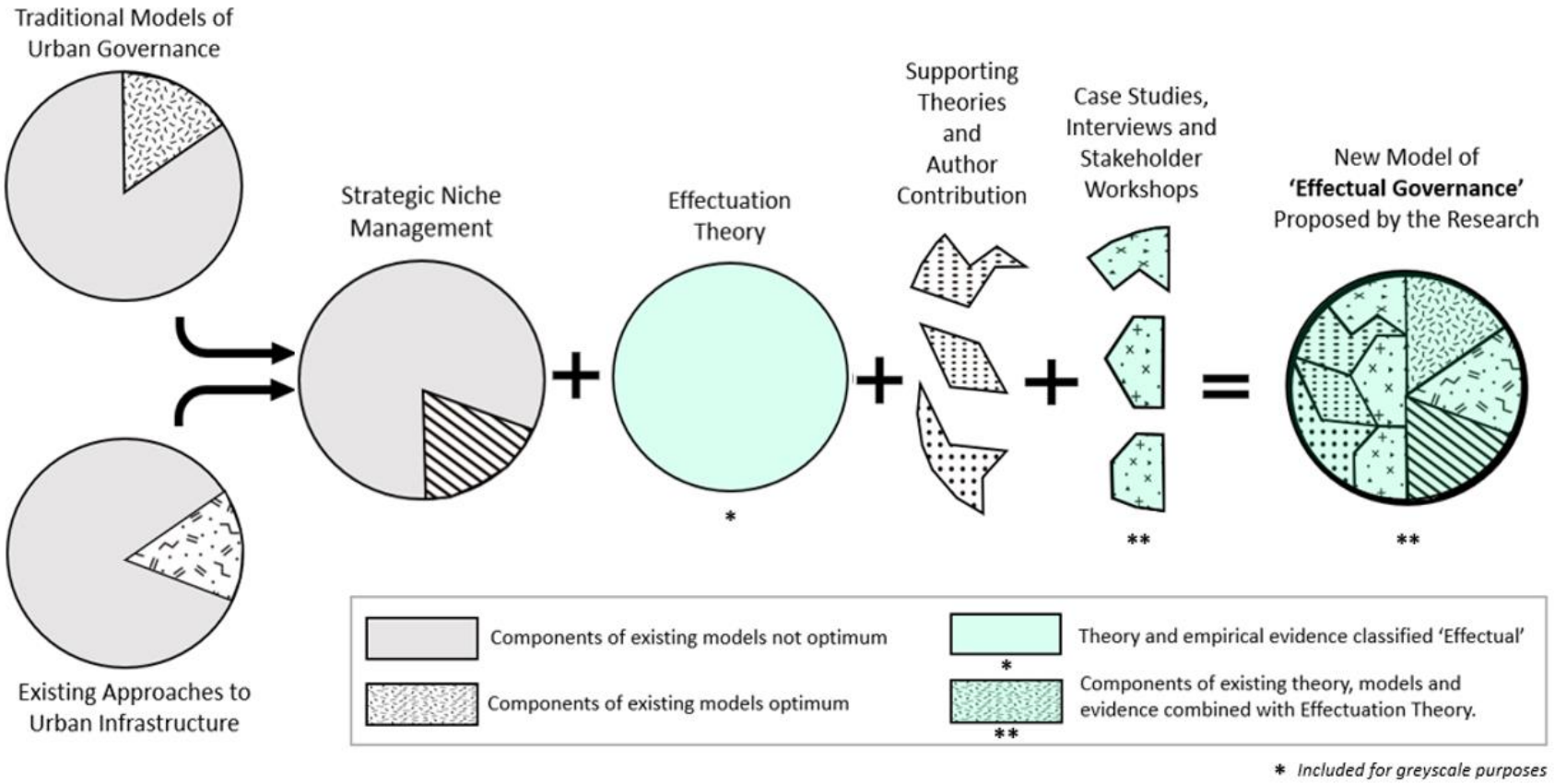


Figure 1-4: Infographic representing the research methodology and the creation of the 'Effectual Urban Governance' model.

1.4 THESIS STRUCTURE

The thesis is structured in two parts, as depicted in Figure 1-5:

Part 1

The multi-disciplinary nature of the research results in the urban governance, sustainability transitions and entrepreneurship literature being the focus of the literature review – culminating in a multi-disciplinary discussion identifying key research gaps. The literature review identifies the potential for tenets from entrepreneurship to inform a new model of urban governance to promote sustainability transitions and transformations.

Given the multi-disciplinary nature of the work, the synthesis of entrepreneurship literature with governance and transitions concepts is developed over multiple chapters. In order to further interrogate the potential of entrepreneurship in a new context, Chapter 3 explores the role of entrepreneurial agency in urban system transformation throughout history, validating the potential for the entrepreneurial domain to provide insights to inform infrastructure transitions in the built environment.

Effectuation theory, central to the thesis, is introduced in Chapter 4. Building on the premise that translating entrepreneurial insights into the sustainability transitions/niche management domains has promise, as established in the literature review and further reinforced in Chapter 3 – Chapter 4 begins by developing a novel framework for urban governance based on Wiltbank et al's (2006) strategic management framework of prediction and control. Translating this framework to an urban governance context directly links the two dimensions of prediction and control to the dimensions of the thesis' overarching research questions and concerns systems change, urban governance and uncertainty. In synthesising these two fields of theory it became evident there was insufficient literature and research on 'Transformative Urban Governance' approaches (capable of systems change under conditions of uncertainty) to adequately respond to the research question. As a result of (1) the need to identify transformative approaches; and (2) demonstrate entrepreneurial agency was translatable to urban governance; effectuation was distinguished as the entrepreneurial concept with the most potential to respond to the research question. Chapter 4 then articulates an effectual approach to strategic niche management using an in-depth civil infrastructure case study of the Willunga Basin Water Company supported by the empirical data from the semi-structured research interviews.

Part 2

Part 2 of the thesis focuses on further elucidating the effectual urban governance model by applying effectual decision-making logic to the urban governance domain. The four chapters in Part 2 each focus on a key principle of effectual urban governance and apply the model to a public transit infrastructure development for illustrating these principles in practice. Each chapter provides a theoretical rationale for the respective principle, and includes additional insights from the effectuation literature, drawing on complementary academic theories and research conducted during this candidature, for example, the practitioner workshops and international case studies, to highlight exemplars of the principles in practice. Part 2 also highlights the contrasts between a conventional approach to infrastructure development and governance and an 'effectual' approach in overcoming common challenges highlighted in the literature.

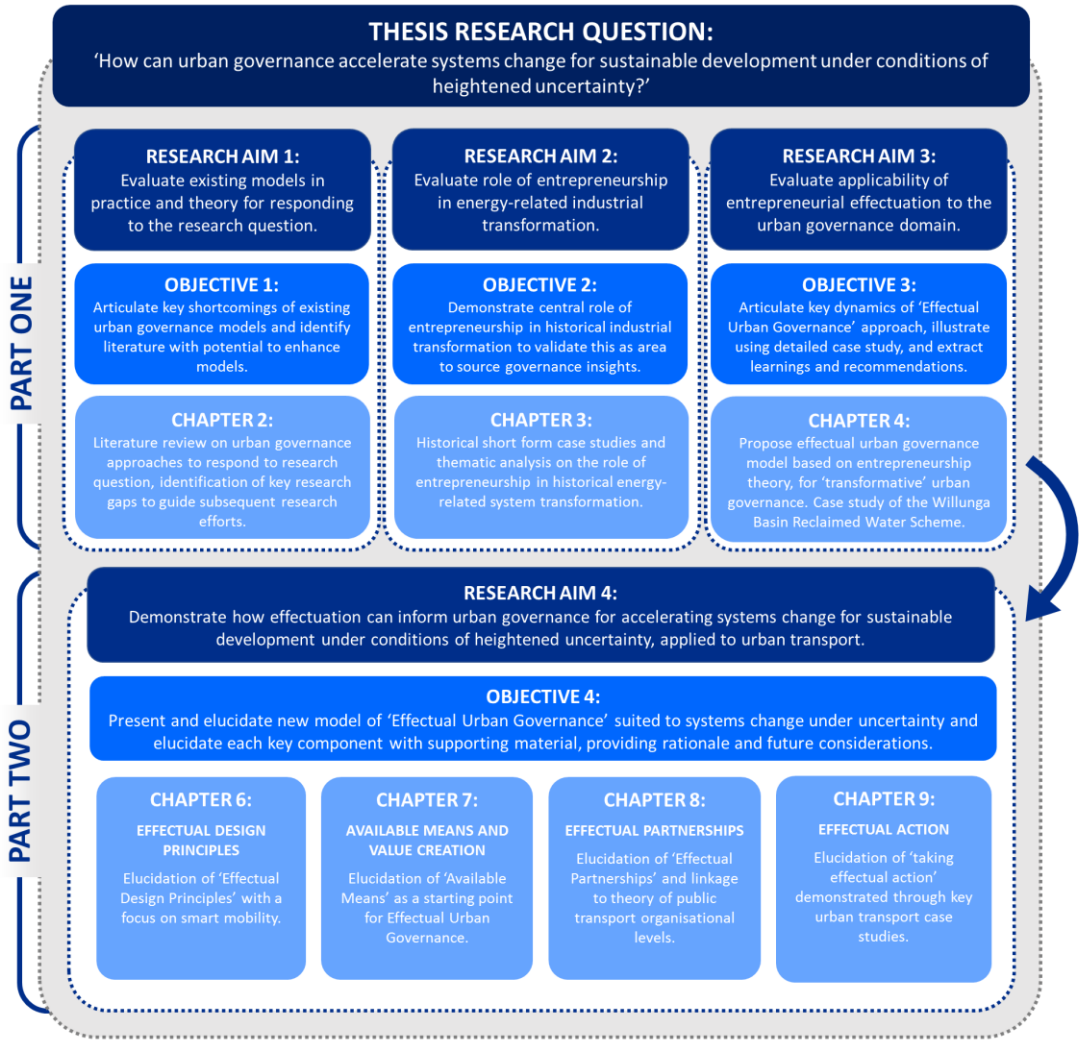


Figure 1-5: Schematic flow chart illustrating the research framework, and the connection between the main research question, the aims, the objectives, and the chapters contained in this thesis.

CHAPTER 2

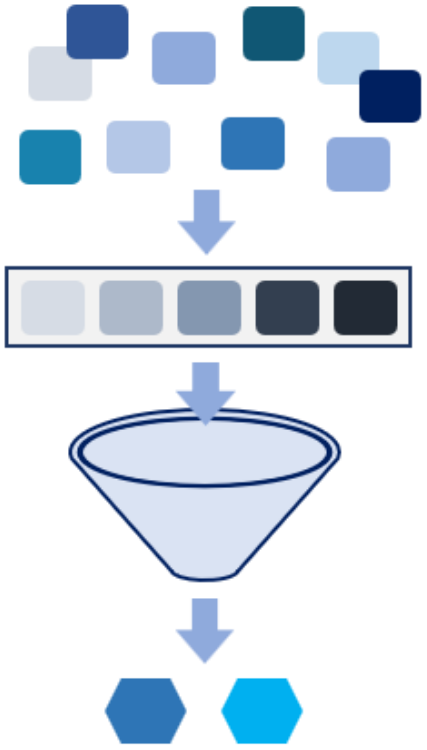
LITERATURE REVIEW

2.1 CHAPTER OVERVIEW

Due to the multi-disciplinary nature of this thesis, this chapter critically synthesises key literature across several disciplines. These disciplines span urban governance, socio-technical systems change, Strategic Niche Management (the facilitation/management of safe spaces for radical niche innovations to be cultivated), uncertainty and associated challenges for governance, and entrepreneurship as a discipline of applying agency in conditions of uncertainty to induce systems change.

This chapter, as the primary review of literature, establishes the gaps that guide the research. The additional fields of academic theory, primarily effectuation and causation logic, which are central to the contribution of this research are introduced in Chapter 4. Before focusing on *what* entrepreneurial approaches are relevant to the thesis research question (i.e. effectuation) and *how* they might inform urban governance – this chapter first demonstrates, more fundamentally, the potential for entrepreneurship as a process to be relevant and applicable to urban governance.

Figure 2-1 below illustrates the process followed to conduct this literature review.



1. Broad review of literature (Section 2.3)
2. Consolidated summary of key literature relevant to the research question
3. Synthesis of multi-disciplinary research areas and discussion in multi-disciplinary context (Section 2.4)
4. Identify gaps and promising areas for future research

Figure 2-1: Representation of literature review process

2.2 CONTEXT

There is broad scientific consensus that humanity faces a number of pressing ecological and social challenges that require significant systems change to address. Despite the availability of technologies to enable systemic transformation towards sustainable development, global progress towards achieving the sustainable development goals has been broadly insufficient (von Weizsaecker et al., 2009; Rockström et al., 2009; IEA, 2011; Baumgartner, 2011). Viewing innovation and systems change through a 'socio-technical' lens helps explain why technology is only one piece of the puzzle in implementing transformative systems change.

The world's cities are critical in the transformation towards sustainable development as they contribute over 70 percent of global greenhouse gas emissions (IEA, 2016). The world's population continues to urbanise, with over half now living in cities. However, steering urbanisation towards preferred sustainable development trajectories is not straightforward. Cities are complex systems, where interactions and feedback loops between various components lead to collective or 'emergent' features which cannot be reduced to the sum of the parts (Cilliers, 1998; Batty, 2005; Crawford, 2016). This is in contrast to 'complicated systems'. Complicated systems contain a number of intricate parts and are difficult to understand. Problem solving in complicated systems is achieved by reductionist approaches and expert analysis, or by isolating parts of the system and seeking to understand the 'cause and effect' relationships between these parts (Cilliers, 1998; Snowden & Boone, 2007). This approach fails to account for the emergence of unforeseeable properties and phenomenon in the planning and governance of cities.

Several factors contribute to the emergence of unforeseeable properties and phenomenon in cities that are difficult to plan for. These include, but are not limited to, the interactions between different types of technologies, the interactions between civil infrastructure and the natural environment, and the behaviours of people. The many interconnected sub-systems, each with their own uncertainties, path-dependencies and feedback loops further contribute to the emergence of unforeseeable properties and phenomenon. These are all properties of complex adaptive systems (Portugali, 2016). For instance, the collective behaviour of a population can create collective emergent properties that are not observable at the level of individual. In comparison, civil infrastructure, for example, a bridge or building, performs as expected due to being merely 'complicated' based on the above definitions (Portugali, 2016). It is therefore crucial to examine cities through a socio-technical lens which appreciates both the emergent and the predictable behaviours, and recognises how both these properties and the interactions can be harnessed to stimulate innovation. The automobile-centric approach to planning transportation in many cities provides a telling example as the transport system is 'socio-technical' in nature, involving technology, rules and regulations, distribution networks, maintenance, road and fuel infrastructure, financing, culture, symbolic meaning, industry structure, markets and user practices (Geels, 2005). The appreciation of these integrated 'social' elements

that are both shaped by, and re-shape technology, are central to understanding sustainability transitions and transformations.

For example, in the transport sector over 30 years ago Newman and Kenworthy (1989) warned of the outcome of designing and operating cities based on a model of personal transport, or 'Automobile Dependence' - where path-dependencies caused by placing the private automobile as the central artefact of city and infrastructure planning result in detrimental social, economic and environmental outcomes. In this automobile-centric paradigm, institutions, structures and practices prioritise the use of the automobile. As a result, roads have become more congested with the response being to expand the road network to allow for more vehicles. This creates a reinforcing feedback loop and deepens path dependency. In cities around the world, this expanding cycle of automobile dependence has negatively impacted economic productivity due to higher levels of traffic congestion, the environment through growing levels of air pollution and greenhouse gas emissions, people's quality of life through poor air quality and respiratory illnesses related to particulate matter contained in vehicle pollution.

Such an outcome represents a higher-level, emergent impact of road-based transport within a complex system. Highway engineers in the 1950s did not explicitly decide to produce congestion and environmental side effects, nor do they today, however isolating and optimising roads as a single part of the complex system that makes up a city creates unintended emergent properties at a systems level. In this case, 'personal transport' represents a complex system which cannot be reduced to the sum of the parts.

More broadly, and fundamentally, in the case of urban transportation, transport systems exist to connect land uses and enhance the efficiency of economic systems; the integrated role that transport plays in a broader city context is therefore crucial to steering the complex, emergent properties of the city. The reductionist approach of isolating a transport system away from its interrelated counterparts in land use activity and economic markets prevents integrated and sustainable solutions being cultivated. Planners around the world now realise that the 'automobile dependent' approach that has been prominent since the mid-20th Century falls short in optimising integrated and holistic benefits for the city (Kenworthy & Newman, 2015). In contrast, thinking, designing, and implementing innovative solutions at a systems level accounts for the interconnectedness and emergent properties. This differs from a reductionist methodology of breaking down a system into parts, as commonly used by engineers and planners (Meadows, 2009; Crawford, 2016). Systems thinking instead recognises the interactions between components and actors (Ackoff et al., 2010), and how interventions can be more effectively designed to lead to preferred changes in the system (Newhofer, 2003; Patel and Mehta, 2016).

2.3 SUMMARY OF KEY LITERATURE RELEVANT TO RESEARCH QUESTION

2.3.1 Urban Governance in the 21st Century

In the 1960s, one organised and cohesive society was once thought to exist in a city. It is now understood that cities instead comprise a complex and diverse fabric of unique, interrelated elements due to the rich patchwork of different micro-cultures and infrastructures (Jacobs, 1961; Amin and Thrift, 1995; Gehl, 2010). This means that reductionist 'one size fits all' planning approaches fail to account for local intricacies that exist within a city. It also means that urban initiatives and policies do not always translate well from one political or economic context to another, and in some cases, not even from one part of a city to another. In complex systems, it is not always 'best practice' to take best practice approaches from one context and simply transfer them to another (Madanipour et al., 1998). It is therefore important that urban initiatives appreciate local character and values.

Urban governance takes place within the social norms, values and cultures of society; in turn, those societies place pressure on urban governments with the aim of influencing what they must do and how they should act. This can make policymaking very sensitive, with some arguing that for urban governments, public policies "can be no more than experiments inserted into the 'relational ensemble' of the city" (Kearns & Paddison, 2000). Kearns and Paddison (2000) go so far as to state that real understanding of how the complexities of urban systems operate is inadequate for governance to be effective, while da Cruz et al (2018) observe that theories and academic studies on urban governance are yet to establish a mature and consolidated field of study (Davies, 2014; Lucas, 2017; Pierre, 2005; 2014).

Analytically, governance is a useful concept because it focuses on the relationships and interactions between actors and the rules that govern their interaction, rather than the specific 'pre-requisites' or assumptions related to the actors themselves – the visioning, steering and implementation of projects can be unique in different contexts, however effective governance can display the same traits (Pierre, 2014). In a summary paper of a special journal edition on sustainable cities and governance, May and Marvin (2017) state that it is important that governance models should not be focused on 'ready-made' and directly 'replicable' governance approaches, but rather provide models that can work on local issues in local ways. They state, 'what becomes comparable is the process of defining, shaping, articulating and integrating different voices and visions within a city-region to contribute to more sustainable and just urban futures.'

This distinction reflects the understanding in the wider literature on governance, where the synergy between social and technical systems is being scaled up from the level of organisation (or chain of organisations) to the level of urban system (Meijer and Bolivar, 2015). This approach to urban governance requires

permeable relationships between the public and private sectors which bring parties together to co-create urban futures that overcome complex challenges. It is integrally important that the community sectors are also involved in these processes and that 'social good' outcomes are achieved through urban initiatives, as evidenced, for example, through the provision of affordable housing in new property developments in London (Whitehead, 2006). The collaborative planning process established includes the community and ensures that local knowledge is leveraged, local needs are met and that initiatives are not mismatched to their ultimate users. Such an approach builds local capacity that then reinforces positive feedback loops to enable further solutions to develop. This approach also works towards addressing Kearns and Paddison's (2000) observation that 'the challenge facing urban governance is to achieve the material and psycho-social security and empowerment of citizens to such a degree that self-generating and self-perpetuating social and economic solutions are forthcoming'.

Cities also have ambitions; they seek to be safe and sustainable, and also culturally and economically vibrant (Landry, 2006). This is evident in the increasing trend towards competition between cities to attract company headquarters, investment, and top talent or the 'creative class' (Florida, 2002). This trend towards 'competitiveness' must be weighed against the importance of 'inclusiveness' and social cohesion. Short and Kim (1999, p. 118) refer to this as 'the transformation in urban governance from the welfare-state model towards the economic development model'. Governments are thereby seemingly becoming more entrepreneurial to promote their cities and facilitate economic development. This, in turn, can create opportunities for the population, and may be pitched as the shift 'from government to governance' and from 'managerialism to entrepreneurialism' (Harvey, 1989; Stone, 1989; Pierre, 2011; Koch, 2013).

Urban governance in summary

In summary, urban governance in the 21st Century faces *increasing complexity and uncertainty*. Governance is more than governments, as governments must *blend resources* with private and community sectors in a *flexible and permeable way*, while *simultaneously responding to local conditions and challenges in localised ways.* Governance today must be capable of *facilitating systems change towards sustainable development* under *conditions of heightened uncertainty*.

2.3.2 Systems Change as a Process of Socio-Technical Transition

There is extensive literature across many disciplines focused on the complex global issues confronting society and how to address them through socio-technical transition (Coenen and Truffer, 2012; Markard et al., 2012; Weber and Rohracher, 2012; Wells, 2013; Sen, 2013; van den Bergh, 2013; Coenen et al., 2015; Torgerson, 2017; Fagerberg, 2018; Schot and Steinmueller, 2018). Central to this literature is the role of innovation, public policy and experimental governance at national and regional scales (Geels, 2002; Grin et al., 2010; Truffer and Coenen, 2012; Boschma, 2015; Hargroves, 2015; Boschma et al., 2017). The

sustainability transitions literature posits that technologies exist within 'socio-technical systems'; these systems are constantly co-evolving with user systems, rules, regulations, norms, beliefs, conventions and routines shaping how actors interact and behave in the economy (Hodgeson, 1993; Geels, 2005). Transforming these socio-technical systems, or systems change, is a transitionary process that has been observed to occur over the course of decades throughout history (Geels, 2002).

The Multi-Level Perspective (MLP) shown in Figure 2-2 represents the 'levels' at which configurations of social structures and technology - socio-technical systems - can be conceived, as distinguished by varying levels of structuration – a concept introduced here and discussed in more detail later in this section. Structuration describes the interrelated and reciprocal relationship between human agency and societal structures – whereby societal structures influence human behaviour and human agency recreates these structures (Giddens, 1984).

The Multi-Level Perspective has three levels (Geels, 2002):

1. ***Socio-technical landscape (exogenous context):*** The socio-technical landscape holds the highest level of structuration of the three levels. This level consists of slow-changing external factors, such as multi-national geopolitics, natural disasters, or climate change. These trends are difficult for individual actors to influence in the short-term, and instead place pressure and influence activities that occur at both regime and niche levels.
2. ***Socio-technical regimes:*** Socio-technical regimes represent prevailing socio-technical configurations, defined as "the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures" (Rip and Kemp, 1998). In the context of sustainability transitions, these regimes commonly comprise elements that do not align with sustainable development, and therefore require transition towards sustainability. By nature, established regimes seek to retain their structure and resist systems innovation (Coenen et al., 2015).
3. ***Niche innovations:*** Niche innovations represent radical innovations that emerge among networks of actors and at this level of structuration, they do not have widespread influence over society. Examples of niche innovations may include technologies from universities or innovation clusters/start-ups, or novel policy frameworks being applied at a local scale. Niche innovations are usually influenced by the regime and landscape levels, however they are not necessary 'aligned' to these levels – they may present innovative solutions to shortcomings of the prevailing regime.

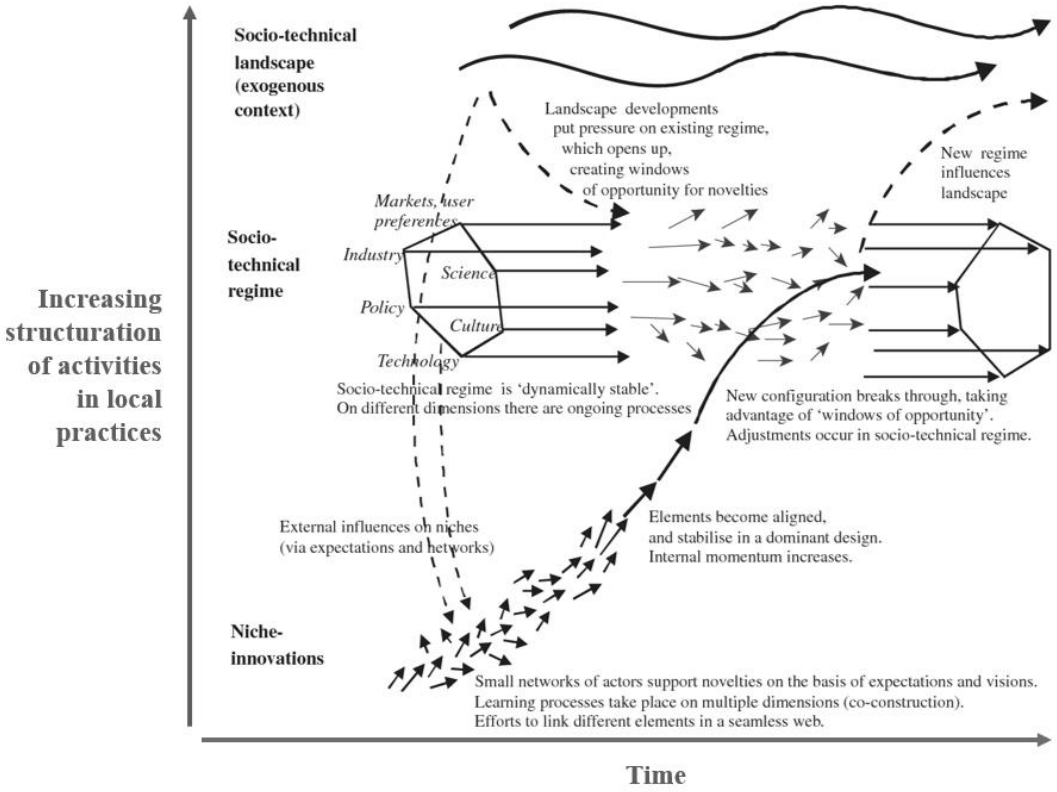


Figure 2-2: The Multi-Level Perspective (MLP) on socio-technical transitions (Geels, 2011)

'Structuration' as the characteristic that distinguishes the three levels of socio-technical configuration

What distinguishes socio-technical regimes from emerging niche innovations and exogenous landscape pressures is the level of structuration of the socio-technical configuration within local practices – displayed on the vertical axis of the MLP (Geels, 2002). In many Anglosphere cities, for example, the socio-technical regime for transportation is structured around the private automobile as a key technological artefact. In these Anglosphere cities, niche innovations such as autonomous vehicles, cycling, electric scooters and micro-mobility or mass transit have a much lower level of structuration and usage. For example, commuter cycling has a much higher level of structuration in cities like Amsterdam or Copenhagen, and commuter mass transit a much higher level of structuration in cities like Hong Kong. In Hong Kong, over 90 percent of commuter transport journeys are made by rail, representing the dominant socio-technical transport regime in this city. In an Anglosphere city like Adelaide, South Australia, the private automobile represents the dominant commuter transport regime (with over 90 percent of commuters driving by car). Work done by Coenen et al (2011) on the spatial aspect of transitions suggests that niches and regimes are not confined to geographic locations however, and that niches can be both global and local. It is not necessarily the

'spatial scale' of a niche or regime that defines it, but the level of structuration within the defined boundary of analysis.

Structuration is represented on the vertical axis of the MLP and is the differentiating factor between socio-technical niches, regimes and landscape phenomena. Societal structures both influence human behaviour while being recreated by human agency. 'Agency' implies that actors have the knowledge and ability to intervene in the world, or choose not to, and are aware of social norms and the implications of their actions. Structures are the rules or norms within society that influence how individuals act and are a 'virtual' concept that do not exist outside of the actions of agents. As such, social structures are constantly influencing behaviour and are then reproduced by agents who act within the context of the prevailing social structure. Giddens, in his seminal work defining this concept, describes this relationship as the 'duality of structure'. Rather than viewing agents and structure as a dualism, where the concepts are separate from each other, they instead form a duality where the two are interdependent and recursive (Giddens, 1984).

When considering change to socio-technical systems, or 'systems change', agency exists at the core of this change as the very structures that define the system are created and re-created by the agents within it. In this way, the duality that exists between agents and structures empowers agents who seek to induce such change, as societal structures change through groups of individuals acting outside of the traditional structure and in new ways over time. Giddens states "actors are at the same time the creators of social systems, yet created by them" (Giddens, 1991: 2014). While agents are influenced by the prevailing social structure, they may also act in ways that differ from the prevailing structures in society – creating a niche. Although a time-consuming and complex process, systems change within a socio-technical framework occurs as a new socio-technical configuration, or niche, emerges and achieves broader societal uptake to replace the prevailing regime. Strategic niche management is a key governance approach for facilitating and supporting the emergence and increased structuration of niche innovations (Kemp, Schot and Hoogma, 1998; Weber et al, 1999; Kemp, Rip and Schot, 2001).

Facilitating the structuration of sustainable niche innovations through Strategic Niche Management

Strategic Niche Management (SNM) is the process of supporting new technological innovations entering the market that have significant potential to contribute to achieving sustainable development (Kemp, Schot and Hoogma, 1998). New technologies are invented all the time, however, more often than not, they do not succeed in achieving broad societal uptake. In fact, many do not make it beyond research and development facilities, with the seminal work of Joseph Schumpeter (1934) distinguishing between 'inventions', often in the realm of science and technology, and 'innovations' where such inventions are commercialised for widespread adoption.

There are a number of reasons why many new technologies fail, two key factors are the 'selection pressures', from an evolutionary economics perspective, that exist within the economy or prevailing regime are generally in favour of existing, established technologies and the incumbent firms and actors possess greater resources than new market entrants (Van de Belt & Rip, 1984; Schot & Geels, 2008). Incumbent technologies within an existing socio-technical regime have co-evolved with societal factors over time and have iteratively achieved greater and greater levels of structuration within society. User preferences and behaviours align to these existing incumbent technologies and often new radical innovations do not present a 'ready fit' for the existing regime. The sustainability transitions concept posits that an incremental and co-evolutionary process of adapting existing technical and social elements of the prevailing regime is required to increase the structuration of new radical innovations for sustainability.

Strategic Niche Management, as a framework, can guide this co-evolutionary process by bringing together networks of actors to experiment with early-stage niche innovations, and share learnings and experiences; this process can also incubate the iterative development of a new technology with users (Schot & Geels, 2008; Romijn, 2010). As the name conveys, SNM bridges the gap between (1) the concept of strategic management and (2) the calls in the literature for innovation at a 'systems' level; in this case, the socio-technical system oriented around a socio-technical niche innovation rather than just technology alone. A key focus of SNM is supporting or 'protecting' niche spaces in their early stages of development from external market pressures. As with all good governance, SNM is not something that one actor can achieve on their own, and success requires multi-sector parties to act together. Key actors in an SNM context may therefore be state policy-makers, regulatory agencies, local authorities (e.g. development agency), non-governmental organisations, citizen groups, private companies or industry organisations.

SNM is commonly divided into four key steps by leading authors (Kemp, Schot and Hoogma, 1998; Weber et al, 1999; Kemp, Rip and Schot, 2001):

1. ***Step 1 - Choice of technology:*** This step involves identifying the technology that will be supported through subsequent experiments. It is recommended that the technology is compatible with user needs and values. Weber et al. (1999) suggest the technology must have organisational characteristics or requirements that are close to the existing regime, but can be altered over time.
2. ***Step 2 - Designing an experiment:*** Experiments are designed to suit a particular technology and bring the appropriate partners together to facilitate learning. It is recommended that experiments are designed to be simple enough to avoid skipping potential learnings, while still tackling a bold issue to ensure the parties remain engaged.
3. ***Step 3 - Implementation of experiment:*** A key focus of experiment implementation is learning among network participants. Experiments should involve a broad range of participants ranging from technology providers to a representation of 'end user' groups. As the experiment unfolds,

learning should be fostered across the network; What worked? What didn't? This learning should re-shape the subsequent experiments and the expectations of the market of the future (Elmustapha et al., 2018).

4. ***Steps 4 - Scaling up of the experiment and phasing out of protection:*** Over-protection of niche innovations can lead to such innovations becoming 'over protected' and cannot survive on their own (Geels, 2010). Therefore, at this stage of the SNM process it is recommended that multiple experiments are conducted and linked, while support mechanisms are gradually removed to enable the technology to compete on the market.

In practice, it has mostly been applied as a research tool to analyse past experiments (Mourik and Raven, 2006). SNM has been used to analyse the success and failure of experiments with new technologies such as wind energy, biogas, public transport and electric vehicles. Often these examples have been 'pilot projects' and have not progressed into viable commercial market niches that are capable of surviving and scaling on their own, nor did they significantly influence government priorities or investment decisions. There is a lack of SNM examples in the literature that have successfully reached and carried out Step 4 (i.e. progressed from single experiments or pilot projects to scaled niches with increased structuration).

In principle, SNM offers insights as a policy tool for urban governance that seeks to focus on facilitating transitions towards sustainability. SNM intends to provide conditions for experiments and learning to shape socio-technical configuration, taking a new technology/innovation as the starting point. A weakness, at present, is that it lacks a demonstrated capacity to perform as a governance instrument capable of facilitating broad systems change through the scaling of innovations although insights drawn from previous experiments indicate it has potential. SNM has been further criticised for lacking practical guidance to underpin its practical application (Mourik & Raven, 2006). Caniels and Romijn (2006) suggest that SNM would benefit from additional insights from complementary fields of innovation studies to inform its application, and into the process of linking micro and macro dynamics for it to effectively function as a policy tool.

The extract below from Hoogma et al. (2002, p. 195), key SNM authors, reflect these concerns:

> "We were certainly over-optimistic about the potential of SNM as a tool for transition… The positive circles of feedback by which a technology comes into its own and escapes a technological niche are far weaker than expected and appear to take longer than expected… The experiments did not make actors change their strategies and invest in the further major development of a technology…"

Systems change in summary

In summary, transformative system change for sustainability is a process of *applying agency to increase the level of structuration of sustainable socio-technical innovations* to the point that they form a new, established socio-technical regime. *Strategic Niche Management* has been highlighted as a key governance approach *for facilitating the structuration of niche innovations*, however, it has had limited practical application, especially for scaling up innovations.

2.3.3 Heightened Uncertainty as a Constraint on Governance

When characterising uncertainty, it is firstly important to differentiate between uncertainty and risk. This distinction was first made by economist Frank Knight in his seminal work on uncertainty in the early 20th Century (Knight, 1921). Both uncertainty and risk relate to situations where a future outcome is unknown, however risk relates to 'known unknowns' - or to those situations where it is possible to calculate probabilities based on knowledge from past experience. In the case of uncertainty, there is inadequate information or capacity to assess likely outcomes, i.e. past experience is not reliable. Uncertainty is about both 'unknown unknowns' and a lack of confidence and knowledge about the stability of the future. Contemporary socio-technical systems are subject to significant uncertainty, most notably due to the likelihood of increasingly unpredictable global impacts due to climate change, technological paradigm shifts or, as seen in 2020, global pandemics. In the context of urban development, infrastructure decisions have a lasting legacy and while many infrastructures may outlast the technologies that they are initially designed to serve, 'predicting' a long-term optimal outcome becomes impossible. In 2020, the global social and economic crisis created by the COVID-19 pandemic exemplifies the types of uncertainties that can result from global disruptions, where the abilities of pre-existing 'models' to inform decision-making about the future falter in the face of uncertainty.

The shortcomings of traditional planning approaches to deal with uncertainty have been highlighted in the literature due to current decision-making processes' heavy reliance on prediction, stability and risk reduction (Abbott, 2005; Albrechts 2010; Albrechts & Balducci 2013; Gunn & Hillier, 2014; Rauws et al., 2014). As identified earlier in this chapter, cities by their very nature as dynamic complex systems are subject to uncertainty and this creates difficulties for policymakers and decision-makers (Duit & Galaz 2008; Teisman 2008). Agents of systems change in cities grapple with how to deal with uncertainties; as a result planning literature is placing increasing emphasis on the widespread nature and impacts of uncertainties (Albrechts 2010; Bertonili 2010; Van Woerkum et al. 2011; De Roo, Rauws 2012; Batty, 2013; Salet et al. 2013).

Uncertainty is an unavoidable reality of systems change. Evolutionary economist Joseph Schumpeter (1934) spoke of the cyclical nature of systems transformations – where he refers of the 'perennial gale of creative destruction', with continuous changes within a system. Meyer et al. (1990) makes the distinction

between these ‘first order changes’ that happen within a system, and ‘second order changes’ that are discontinuous and change the entire system. While Schumpeter talks of a more evolutionary change, these changes over time can build to lead to large changes, whereby old models of the past become outdated. Darwin’s analyses of the finches (Lack, 1983) shows how small variations can eventually result in such discontinuous change, such as the origin of a whole new species.

One objective of strategy can be to convert uncertainty into measurable and manageable risk. This process can be manipulated by incumbents within existing socio-technical regimes to defend their dominance and prevent new innovations from emerging. In a world where analytics, prediction-based models and cost-benefit analyses inform decision-making and investment, uncertainty that cannot be defined in terms of manageable risk can be largely dismissed. With investment playing a major role in the lock-in of socio-technical systems (Unruh, 2000), incumbents are able to refer to ‘what has worked in the past’ as a means of removing perceived uncertainty for investment decisions, thus further embedding existing path dependencies in the system – and allowing them to maintain their dominant position (Bolton and Foxon, 2015).

However, often the scientific, reductionist methodology of accounting for risk in the face of uncertainty in complex systems does not accurately reflect the workings of the system itself. The world is not without uncertainty. As Knight posits in his seminal work (1921):

> “The importance of uncertainty as a factor interfering with the perfect workings of competition in accordance with the law of pure theory necessitated an examination of foundations of knowledge and conduct. The most important result of this survey is the emphatic contrast between knowledge as the scientist and the logician of science uses the term and the convictions or opinions upon which conduct is based outside of laboratory experiments, [which] have little similarity with conclusions reached by exhaustive analysis and accurate measurement.”

To respond to the challenges uncertainty presents to prediction-based planning approaches, the literature calls for more flexible and collaborative planning approaches to allow for future uncertainties and learning processes (Folke et al., 2002; Linnenluecke et al., 2017). Given that uncertainty is a fact of life in cities and that infrastructure decisions will always be subject to human complex adaptive systems that shape and re-shape themselves over time, new approaches must not shy away from uncertainty but act in the face of it.

Uncertainty in summary

In summary, *uncertainty constrains traditional decision-making processes* due to incompatibility with pre-existing models and formulas, and by doing so can *further embed the path dependency of unsustainable*

regimes. In the process of enabling systems change towards preferred development trajectories, *urban governance must adopt new approaches for dealing with uncertainty* that *strengthen the systems' responsiveness to future unknowable events*.

2.3.4 Entrepreneurship: A Process of Systems Change Under Uncertainty

Some authors in the literature on 'entrepreneurship' claim that it is a somewhat broad term that lacks definition of what definitively defines it (Garavan and O'Cinneide, 1994; Rauch et al, 2009; Hitt et al, 2011; Amolo and Migiro, 2014). A common thread throughout the prominent literature is that entrepreneurs are often faced with conditions of heightened uncertainty (Knight, 1921; Schumpeter, 1934; Sarasvathy, 2009). This section summarises relevant literature on entrepreneurship in the context of the research question focused on systems change and uncertainty. It holds that entrepreneurs are fundamentally actors who apply agency to (1) facilitate systems change towards a preferred future; and (2) operate under conditions of heightened uncertainty.

Schumpeter's (1934) seminal economics work posited that the entrepreneurial process of translating inventions into innovations - with innovations defined as commercial realities in the economy rather than just new technologies in a laboratory - and the subsequent scaling of those innovations, is the driving force of 'creative destruction' whereby economic paradigms are continually replaced and renewed through the process of entrepreneurial endeavour (Schumpeter, 1934; Bower & Christensen, 1995).

Entrepreneurs operate in conditions of high uncertainty and complexity, and in his seminal work Knight (1921) posited that it is this uncertainty that constitutes the ultimate source of profit for an entrepreneur. This presents a stark contrast to how uncertainty is generally perceived outside of the field of entrepreneurship, where it presents a challenge and constraint on action (Abbott, 2005; Albrechts 2010; Albrechts & Balducci 2013; Gunn and Hillier, 2014; Rauws et al., 2014). Seen through the eyes of an entrepreneur, uncertainty reflects a general lack of knowledge that exists within a specific domain – creating space for novel and unique solutions. A defining feature of entrepreneurship is the necessary engagement with this uncertainty and agency in the face of it. Entrepreneurial agency is often embedded within uncertainty and ambiguous contexts that lack structure and can be plagued with constraints. In the face of generally constraining and difficult conditions for most actors within the economy, characterised by resource scarcity and monetary constraints, entrepreneurs see opportunity. Entrepreneurs act in ways which can be unique to the situation in order to create value, often linking invention to commercialisation with intentions of high-growth and scalable businesses (Global Entrepreneurship Network, 2017). In order to successfully manage and survive the 'start up' phase, entrepreneurs must work with a range of individuals, organisations and external subsystems (Patel & Mehta, 2016).

A large and growing body of literature suggests that entrepreneurial ventures are a result of the nexus between opportunity and agency – rather than just responding to an opportunity external from the entrepreneur (Shane & Venkataraman, 2000). In the same way that structuration theory suggests that agents and societal structures form a duality, a range of work in the entrepreneurship literature seeks to overcome the divide between 'entrepreneurs as individuals' and a given 'entrepreneurial opportunity' to more appropriately consider them both part of a dynamic and co-evolutionary process (Sarason, 2006; Shane & Venkataraman, 2000). In the same way that agents in socio-technical transitions theory apply agency to increase the structuration of preferred sustainable niche innovations, entrepreneurs are also agents within socio-technical systems applying agency to transform the system towards a preferred future. Entrepreneurs strategically implement new innovations and seek to scale them over time as structuration for the new innovation grows, shifting societal agency towards a preferred future where their innovation achieves significant scale. Regardless of an entrepreneur's motives - whether it be capital gains or social impact - the 'reward' is greatest when system change occurs as a result of their innovation.

However, overwhelmingly in the literature entrepreneurship is considered an individual phenomenon, where business ventures are focused on scaling to build wealth for the benefit of the business owners (Amolo & Migirio, 2014). There has been some broadening of the entrepreneurial process beyond founding or managing companies, however these mostly remain at the level of individual or organisation, rather than being considered an approach applicable at a systems governance level.

These examples of types of entrepreneurship can instead be considered the act and process of creating opportunity with limited resources, navigating uncertainty, and driving the structuration of new innovations to create value. It is the case that the literature has been expanded beyond the concept of capitalist entrepreneurship to other domains. There are many subsequent studies that have built on the six concepts listed below, however only some of the core and seminal works are referenced. Beyond just starting a new company for profit, examples of 'acting entrepreneurially' include:

- Social Entrepreneurship: Where entrepreneurial actors implement solutions to solve social, cultural and/or environmental issues (Emerson & Twersky, 1996; Leadbeater, 1997; Wee-Liang et al., 2005);
- Intrapreneurship: Entrepreneurial actors within existing (often large) organisations seeking to implement innovative new ideas (Stopford & Baden-Fuller, 1994; Shane & Venkataraman, 2000; Ağca et al., 2012).
- Civic Entrepreneurship: Public sector actors acting entrepreneurially by harnessing new ideas and new partnerships to solve local problems (Henton et al., 1997; Leadbeater & Goss, 1999);
- Academic Entrepreneurship: Academics and researchers adapting their behaviour and research to be more focused on commercialisation, furthering research and increasing impact (Balazs, 1996);

- Institutional Entrepreneurship: Actors leveraging resources to create new institutions or to transform existing ones (Maguire, Hardy & Lawrence, 2004; Garud, Hardy & Maguire, 2007); and
- Policy Entrepreneurship: Acting in an entrepreneurial manor to leverage networks and opportunities to influence policy outcomes (Kingdon, 2003).

These six examples illustrate where 'entrepreneurial behaviour' is applied in a range of contexts outside of a start-up business, creating a much more multi-dimensional view of what it means to be entrepreneurial, while using the same framework of analysis as traditional entrepreneurship (Olsson et al., 2015).

Entrepreneurship in summary

In summary, *entrepreneurs are agents of systems change under conditions of heightened uncertainty*. However, the process of entrepreneurship is *mostly considered an individual phenomenon*, rather than broadly accepted as *a process that can be applied at a systems/governance level*.

2.4 MULTI-DISCIPLINARY DISCUSSION

The literature reviewed in this chapter has spanned multiple disciplines. For simplicity, each of the subsections of this chapter have culminated in a summary definition. These summary definitions are:

1. **Urban Governance:** Urban governance in the 21st Century faces *increasing complexity and uncertainty*. Governance is more than governments, as governments must *blend resources* with private and community sectors in a *flexible and permeable way*, while *responding to local conditions and challenges in localised ways.* Governance today must be capable of *facilitating systems change towards sustainable development* under *conditions of heightened uncertainty*.
   Systems Change: Transformative system change for sustainability is a process of *applying agency to increase the level of structuration of sustainable socio-technical innovations* to the point that they form a new, established socio-technical regime. *Strategic Niche Management* has been highlighted as a key governance approach *for facilitating the structuration of niche innovations*, however, has had limited practical application especially for scaling up innovations.
2. **Uncertainty:** *Uncertainty constrains traditional decision-making processes* due to incompatibility with pre-existing models and formulas, and by doing so can *further embed the path dependency of unsustainable regimes*. In the process of enabling systems change towards preferred development trajectories, *urban governance must adopt new approaches for dealing with uncertainty* that *strengthen the systems' responsiveness to future unknowable events*.
3. **Entrepreneurship:** *Entrepreneurs are agents of systems change under conditions of heightened uncertainty.* However, the process of entrepreneurship is *mostly considered an individual*

phenomenon, rather than broadly accepted as a process that can be applied at a systems/governance level.

The previous section identified that modern urban governance requires the ability to deal with complexity and uncertainty while responding to major ecological, societal and economic imperatives. The process of facilitating 'systems change' in response to such imperatives is defined as a process of socio-technical transition, aimed at fostering the increased structuration of new sustainable socio-technical configurations over time, such that they form part of the prevailing socio-technical regime that exists within society. This process is the focus of much academic research that has identified factors such as technology, science, consumer preferences, policy and socio-cultural regimes as crucial to enabling such transitionary processes. These processes require multi-sectoral governance approaches to coordinate actors and iteratively expand new innovations.

While predominantly focused on the founding of new businesses, entrepreneurship as a discipline has some immediate synergies with the objectives of governance for systems change, as identified in this literature review. Entrepreneurs apply agency to facilitate systems change. They operate within resource constrained environments with heightened uncertainty. Concepts like uncertainty that are often synonymous with challenge or constraint, for entrepreneurs have been posited to be the very source of opportunity. It is no surprise then that 'entrepreneurial approaches' have developed over time to deal with such factors. This prompts the query, can urban governance actors who are focused on facilitating the structuration of a new sustainable socio-technical innovation, apply the same approaches entrepreneurs use to increase the structuration of their businesses within the same complex, multi-stakeholder socio-technical systems?

The broadly-defined concept of 'entrepreneurial governance' describes how governments and civil society can act entrepreneurially to achieve their goals given resource constraints, uncertainty and other challenges that entrepreneurs not only face, but have developed skillsets to address (Link & Siegel, 2007; Olsson et al., 2015). Local governments often suffer from resource shortages, and also seek to facilitate economic growth, leading to examples of local government action being labelled 'entrepreneurial' in achieving these outcomes (Wilks-Heeg et al., 2003; Olsson et al., 2015). After all, one of the core features of entrepreneurship is an ambition to create value, which for individuals often takes the form of private wealth (Hitt et al., 2011). However, such value creation can occur for governments in the form of economic development, job creation, reduced pollution, green space, cleaner cities, and healthier and more productive populations (Frederick et al., 2013).

Policy entrepreneurs, mentioned in Section 2.3, apply entrepreneurial strategies to mobilise support from a range of stakeholders or decision-makers which require many of the qualities that successful business entrepreneurs must employ to mobilise support for new ventures – such as networking and brokering

(Pozen, 2008). Within the realms of policy and business, and all other types of multi-sectoral entrepreneurship, agents acting entrepreneurially must navigate existing societal structures of resources, institutions and stakeholders (Olsson et al., 2015). Often these contexts feature complexity, uncertainty, and agents have an ambition to achieve a new reality against a much more structured existing regime.

It is evident from the areas of literature listed above that there are ongoing efforts to translate entrepreneurship beyond the business domain, illustrating the potential for entrepreneurship to expand beyond a subset of individuals within society that are considered 'entrepreneurs'. Given the synergies between sustainability transitions and entrepreneurship evident from this literature review, and particularly the agency required to bring about systems change in each context, this research posits that entrepreneurial approaches have the potential to inform 21st Century urban governance processes if it is adopted by actors within society such as governments, non-profit entities, community groups, individual champions and large corporations. In adopting entrepreneurial approaches, these societal actors may be better equipped to apply agency in the face of uncertainty to drive the increased structuration of niche innovations for system transformation.

Sustainability transitions have a tendency to focus on the role of governments and incumbents as the key influential actors within socio-technical systems who hold the most potential to accelerate transitions. In contrast, the Strategic Niche Management (SNM) literature which focuses on niche innovations and therefore has the most relevance to new venture creation, where entrepreneurs are often credited for their ability to generate 'radical innovations' and bring them to market. The focus is on fostering early stage niche innovations, with the role of SNM at a governance level being to implement protection measures from external market pressures for such sustainable innovations. However, the role of entrepreneurial approaches in facilitating the increasing structuration of niche innovations into transformational regimes, at a systems level which is the focus of SNM, rather than an individual business level, is not well defined. To date, translating entrepreneurial approaches to a 'niche management' context has not been achieved to the extent that it could be readily applied at a governance level by multi-sectoral urban governance stakeholders.

While the SNM literature has evolved over the past 10 years from a research analysis framework to an operational tool, there is no single unified and agreed approach for applying SNM that is of a satisfactory standard for practitioners - with critiques of SNM highlighting the lack of practical recommendations to guide the model's application in practice (Mourik & Raven, 2006). Given that SNM has predominantly been used as an analytical framework for assessing historical transitions, recent literature has focused on translating it to a practical tool that can be applied by practitioners. SNM currently remains somewhat of a 'technology first' approach, in that it leads with the selection of a preferred niche innovation and then seeks to support this innovation through various mechanisms while conducting learning experiments. While the

experimental approach aligns with the conventional entrepreneurial approach, SNM has been limited in its success of scaling innovations to greater levels of structuration beyond protected market niches. Explored further in Chapter 4, the SNM process resembles that of entrepreneurial 'causation' logic (Sarasvathy, 2009), in that it consists of traditional strategic management decisions that centre around a preferred innovation, strategically organised networks and hypothesis-driven analytical targeting of market niches.

A key challenge identified in the SNM literature is the need to balance protection mechanisms while allowing new innovations to establish their own competitive advantages so that they are not reliant on protection for survival. Returning to structuration theory that underpins the multi-level perspective and drives the structuration of new innovations – demand must be present from the market to build traction for a new niche to scale. The risk associated with supply-side or technology push approaches to niche development is that the fundamental demand needed to increase structuration of a new innovation over time is not authentically developed. Governance approaches that seek to address complex challenges, such as mitigating human-induced climate change, lowering carbon-emissions and other environmental threats such as the pollution of water, air and soil, must be effective in inducing increasing structuration of new practices that are aligned to sustainability. This will not come about through a 'technology push' approach as without the demand-side 'social' embeddedness of a new innovation, it is likely that the innovation will not succeed based on its technical performance alone. While the SNM approach is conscious of this necessity, and involves processes of experimentation and iteration with networks to allow co-evolution of new innovations with markets, the approach is still one that begins with a product and market niche, and designs experiments based on hypotheses about a pre-determined market niche. This is in contrast to the 'effectual' entrepreneurial approach developed by Sarasvathy (2009) that is highly suited to uncertainty, involves partners from an earlier stage in the innovation process, and allows pre-commitments to shape the trajectory of the niche. This type of partnership-first approach resembles the new model of permeable and partnership-based governance called for in the literature, and has demand and structuration embedded in its very logic. This is explored further in Chapter 4.

Gaps emerging from the literature review

The overarching gaps emerging from this synthesis of the relevant research fields are (1) the lack of linkage between broader governance fields and the entrepreneurship domain and (2) translation of entrepreneurial approaches to the strategic management of innovations at the systems level in the face of uncertainty – a context in which entrepreneurs find opportunity. These overarching gaps indicate other gaps.

Firstly, the role of entrepreneurial agency is under-emphasised in the sustainability transitions literature. This is particularly the case in civil infrastructure contexts, where in both research and practice there is a predominant focus on the role of governments as primary actors. Partnerships with the private sector (Public

Private Partnerships) are increasingly implemented globally to address the critical infrastructure gap. As a first step in establishing the validity of translating approaches from the entrepreneurship literature to the urban governance field, Chapter 3 interrogates the role of entrepreneurial agency in historical transitions in a civil infrastructure context.

Secondly, although SNM acknowledges entrepreneurs as drivers of innovation and participants in niches, there is no translation in the literature of specific entrepreneurial frameworks to inform the SNM process itself, especially for the purposes of contributing to the ongoing translation of SNM from an analytical framework to a practical tool. Further, because there are multiple schools of thought within the broad category of 'entrepreneurship literature', the sub-set of entrepreneurial approaches or methodologies applicable to systems change under uncertainty remains undefined. To address this second gap, which is central to the contribution of this thesis, Chapter 4 develops a framework for conceiving 'urban governance' typologies. This framework is adapted from the strategic management literature for assessing types of governance against the dimensions of uncertainty and systems change. It is then used to identify the appropriate entrepreneurial logic – effectuation, an approach to entrepreneurship that is grounded in an ability to facilitate systems change while dealing with uncertainty. Chapter 4 focuses on developing and elucidating an 'effectual' entrepreneurial approach to SNM.

Part 2 of this thesis further elucidates this approach in a civil infrastructure context, drawing on multiple case studies from urban projects around the world to illustrate how the 'entrepreneurial' concepts (that are translated from the entrepreneurial literature) are not only relevant, but are indeed evident in many successful urban projects.

CHAPTER 3

ENTREPRENEURIAL AGENCY AS A DRIVER OF URBAN SYSTEMS CHANGE THROUGHOUT HISTORY

3.1 CHAPTER OVERVIEW

The literature review identified that agency is inherent to the structuration of new innovations. It also indicated that entrepreneurship, as a process of driving structuration of new innovations in conditions of heightened uncertainty, has potential to inform broader governance efforts at a systems level to support the structuration of sustainable socio-technical configurations. This chapter focuses on the role of entrepreneurial agency as a key driver of urban systems change throughout history. The chapter examines contexts of innovation that are closely tied to infrastructure. These are the steam engine, railways, the electrical grid and the automobile.

Over the past century, the provision of civil infrastructure in cities around the world has increasingly been considered the responsibility of governments. Similarly, in the sustainability transitions literature, there is an overwhelming focus on the role of public policy in facilitating transformative systems change, with a common criticism being the neglect of agency and actors (Smith et al., 2005; Shove & Walker, 2007; Genus & Coles, 2008; Bakker, 2014). This chapter, seeking to address this criticism, argues that entrepreneurial agency has been central to historical waves of innovation. Further, the chapter reinforces the premise that given the role of entrepreneurial agency in past transitions, there is potential for such an approach to play a central role in driving the modern day wave of innovation in-line with sustainable development. The chapter specifically distinguishes between technological advancement and entrepreneurial agency, given that the technologies capable of underpinning sustainability transitions and mitigating human-induced climate change are broadly acknowledged to already exist (von Weizsaecker et al., 2009; Hawken, 2017).

This chapter presents multiple case studies following Yin's (2003) multiple case study methodology that are then analysed using thematic analysis (Braun and Clarke, 2006) to interrogate the application of entrepreneurial agency in historical socio-technical transitions. Four examples of past transformative technological advancements are reviewed and presented in short case study form. Short form is used here, as although the cases were studied in detail, their presentation in this chapter does not seek to account for each and every element of the respective period in history. Rather, the focus is on the role of entrepreneurial agency in response to the under-representation of this in the wider socio-technical transitions literature. The case studies on the steam engine (Section 3.4.1), railways (Section 3.4.2), the electrical grid (Section 3.4.3) and the automobile (Section 3.4.4) demonstrate a significant breakthrough in technology with socio-technical infrastructure implications, i.e. both in technological terms and also in terms of broad adoption and social use.

Following the case studies, a qualitative, thematic analysis of the demonstrated examples of agency in each instance is presented (Section 3.5). This analysis informs the subsequent open- and theory-guided

discussion (Section 3.6) (Glaser & Laudel, 1999) of entrepreneurial agency as distinct from technological advancement in the context of 21st Century sustainability transitions.

3.2 CONTEXT

Policy makers (Huhne, 2011), academic analysts (Stern, 2011; 2015) and environmental diplomats (Figueres et al., 2017) have likened transformative systems change towards sustainable development to the scale of the industrial revolution as it reflects the significant shifts in technologies, institutions, and practices associated with the productivity gains and increases in economic welfare gained during that period (Rifkin, 2011; Pearson & Foxton, 2012). Industrial transformation towards sustainable development represents a sixth 'Wave of Innovation', and is focused on low-carbon energy, pollution reduction, resource conservation while creating enhanced productivity, as depicted in Figure 3-1 (Hargroves and Smith, 2005).

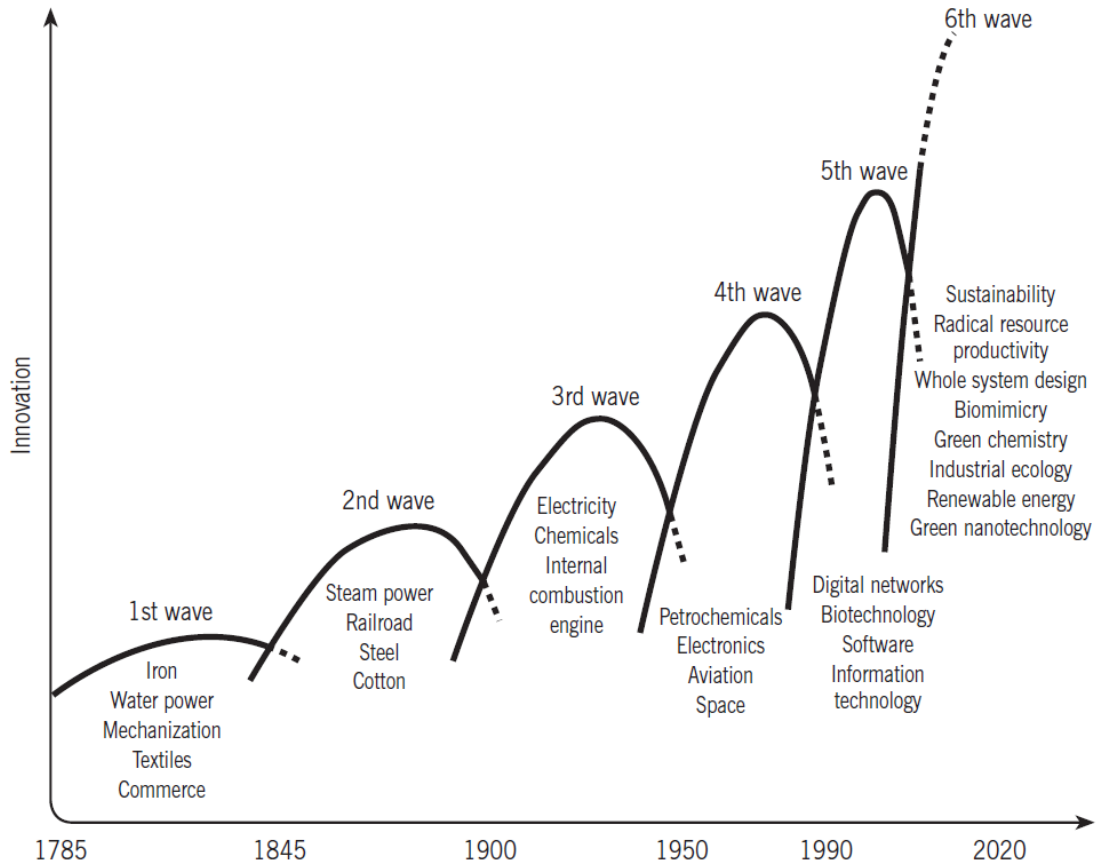


Figure 3-1: Waves of Innovation (Source: Hargroves & Smith, 2005)

The industrial revolution's waves of innovation have been studied in depth for their nature and implications; there has been less focus however on how to steer the direction of technological advancement to achieve preferred goals, such as reducing pollution (Fouquet, 2012b; Hargroves, 2015). Mathews (2013) identifies a disconnect between the current low-carbon energy transition taking place, and the well-established literature on innovation, entrepreneurship and techno-economic paradigms. A

perennial argument in this arena is that it is the responsibility of governments to accelerate a low carbon transition, because low-carbon technologies and infrastructure are perceived to primarily provide a 'public benefit' in mitigating the environmental impacts of climate change, rather than provide a purely private benefit to individuals or firms (Smith et al., 2010).

Since the 1950s, the responsibility for infrastructure provision has overwhelmingly been considered the responsibility of governments. The literature on sustainability transitions has a strong focus on policy interventions to improve governments' ability to facilitate change towards sustainable development - further reinforcing the role of governments as central to transition processes (Geels, 2010; Loorbach, 2010; Smith et al., 2010). As identified in the literature review in Chapter 2, it is now widely acknowledged globally that civil infrastructure governance models must adapt to respond to trends such as population growth, rapid urbanisation, resource shortages, climate imperatives, and changing technologies; a central tenet of these new models is an increased level of productive collaboration with the private sector.

Despite the public sector driven infrastructure paradigm of the 21st Century, history tells us that governments have not led transformative changes in technology, energy and infrastructure – as this chapter explores (Pollitt, 2012). A common criticism of sustainability transitions literature is the under-representation of agency and actors, particularly private sector agency in sustainability governance (Smith et al., 2005; Shove & Walker, 2007; Genus & Coles, 2008; Bakker, 2014). In cases where the private sector is acknowledged with an important role to play in governance for sustainability transitions, it is common for the role of large incumbent companies to be frequently emphasised (Smith et al., 2005; Hörisch, 2014). The role of entrepreneurship is especially lacking despite being a central driver for waves of innovation and systems transformation of all kinds both throughout history and in the modern day.

Socio-technical systems literature places significant focus on the advancement of technology for socio-technical change. While the invention of new technologies has been extremely important throughout history, it has been insufficient for creating widespread transformation alone (Allen, 2012). As established in Chapter 2, central to Joseph Schumpeter's seminal work on innovation is the entrepreneur's role in implementing innovations that drive the evolution of economies (Schumpeter, 1934; Perez, 2009). A key distinction made by Schumpeter is the difference between technological inventions and innovations. Innovation is the commercial realisation of an invention, which arises from entrepreneurial agency. When observing truly transformational technologies, invention is not enough. The level of uptake of new technologies is often directly influenced by entrepreneurial agency.

Many sustainability transitions authors have used historical case studies to illustrate the concepts that now form an established field of literature. Geels (2002) in his original paper on socio-technical

transitions and the multi-level perspective detailed the transition from sailing ships to steam ships during the industrial revolution. The following sections of this chapter highlight how four transformative technologies from the industrial revolution had, and have, significant implications for broader socio-technical infrastructure regimes. These four examples also illustrate the role of entrepreneurial agency in spurring such change. At the time, each of these innovations catalysed socio-technical systems change and created a foundation upon which much more innovation has occurred. In the 21st century, each of the socio-technical paradigms presented here is undergoing advancement to a low-carbon form. This indicates a shift towards system change and sustainable development while maintaining the social function that these technologies provide. However, both current governmental ambition (UNFCCC, 2021) and progress in reducing global emissions (IPCC, 2021) are still lagging behind what is needed to satisfy global climate change mitigation imperatives.

3.3 STUDY DESIGN

This chapter applies a multiple case study methodology as defined by Yin (2003), combined with thematic analysis for cross-case analysis as defined by Braun and Clarke (2006). Because sustainability transitions is a socio-technical phenomena, a qualitative case study approach has been chosen for understanding transition processes on both an individual and group level, with this approach more applicable to this analysis than purely quantitative, technology focus. Because sustainability transitions involve not only the changes to norms, values, and practices of individuals and communities but also the strategies deployed by actors in bringing about the structuration of new configurations, a qualitative case study approach was selected to construct both a social and technical view of the transitions investigated.

Various authors have discussed the limitations of a technology-centric focus for the analysis of the socio-technical processes that underpin sustainability transitions (Seyfang & Smith; 2007; Geels, 2010; Hodson & Mavin, 2010; Loorbach et al, 2017). A technology-centric approach can neglect the broader social dynamics, including actors and their strategies (Geels, 2010; Loorbach et al, 2017). Given that sustainability transitions requires not only technological change but social and institutional change where the role and strategies of actors are key (Seyfang & Smith, 2007; Hodson & Marvin, 2010), this chapter focuses on the strategies employed (in the form of entrepreneurial agency) to drive major socio-technical change throughout history.

This study has been designed to respond to the guiding research question of this chapter: ‘What role has entrepreneurial agency played in urban systems change throughout history?’ Case study was assessed to be the most appropriate study methodology for addressing this question, as primary and secondary sources of data (such as historical documents) can be used to construct a nuanced understanding of historical events in the absence of conducting direct interviews. Similarly, historical documents and

accounts can provide a diverse set of data to construct case studies in historical contexts where modern-day quantitative data is not available.

Yin's (2003) case study methodology was used to guide the design of the study (see Figure 3-2). Multiple case study approaches were considered – with focused consideration of two leading methods proposed by Stake (1995) and Yin (2003). Overall, Yin's approach was deemed more suitable for this study, due to: (1) Yin's approach placing a greater emphasis on theory development during and after the research process, rather than the development of a theoretical framework before the research is conducted as per Stake's approach; (2) Yin's approach placing a greater emphasis on using more data within an available data collection method (in this case historical documents and accounts) rather than Stake's approach that places greater emphasis on multiple data collection methods (e.g. surveys, interviews, focus groups) which are not possible for these historical actors; and (3) Yin's cross-case analysis approach which lends itself to developing theory and generalisations across multiple cases, which is more relevant for this research as the research question is positioned to develop theory and learnings that are applicable across urban sectors.

The four case studies selected for this analysis are the steam engine, railways, the electrical grid and the automobile – which are each transformative technologies that intrinsically link infrastructure, cities and society. Each case focuses on a critical period of development for each technology and considers both the technological elements, social elements, and actor strategies associated with their breakthroughs. Each case seeks to extract examples of entrepreneurial agency in the approaches and actions of the individual actors pivotal in the structuration of the technologies. The entrepreneurs in focus are James Watt and Matthew Boulton (Steam Engine), Matthew Brassey (Railways), Thomas Edison (Electrical Grid) and Henry Ford (Automobile). Each case study was constructed using the textual analysis of peer-reviewed journal papers, books and historical accounts related to the history of technology, technological advancement, and biographies of the individuals in focus.

As per Figure 3-2, thematic analysis (Braun and Clarke, 2006) is applied to identify cross-cutting themes across the case studies. Braun and Clarke's thematic analysis was selected as it is flexible and adaptable to different types of data and is an iterative process that allows for the refinement and development of patterns that emerge from the data across case studies as new data or information is encountered (Braun & Clarke, 2006).

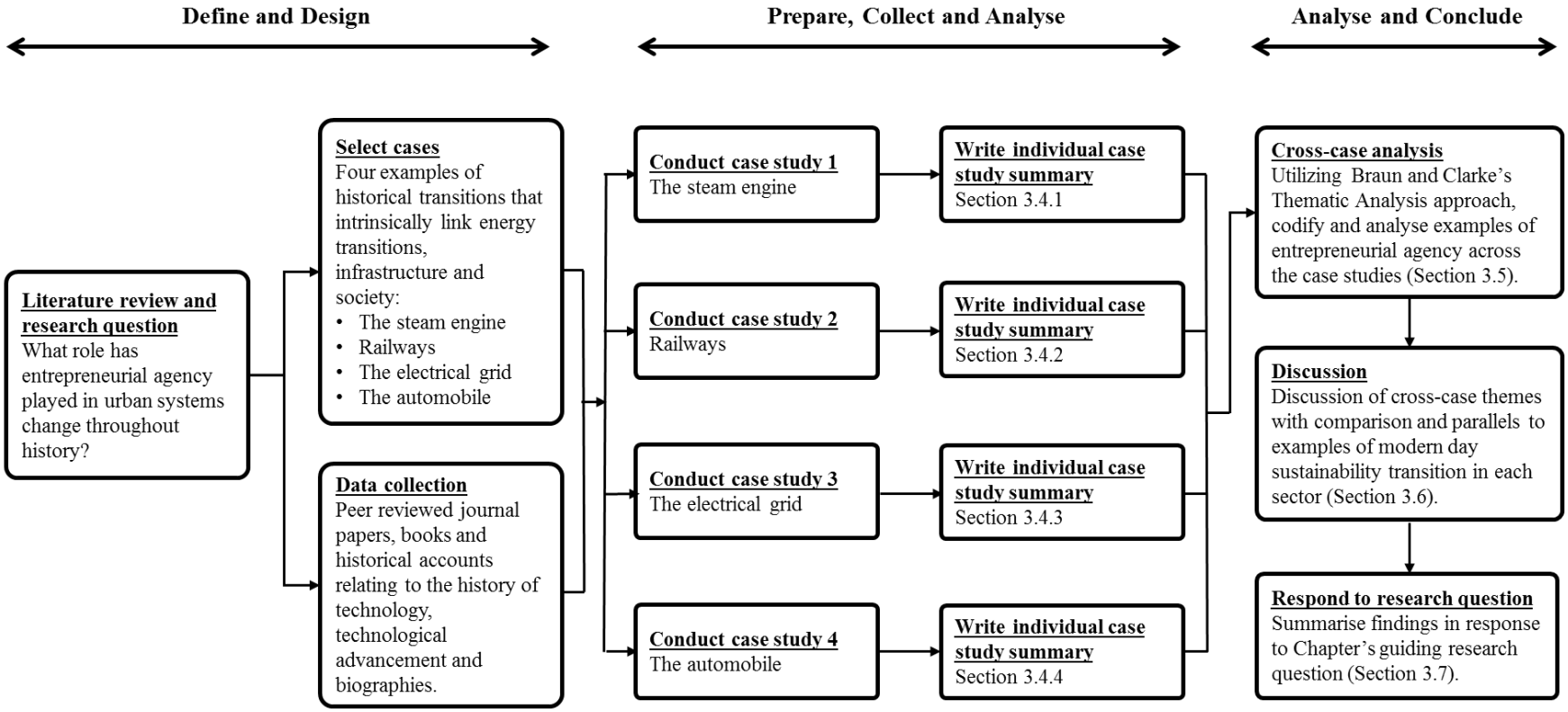


Figure 3-2: Multiple Case Study Design based on Yin (2003)

3.4 CASE STUDIES

The following four historical accounts are presented in the order which they occurred since the industrial revolution. The historical cases are tied together by their relevance to industrialisation and the subsequent shaping of civil infrastructure systems that resulted from ongoing innovations within the systems they underpin.

3.4.1 The Steam Engine: A Partnership Between Inventor and Entrepreneur

The steam engine was arguably the most vital, enabling innovation of the industrial revolution. Its inventors represent one of the most impactful business partnerships of the industrial age: James Watt and Matthew Boulton. James Watt was a Scottish inventor and engineer who, in the late 1700s, conceived of a steam engine design that could double the efficiency of existing machines. The key differentiating characteristics of Watt's design were its separate condenser, and further modification of the design to allow the steam engine to create rotational motion. Watt is now famous for this contribution to the industrial revolution: The System International (SI) unit of power being called a 'Watt'. Matthew Boulton, despite being crucial to Watt's success, is all but unknown. Boulton was a British mechanist and entrepreneur whose ventures included the production of metalworks, silver and plated wares, ornaments and toys in his Soho Manufactory. Boulton was one of the great entrepreneurs of the age and he had two motives in contacting Watt. First, he wanted to see if they could work together to develop Watt's proposed new design so that Boulton could use it in his Soho Manufactory; and secondly, Boulton saw the potential for building a business venture around this new machine (Andrew, 2009). Energy prices in Britain at the time were relatively low compared to labour wages, which created demand for anything that could improve the productivity of factories, and that could lower costs through mechanical means.

It is commonly misconceived that James Watt 'invented' the steam engine. The power of steam was first demonstrated around the first century by Hero of Alexandria (Hero, 1851). Early steam innovators included Taqi Al-Din, a 15th century philosopher, astronomer and engineer in Ottoman Egypt, who proposed a steam jack in his 1551 work 'The Sublime Methods of Spiritual Machines'; and Giovanni Branca, an Italian engineer and architect, who in 1629, proposed a so-called 'steam engine'. However, both engines had evolved little from Hero's original proposal (Lardner, 1840). The development of steam technology into something productive began in the late 1600s. In 1698, Thomas Savery, a British engineer and inventor, invented and patented a steam pump which pumped water from mines, a prominent challenge in 17th Century Britain. Then from 1705, and inspired by Savery's design, steam engines were built based on Thomas Newcomen's improved atmospheric pressure-driven design. While this design was relatively inefficient, it dominated the design of steam engine for decades, until Michael

Boulton reached out to James Watt after hearing of Watt's ideas. The initial enhancement conceived by Watt was the separation of the piston cylinder and the steam condenser after Watt realised that three-quarters of the steam's thermal energy was being used to heat the piston cylinder. That heat was dissipated later in the cycle by spraying water into the cylinder to reduce the steam pressure (Persifor, 1859). This change to the design doubled the efficiency of Newcomen's engine and was revolutionary because it resulted in the engine being able to produce the same outputs with far less fuel (Andrew, 2009).

Boulton approached Watt when he heard of his ideas. While Watt had conceived of his design in the early 1760s, until his partnership with Boulton there were 10 years of unsatisfactory progress (Hills, 2005). Andrew (2009) cites two reasons for this. Firstly, Watt was a 'diffident' inventor; he was constantly looking to improve and perfect his design; secondly, Watt required the production of a cylinder with much greater accuracy than what was available from Newcomen engines, making the new design expensive. The partnership between Watt and Boulton led to their commercial success, with Boulton providing the foresight, capital and motivation to drive - and match - market demand with Watt's inventing ability (Kelly & Kranzberg, 1975; Hills, 1993).

The following passage by Andrew (2009) highlights the critical role of Boulton's entrepreneurial approach in overcoming Watt's roadblocks:

> "Boulton was a great grasper of opportunities and a great networker of people. He got John Wilkinson, the ironmaster, to use his cannon-boring machine to produce an accurate eighteen-inch diameter cylinder for the experimental engine, then encouraged him to develop an accurate machine for boring larger cylinders. Boulton also constantly pressed Watt to be decisive and to finalise the design for each engine, going back to improve it later if necessary."

Only one year after Watt's move to Birmingham to work with Boulton (1775), the pair obtained a patent for the pump steam engine (Mason, 2009). Boulton initially sold the engine to owners of mines to pump water (Bolton & Thompson, 2013). The technology was innovative and Boulton offered an incentive to customers: They would pay for the purchase of new engines out of the savings they achieved on coal inputs when compared to traditional Newcomen machines. This 'no-savings no-fee' approach enhanced the appeal and uptake of Boulton and Watt's new engines (Andrew, 1995; Baggot, 2009), and they had saturated the mine market by 1781 (Bolton & Thompson, 2013). The next advance came when Boulton pressed Watt to develop a rotative engine which converted its linear motion into a smooth rotary motion needed to power machinery (Andrew, 2009), enabling the steam railways locomotive and the widespread expansion of their joint enterprise.

3.4.2 Railways: Driving the Rapid Expansion of the Industrial Revolution

One of the most transformative applications of the steam engine was to create the railway locomotive. At the time, the technology for land-based personal transport and freight was horse-drawn coaches, which is why the steam engine, as a technological innovation, was transformative. The subsequent expansion of railways, starting in Great Britain in the 19th Century, was used by Schumpeter (1934) to demonstrate how innovations drive economic evolution. As in the case of the steam engine, Jenks (2011) points out that while certain enterprising individuals played a significant role in the technology's success, a multitude of actors is required to create a paradigm shift at such a scale. The railways enabled greater distances to be covered in less time, and linked ports with production facilities and areas of agriculture previously not considered feasible by horse-drawn means. The success of the Liverpool-Manchester line in Britain in 1892 provides a glimpse of the potential of this next 'great surge of development' (Perez 2009).

The Liverpool-Manchester railway was the first railway constructed between two cities. George Stephenson and son's locomotive design, named 'Rocket', won a race against two other locomotives to cover the distance between Liverpool and Manchester. It became known as the 'steam horse'. This inter-city railway was a great success for transporting goods and people, and it ignited a 'railway mania' across Britain, as entrepreneurs built lines between a number of cities and towns (Bulliet et al., 2018). From a technological standpoint, Stephenson's design was a series of small incremental improvements to existing designs that, when combined, created a significant advancement in the technology (Casson, 2009). In contrast, competitor Isambard Brunel was adamant that he would implement his own ideas rather than build on the progress of others. His vision for a range of rail gauges that he thought would spur innovation further was not a commercial success. (Jenks, 2011).

By the 1840s, railway technology was maturing, and financiers and material suppliers were increasingly looking to contribute to new projects. The railway industry learned from the practices of the canal promoters for financing, as the majority of canals were developed by raising private capital through joint stock companies (Smith, 1999). As more lines were constructed, more opportunities to connect lines and offer additional services arose. This was seen as a lucrative entrepreneurial opportunity. Schumpeter notes this shift from 'innovations', which are characterised by the first phase of railways, where challenges and new solutions were developed, to the 'repetition', which followed during this subsequent period (Schumpeter, 1934; Jenks, 2011).

In 1844 there were 48 Acts passed for railway construction; the following year, a further 240 Acts were passed. Profits for shareholders continued to increase, and more money flowed in, until the market was saturated. Shortly after this mania phase, collapse followed and many investors lost money. However,

the railway mania had created the vast expansion of the British railway network that would underpin economic development and provide public benefit for decades to come.

Thomas Brassey, a British entrepreneur, played a significant role during this period. He expanded the railways throughout Europe, and across the world, during the 19th Century. He capitalised on railway mania. By 1847, he had privately constructed approximately one-third of Britain's railways, and had over 80,000 employees during the peak years of his career (Stacey, 2005). Notably, only about one in seven of Brassey's tenders were successful (Stacey, 2005), and Brassey even undertook unprofitable contracts to avoid needing to lay off his workers (Helps, 1805-1870). Brassey undertook most of his work in partnerships, working with other entrepreneurs such as Morton Peto, Edward Betts, Ferdinand de Lesseps and Henry Meiggs to expand the privately-pioneered railway approach around the world. This included the United States, Europe and Australia (Freeman, 1999), where land value was a significant impetus for their railway developments.

George Stephenson, the innovative locomotive designer, originally advised Brassey to become involved in the railway business. Stephenson, while predominantly referred to as an engineer, was much like Michael Boulton. He had an entrepreneurial approach to navigating uncertainty which was needed as following his success with the Rocket, uncertainties around railway construction multiplied as the network expanded to include more inter-city links. These uncertainties encompassed technological and economic uncertainties in categories such as power, construction, operation, demand and more, with most being either over- or underestimated during the first stage of the railways expansion (Casson 2009). Stephenson often overcame these uncertainties by assembling resources and partners to drive the uptake and expansion of the technology.

Such entrepreneurial approaches were a common characteristic of Britain's railway expansion, and of the industrial revolution more broadly. When France and the United Kingdom needed to develop railroad infrastructure, the market and its entrepreneurs led the British development, while the French relied on government-led concessions to engage private parties. In Britain, private interests almost entirely led the expansions of railways, with state-facilitated and regulated construction; in France under the concession system, the state chose the routes and required facilities, and then invited bids to supply it. The British had a complete rail network decades before the French (Winch, 2002), with the length of the British railways increasing from 160 km in 1830, to 10,000 km in 1850 (Anderson, 2009). Britain's superiority in civil and mechanical engineering was largely a result of the skills developed throughout the extensive work on railway development (Spielvogel, 2011).

In America, entrepreneurs used railways to unlock new regions for agricultural production and to create new cities, as geographical distance was a lot less limiting. However, the railroads were only part of the

picture. Railway development was linked to town promotion and real-estate speculation, as the new land value created by railway access was incentive for entrepreneurs to act (Jenks, 2011).

3.4.3 Electricity: Thomas Edison and Associates' Electrification of Society

Electricity is another technology that, like steam engines and railways, created the foundation for the emergence of many other technologies. Scientists were demonstrating electricity in the early 1800s; they included Alessandro Volta, the Italian physicist, who invented the first electric battery in 1800, and the British scientist, Michael Faraday, whose electric motor was used for power generation in the 1860s (Aunger, 2007). However, it was the American inventor and businessman Thomas Edison and his associates who shifted electricity from an invention to a household necessity, and enabled the electrification of America. In turn, this created a template for the rest of the western world to adopt electricity. While there were other very important actors during this time, such as Nicola Tesla, virtually every historical account of the development of the electric utility industry, from real-time industry publicists and federal investigators to recent academics, credit Thomas Edison, and later his employee and colleague Samuel Insull, as central to this process (McGuire et al., 1993).

Kerosene and coal gas had dominated the lighting industry in the 19th Century until the incandescent light globe emerged in 1879. Thomas Edison is often credited for inventing the light bulb but while he created the first *commercially viable* incandescent light as it was less intense than previous globes, making it ideal for indoor and domestic use, there were up to 22 inventors of various lightbulbs prior to Edison (Friedel, Israel & Finn, 1986). Hughes (2004) attributes Edison's overall success to his ingenuity within the overall electricity system, including generators and distribution networks, of which the bulb was an enabling component. Significant promotion accompanied the development and commercialisation of lighting, for example, it was showcased in high-class theatres and exhibitions, and it was perceived by the public as a powerful symbolic medium that represented progress and the Darwinian evolution of mankind (Nye, 2004).

Domestic consumers of lighting in the 1880s were predominantly wealthy, privileged individuals who installed electric lighting for social prestige. Even the majority of power entrepreneurs at this time considered electricity to be a luxury product for the privileged and many believed it would remain this way. The common approach to the electricity business at the time was to focus on the niche market of wealthy consumers which would avoid attracting additional customers who would "only require the borrowing of more money and the construction of expensive generators and distribution lines, which would increase costs and decrease profits*"* (Munson, 2005). In contrast, Edison conceived the incandescent light as an entrepreneurial opportunity for selling globes, he then also created a need for the associated distribution networks, so that electricity could power every home. Given this opportunity, Edison was fixed on centralised generation facilities that could be owned by the Edison Electric Light Company, rather than distributed, isolated generation where consumers could power themselves. At the

same time, a ‘war of the currents’ was occurring between Edison’s Direct Current (DC) and competitors’ Alternating Current (AC). Edison succeeded over his competitors and developed a system of centralised stations and local utilities across America, which shaped the city-electricity interface of the future.

McGuire, Granovetter & Schwartz (1993) portray Edison’s efforts in establishing his first centralised station in New York City:

> “The fundamental fact is that Edison overcame enormous technical and financial obstacles to erect the first power central stations. His heroic efforts first to finance and then to build the Pearl Street Station in New York, constantly improvising solutions to the most difficult problems, and working himself in the trenches (literally) with his men, have been chronicled many times.”

Edison did not achieve his success alone. He built teams that could contribute to achieving his vision, and also operated in close partnership with select individuals such as Charles Batchelor, whose technical background created many of the pair’s technical breakthroughs while Edison focused on the entrepreneurial engagement of clients and investors (Hargadon, 2013). Francis Jehl, who worked at his Menlo Park operation, said, ‘Edison is really a collective noun and means the work of many men’ (quoted in Lindgren, 1979:17).

Most of Edison’s innovations were based on others’ patents. He obtained them, sometimes evolved them, and then commercialised them. Edison was firmly focused on commercialisation opportunities and he amassed a record 1,093 patents throughout his lifetime, partly in thanks to his application of ‘mass production’ methods to invention at his industrial-research facility at Menlo Park. It was the first of its kind, eventually spanning two city blocks, and employing about 200 inventors. His move to New York to focus on the Pearl Street Station employed an extra 200 to 500 people (McGuire, Granovetter & Schwartz, 1993). One of Edison’s employees, Samuel Insull, was particularly influential in the expansion of Edison’s empire, and in the shaping of the industry. He was an early proponent of State legislation, and, representing his utility, shaped regulation in various states. This saw utilities operate on a cost-plus basis that enabled economies of scale, protection from competition, and unconstrained growth (Sine & David, 2003).

By 1930, a major shift from gas to electricity had occurred. Domestic electricity, which was once a novelty and/or luxury, was becoming a necessity. Edison’s lights had brought electricity to the home, and the electricity demands of cities were growing rapidly as a range of electric appliances came onto the market. Despite Edison being forced out of his own company by J. P. Morgan in 1892 when his company merged with General Electric, the Edisonian system was firmly embedded in the fabric of cities and their electricity supply. This included centralised generation, over J. P. Morgan’s preference for decentralisation, centralised manufacturing for the full range of products rather than J. P. Morgan’s

preference of small-scale, manipulable manufacturers, and credit arrangements that saw electrical equipment manufacturers wield great influence over utilities rather than this influence coming from financiers as J. P. Morgan advocated (McGuire, Granovetter & Schwartz, 1993). The widespread adoption of new types of electrical products, coupled with the development of the electricity grid, enabled a major increase in electrical energy to flow throughout society. Spurred on initially by Edison and his associates, as well as competing inventors and entrepreneurs, and then by this swift and vigorous expansion, electricity continued to replace other energy sources in households, industry and transport. In doing so it changed people's lives and created a widespread techno-economic paradigm shift that has since given rise to countless new products and opportunities.

3.4.4 The Automobile: Henry Ford's Vehicle for the Masses

The automobile revolutionised the western world. Building on advances in steam engines that were shown to be viable for vehicles from 1769, such as tricycles and tractors, the first 'road locomotives' were demonstrated by Richard Trevithick, a British mechanical engineer and inventor, from 1801. This was followed by a number of steam-powered automobiles that were used in the early part of the 1800s. Other electric and combustion vehicles were used during the 1800s, such as Charles and Frank Duryea's gasoline-powered motor wagon in America (Parissien, 2013). However, it was Henry Ford's innovation of mass production through the assembly line, and its accompanying affordability, that saw the internal combustion engine emerge as the preferred engine-type and that gave rise to the Age of Oil, even though it was originally designed to run on biofuels. In the late 1800s and the beginning of the 20th Century, automobiles, like electric lighting, were very expensive and were considered a luxury for the upper class. Many of the early entrants in the automobile production industry were firms that diversified from other markets, such as wagons, carriages and bicycles (Klepper, 2006). When Henry Ford revolutionised the manufacturing and production process of motor vehicles, he ignited a modern industrial revolution that would transform western civilization.

Henry Ford is considered by many to be the greatest entrepreneur in American history (McCormick & Folsom, 2003). Ford was an engineer and inventor and he envisioned a significant shift in transport, one in which the automobile could be accessible to more than just the elite. Henry Ford originally worked for Thomas Edison and was chief engineer at the Illuminating Company in 1896, tinkering with automobile design on the side. At this time, many groups and firms were entering the automobile market (Klepper, 2002). Ford assembled his first gasoline automobile in 1896, with the help of wealthy businessman William H. Murphy. Murphy had the capital to create a company that could make the production of Ford's vehicles a reality. In the years following Ford and Murphy's first venture in 1899, the company failed due to disagreements around production and specialisation.

Ford built a reputation through car racing to demonstrate the potential of his automobile designs. He entered into another business partnership in 1902 with coal dealer Alexander Malcomson, and named

this venture the Ford & Malcomson Company, which was renamed the Ford Motor Company in 1903 upon Malcomson's suggestion. Malcomson provided the majority of the funds to make this venture happen and in 1908, the Model T was released in line with Ford's vision. His vision cemented him as more than an inventor or engineer (Ford, 1922):

> "I will build a motor car for the great multitude. It will be large enough for the family but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one".

The design of the Model T was a major advancement in automobile design. It was lighter than other automobiles on the market, had a one-piece cylinder block and a detachable cylinder head making maintenance easier and cheaper. It was also built of strong materials and competed with the standard 'luxury' cars of the time in performance. By 1913, however, given the demand created by a vehicle cheap enough that it was available for the middle class and not just the privileged, the differentiating and revolutionary innovation intrinsic to the Ford Motor Company was underway: The assembly line. In 1909, the Ford Model T cost US$850 (Cross, 2002). Each incremental improvement achieved by the production process was reinvested by Ford into creating more efficiency; this ultimately contributed to the affordability of the product with the Model T costing less than $300 in 1924 (Ford Motor Company, 2017). The development of efficient assembly-lines was integral to this and the features adopted from the production of clocks and watches (jigs and fixtures for intricate parts), breweries (conveyors), and meat packers (progressive dismantling of animals, which Ford reversed and created a progressive production line where each worker added a part of the vehicle) meant the time required to build a car reduced from 12 hours to 90 minutes. This method facilitated the rapid spread of hundreds-of-thousands of automobiles over the coming years with the assembly line and the 'Fordism' approach being adopted by competitors and spreading to many other industries of consumer goods to define a new mode of American production.

Alongside the development of the assembly line at the Ford Motor Company, Henry Ford doubled the pay of his workers to $5 per day in 1914. He also reduced working hours to eight hours for five days a week (40 hours); this was in contrast to the standard 60 hour work week at the time. Workers were required to meet a number of criteria to be eligible for these benefits, including a good moral character, a clean home, and a savings account (Watts, 2005: 200-201). While these criteria are perceived as controversial in contemporary society, at the time they significantly lifted morale, which lead to greater productivity and factory outputs. The increase in pay also allowed the workers to afford a Model T themselves, and this further increased demand for the vehicles. By 1927, there was a Ford Model T being produced every 24 seconds, and an accumulative total of over 15 million had been sold (Ford Motor Company, 2017). The Model T's impact was profound, it was only the lack of innovation in the

design after the release of this model that led to Ford losing a significant market share to General Motors (Howleg, 2004).

Under the leadership of Henry Ford, the Ford Motor Company, shifted the automobile from a luxury item of privilege to a common artefact for the masses. Henry Ford's ingenuity as an inventor also extends to a reputation as someone who innovated outside of a strictly technical frame, who changed the way workers and processes functioned to achieve radical productivity improvements to expand his product across the economy. He had addressed issues of the day and was, in his view, empowering the everyday citizen to be free from their geographical constraints. Making the car affordable to the masses also had a profound impact on how cities were structured over the coming century, and environmental implications as the widespread economic integration of the car gave rise to oil-fuelled automobile dependence (Newman & Kenworthy, 1989; 1999; 2015).

3.5 THEMATIC ANALYSIS

Thematic analysis was used to first identify examples of entrepreneurial agency in the approaches and actions of each individual actors' case. These individual examples were each coded, with common themes of agency across the four technologies, then synthesised and clustered together to develop a broader theme/concept. The investigation focused on actions and approaches within the control of the inventor-entrepreneurs rather than opportunistic, external events that were outside of their control. As such, the findings are not representative of all examples of 'entrepreneurial agency' presented in the literature identified in Chapter 2.

The thematic analysis, following Braun and Clark (2013), began with the codification of individual approaches. Each code represented one 'idea' in the context of a conventional thematic analysis (Braun & Clarke, 2013), or one 'action' or 'approach' taken in this context (Table 3-1). The second stage of the thematic analysis then captured the broader themes of actions taken by actors in each example (Table 3-2), with each theme clustering similar approaches evident in each of the case studies.

Approaches were then grouped into themes, distinguishing between technology-related actions and actions reflective of entrepreneurial agency. This provided more clarity as it identified and simplified the different approaches for discussion purposes. Specific approaches replicated across the case studies were grouped to form common approaches (Table 3-1 and Table 3-2). A saliency analysis was incorporated to allow less frequently appearing but important approaches to remain (Braun & Clarke, 2013). The approaches identified in each theme were then expanded to highlight additional applications of already-identified entrepreneurial behaviours and approaches beyond those identified in the initial review.

Table 3-1: Examples of agency across four transformative technology innovations

Steam Engine	Railways	Electricity Grid	Automobile
- Seek out innovative ideas **yet to be commercialised** (Boulton approached Watt with the intention to commercialise his ideas). [EA2] - Begin with a clear **initial application** in mind (Boulton wanted a more efficient engine for his own factory). [EA6] - Establish **access to capital** (Boulton brought with him the capital to commercialise Watt's inventions). [EA3] - Desire to build a **business venture**, rather than fixate on the technology (Boulton developed multiple markets for Watt's technology). [EA2] - Focus on **network building** (Boulton was renowned for his marketing and sales flair and as being a 'networker of people'). [EA5] - **Creative approach** to problem solving (Boulton found new ways to overcome issues using low cost solutions available to him). [TA3] - **New business models** (Boulton created a repayment system based on bona fide savings compared to alternatives in the market). [EA7] - **Continually evolve** products to satisfy changing markets (The creation of the rotating steam engine capable of powering machinery). [TA4]	- **Incremental improvement of existing technologies** for new applications (Stephenson improved existing technologies to create a superior version). [TA1] - **Combining components** that are already accessible, without having to be something completely new (Jenks, 2011) [TA1]. - **Access new sources of investment** and funding by linking opportunities (such as linking land use opportunities with transport infrastructure). [EA3] - **Partnerships and collaboration** to overcome uncertainty (Casson, (2009) cites 23 technological and economic uncertainties that were overcome) [EA4]. - **Persistence** (For every one of Brassey's successful tenders, six were not accepted). [EA10]. - **Leverage own expertise** to expand into new markets (Brassey out-bid for projects in other countries using British expertise gained from first-mover advantage) [EA8]. - Exploitation of opportunities **despite other competition** in the market (Additional entrepreneurs were not discouraged by the large multitude of competition in the early railway market) [EA2].	- **Building on existing designs** and solutions that are already accessible (Edison was not the first to design a lightbulb but was the first to make it economically feasible) [TA1]. - Creating an empowering **vision for the future** (like Edison striving to have a light bulb in every home). [EA1] - Focus initially on **affluent customers** (like Edison targeting the wealthy and positioning the electric light as a sign of affluence). [EA6] - **Focus on a niche application** that can solidify the necessity for the wider system (Edison used the light-bulb to necessitate the electrical grid network). [EA6] - **Create a system** around your innovation or at least be clear how it fits into the existing system (Edison created an electricity grid to support his electric lightbulb, locking him in as an energy supplier). [EA11] - Link the innovation to a **social status** or **brand** (like electric lights being seen as a sign of status). [EA6] - **Create teams** ('Edison is really a collective noun and means the work of many men') [EA5]. - **Work with regulators to shape policy** and legislation around the new technology (Edison affecting utility legislation in New York) [EA12].	- Have a **vision that serves a social purpose** (Ford's vision was to enable every family to have a car, freeing them geographically). [EA1] - Treat **failure as an opportunity** to advance (Ford failed in multiple ventures before the Ford Motor Company) [EA10]. - Strive for **design standards that compete** with 'luxury' products in performance (Ford's automobiles achieved a number of design improvements that made them competitive with luxury options) [TA2]. - **Learn from other industries** (Ford learned from watch-makers, brewers and meat packers) [TA3]. - Focus on **efficiency in production processes** and worker output (such as Ford innovating the modern production line) [EA7]. - **Reward your workers** and look after their wellbeing (like Ford offering the '$5 day' and setting working hours to 5 days of 8 hours per week). [EA9] - **Enable new demand** for products (Ford was driven to make the car affordable for his workforce). [EA7] - Shift a product from a **niche market to a mass-market** (Ford was set on reducing the cost of the automobile to make it 'available to the masses') [EA7].

Table 3-2: Emerging themes of agency

Code	Emerging themes of agency
[TA]	**Advancement of Technology**
[TA1]	Incrementally improve or combine components of existing, accessible technologies for new applications
[TA2]	Strive for leading design standards that out-compete market-leading or luxury products
[TA3]	Look for opportunities to apply methods and technologies from other industries
[TA4]	Continually evolve products to satisfy changing markets
[EA]	**Entrepreneurial Agency**
[EA1]	Have a vision that serves a societal purpose
[EA2]	Focus on creating commercial ventures rather than purely the invention/advancement of technology
[EA3]	Establish access to capital to fuel business growth
[EA4]	Establish partnerships and collaborations
[EA5]	Invest in the creation of networks and effective teams
[EA6]	Establish initial application that allows a new innovation to gain a foothold in the market upon which future business expansion can occur
[EA7]	Unlock new demand by facilitating access to non-traditional customer segments
[EA8]	Leverage own expertise to gain a competitive advantage or expand into new markets
[EA9]	Reward workers and look after their wellbeing
[EA10]	Treat failure as an opportunity to advance
[EA11]	Create a system or infrastructure around your innovation
[EA12]	Work with regulators to shape policy and legislation around the new technology

The assessment posits that entrepreneurial agency plays an important role in socio-technical systems change, beyond the invention of new technologies. As per Braun and Clarke's thematic analysis approach – initial codes were first generated from the list of approaches extracted from the case studies presented in Table 3-1. A search and review exercise was undertaken to firstly search for themes across the approaches, with examples of agency aligned to technology advancement and examples of agency of entrepreneurial nature emerging from this thematic analysis. The case studies and associated

approaches were then reviewed against these themes to ensure the themes were robust and reflected in the data. The two themes that emerged across the case study, each of which are described in this section in the context of the case studies are:

1. *Technological Advancement [TA]:* These approaches are technology-centric and are within the realm of 'invention', focused on the processes of advancing technologies;
2. *Entrepreneurial Agency [EA]:* These approaches are specifically focused on 'innovation' as opposed to 'invention' as described by Schumpeter (1934), in that they are strategies that focused on the broader application/commercialisation of technology within society.

Advancement of technology

Each of the transformative cases presented in this chapter explicitly depicts how Technological Advancement [TA] enabled progress in socio-technical systems via the development of new, improved technologies with greater efficiencies, offering new technologies to society. The four technologies discussed in this chapter were all developed through a process of iteration and improvement of previous technologies [TA1]. In some cases, this took the form of a direct improvement of a specific technology, such as Watt's improvement of the Steam Engine's efficiency; or, in Ford's words: "I invented nothing new. I simply assembled into a car the discoveries of other men behind whom were centuries of work" (Gordon, 2001). In other cases, it was the combination of previously separate components, such as Stephenson's combination of locomotive innovations that had undergone some 30 years of previous mechanical development for the railways (Simmons, 1961), or Edison's breakthrough in bringing together the light bulb with energy transmission technologies.

The four case studies also highlight the importance of new technologies being able to compete in the market with other substitutes/options [TA2]. Boulton encouraged Watt to maximise the performance of the engine so it was recognised as the leading technology. The railway locomotive outperformed other engine alternatives (gravity or stationary), and far exceeded the capabilities of the horse-drawn cart. Edison's electric light was much safer than the existing gas alternative and became more affordable. While Ford could have created a cheaper automobile of lesser performance than the current market-leading 'luxury' vehicles, his innovations in materials, machinery, processing and efficiency enabled a technologically-matched vehicle for a much lower price.

Sources of inspiration for technological advancement can come from other industries [TA3]. Ford learned from watch-makers, brewers and meat packers when formulating his production line. Just as new ventures are created around technological advancements, firms should seek to continually evolve products to satisfy changing market needs, and firms driving revolutionary change should continue to adapt their offerings as market preferences change [TA4]. Boulton envisioned the evolution of the steam

engine as a rotating engine capable of powering machinery, which then led to the railway locomotive. Edison and his team continually improved the bulb itself, including an improved vacuum, and the Edison screw, and simultaneously continually introduced inventions that made it more useful, including electrical wiring and tubes powered by a centralised generator, followed by the commercial power utility. In Ford's case, there was significant innovation employed for the production of the Model T, with the declining innovation afterwards that led to reduced market share to General Motors.

Entrepreneurial agency

The four historical cases show that entrepreneurial agency played a key role in the structuration of each respective technology. In line with Schumpeter's insights (1934), the case studies illuminate a series of approaches that extend beyond the advancement of technology and include a clear intention to create commercial ventures around such innovations [EA2]. These entrepreneurs had a vision to improve society in some way, beyond simply acquiring financial gains [EA1]. These included supplying everyone a lightbulb and subsequently other electrical appliances; freeing every family from their geographical constraints by enabling them to afford an automobile; or, in Matthew Boulton's words: "I sell here sir, what all the world desires to have – Power" (Birbeck Norman Hill & Powell, 1934).

Access to capital was critical in all of the cases [EA3], such as Boulton's capital for the Steam Engine partnership, the land values that investors leveraged for railway finance, JP Morgan's financial partnership with Edison, and Henry Ford's multiple financial partnerships. More broadly however, partnerships and collaboration were imperative to the success of these ventures [EA4]. While history often remembers the individual, all of these feats required immense teams and networks of employees, collaborators, financers, initial customers and advocates [EA5]. This is self-evident in the Boulton and Watt partnership, and with the likes of Thomas Brassey, who undertook the majority of his ventures in partnerships. Edison built extensive teams, and also operated in close partnership with select individuals such as Charles Batchelor whose technical expertise was supplemented by Edison's commercial skills.

New innovations are able to gain a 'foothold' in a niche application by targeting an initial market, like household lighting for the wealthy, or a steam engine for factory processes, by providing an opportunity for the technologies to demonstrate their value, leading to wider uptake [EA6]. This allows an entrepreneur to get started, and enables iterative learning and innovations along the way. Boulton created a repayment model that only took payments from customer savings gained from the use of the new technology, and by so doing opened up a new customer base for the steam engine. Edison linked innovations to social statuses or classes by marketing electric lighting as a prestigious technology, while Ford's 'vehicle for the masses' enabled an entirely new class to access the technology [EA6]. By envisioning an automobile for the masses, Ford shifted from a niche market (privileged citizens), to a mass-market (the wider population), by conceiving a new method of production that would re-write the status quo [EA7]. In this way, Ford enabled new customers to access the product, which created a much

greater demand and growing numbers of advocates for the product [EA7]. Ford compounded this by paying his workers enough to afford the vehicles without working long hours.

These entrepreneurs also leveraged their expertise to continually expand into new markets, such as Boulton pushing Watt to develop the rotating steam engine, Brassey' expanding internationally by drawing on his first-mover-advantage from Britain, or Edison creating his famous Menlo Park research facility [EA8]. Like many successful and revolutionary endeavours, failure was treated as an opportunity to advance rather than as a dead-end [EA10]. For each of Brassey's successful tenders, six were rejected; Edison famously responded when sympathetically questioned about a large number of experiments lacking positive results: "Results! Why, man, I have gotten a lot of results! I know several thousand things that won't work." (Dyer & Martin, 1910). Ford had multiple failed automobile ventures prior to the Ford Motor Company.

There is extensive literature that covers the personal traits of successful entrepreneurs (Bygrave & Hoffer, 1991; Koh, 1996; Thomas & Mueller, 2000; Littunen, 2000). It is evident from the cases studied that treating workers well made a difference in a time when it wasn't essential. Boulton introduced one of the first social insurance schemes to his workforce (Magill, 1999); Brassey is known to have been particularly generous in supporting his workers, even taking unprofitable contracts rather than firing them; and Ford revolutionised work hours and pay with the $5 day and 40 hour week [EA9].

Ultimately, widespread socio-technical change is accelerated by interventions aimed at changing the functional form of entire systems, rather than focusing on a niche market. The entrepreneurial agency applied in the case studies was at a distinct scale and level of influence, such that it increased the potential for systems change. In the cases studied, the new technologies fitted into the existing system, or a new system was created around the innovation [EA11]. This is evident in the failure of Brunel's endeavour to have a range of different railway gauges rather than aim for a uniform gauge that integrated easily into the existing system. The railways more broadly were integrated with the widely used existing canal systems, creating a collaborative environment for the expansion of the network rather than a competitive one (Smith, 1999). Edison had the foresight to introduce the lightbulb to every home, and to construct the defining grid and centralised generation to power it – a lucrative entrepreneurial endeavour.

Socio-technical transitions are integrated with institutional change and both political and social factors can encourage or hinder progress. Edison worked with legislators in New York to create the ideal conditions for electricity enterprise to rapidly expand, another element which led to such widespread success [EA12]. Entrepreneurs could not ask for better conditions for railway expansion than in Britain during the mid-19th Century. Showing foresight however, and given the mania taking place, Robert Stephenson was elected into parliament and advocated for more sensible and sustainable schemes, and more engineering input in the form of a tribunal (Smith, 1999).

3.6 DISCUSSION IN THE CONTEXT OF 21ST CENTURY URBAN GOVERNANCE

The four historical cases considered in this chapter reinforce that, while this study is certainly not exhaustive, entrepreneurial agency has played a significant role in transformative socio-technical systems change. This section translates insights from history to current day governance, in both the categories of technological advancement and entrepreneurial agency.

The technologies required to decarbonise economies, and to mitigate climate change, already exist (von Weizsaecker et al., 2009). However, the majority of the world is still dependent on industrial-era technology. The advancement of low-carbon technologies coupled with cost reductions has been occurring for decades [TA1]. The installed capacity of renewable energy technologies is growing rapidly around the world, with a cumulative 644GW of renewable power generation added since 2010 with a lower levelised cost of electricity (LCOE) than the cheapest fossil fuel-fired option [TA2] (IRENA, 2021). Solar electricity experienced higher-than-average earning rates as the price dropped 22.5 percent for every doubling of installed capacity up to the year 2000 (McDonald & Schrattenholzer, 2001) [TA4]. Even without energy storage for intermittent renewables, studies estimate that the 80 per cent greenhouse gas emissions reductions required to meet Paris climate targets can be achieved through a mix of current renewable sources without an increase in the LCOE (MacDonald et al., 2016).

Each technology sector explored above from engines, to vehicles, to electricity generation, is currently being reinvented largely due to the finite nature of fossil energy reserves, the pollution and associated human health issues associated with their use, and the impact on the global biosphere from human-induced global warming (von Weizsaecker et al., 2009). Each of these sectors is thereby entering a new era of innovation and enhanced performance with the intention being to maintain and advance their functionality and develop out their shortcomings. Traditionally, responding to human-induced environmental effects has been considered the responsibility of governments, as environmental impacts have been treated as ‘acceptable’ externalities of economic development. It is now overwhelmingly clear, however, that the previous waves of innovation have led to the accumulation of environmental effects that impose negative economic impacts (Stern, 2006; von Weizsaecker et al., 2009). Businesses and entrepreneurs are increasingly incentivised to actively innovate given the rapidly shifting economics of renewable energy and low-carbon technologies that are increasingly influencing business decisions, for instance, the divestment from fossil fuels (Trinks et al., 2018).

As with the historic technologies considered in this chapter, there is room for a large number of different enterprises to capitalise on market demand for innovations that reduce carbon emissions *[EA2]*. Given the greater levels of energy production decentralisation, much more solar capacity is owned by citizens rather than utilities (Newman and Newton, 2013). For example, in Germany at the end of 2012, 48 per

cent of the installed solar capacity was owned by citizens and only 3.5 per cent by public utilities with the remainder owned by companies, investors, developers, etc. (Hauser et al., 2015); this has worked to drive private sector capital raising and project development as well as provide more decentralised sources of capital [EA3]. In South Australia, Australia, the state is developing a world first 'Virtual Power Plant', where residential batteries will create a decentralised, digitally aggregated 5MW 'power plant' for the state rather than one centralised electricity source (Australian Renewable Energy Agency, 2021). While still some way from widespread commercial adoption, new emerging technologies such as blockchain are enabling peer-to-peer platforms for 'prosumers' (producers and consumers) to trade electricity directly with one another without reliance on a centralised power utility or financers (Kang et al., 2017) [EA7].

Many applications of sustainable technologies are being invented, and arguably many are yet to be mainstreamed through entrepreneurial agency. Commercialisation opportunities exist in many sectors for technologies such as battery storage, biomaterials and fuels, agriculture, and the circular economy (waste management and resource recovery) [EA6]. Firms are presented opportunities to expand into new markets. This may be through diversification into new competencies that stem from their existing specialisations, such as Hitachi's diversification from an electrical repair shop at a mining site to Japan's largest electrical electronics company in 1992 (Hitachi, 2018); or applying already developed technologies to other industries like 3M who applied their micro-replication technology across a number of different markets such as healthcare, automotive, aerospace, electronics and energy (Bowonder & Miyake, 1994; Hargadon, 2013) [EA8].

Firms have the opportunity to leverage the divestment movement to attract new investment for sustainable technologies and ventures, while also redirecting existing cash flows to finance sustainability interventions [EA3]. For example, El Hierro in the Canary Islands realised they could redirect part of a €9 million annual diesel import bill upon which they were previously reliant for energy, to finance a local base-load renewable energy infrastructure (Pauli, 2017). In the transport sector, firms can learn from the 19th Century norm of leveraging land development opportunities to encourage private sector finance (Newman, Davies-Slate and Jones, 2017). Redirecting capital towards 21st century industrial opportunities presents opportunities for governments to engage the private sector in infrastructure provision given the increasing shortage of public funds to keep pace with population growth, urbanisation and the sustainability agenda.

Partnerships and strategic alliances have been shown to enhance corporate technological entrepreneurship performance (Antoncic, 2008). Building on partnerships, broader innovation networks can be fostered where collaboration can occur across sectoral and industrial boundaries. This has been demonstrated by IBM and Intel in their collaborations with universities and many smaller companies. Instead of 'reinventing the wheel', firms and governments are seeking improved models for

collaboration to link and scale innovations across different geographical contexts. In the context of cities, new infrastructure will be required to underpin sustainable growth and lifestyles; this cannot be done by governments alone. Governments can collaborate with the private sector for infrastructure and service provision, leveraging private capital and management expertise, while overcoming their own budgetary constraints and inefficiencies.

Public appreciation for entrepreneurial agency is often most prevalent towards bold visionaries who are at the forefront of technological revolutions. Today, parallels can be drawn between Elon Musk's ambitions and the traits of Edison or Ford. In 2017, Musk boldly asserted on Twitter to the then South Australian Premier Jay Weatherill that his company, Tesla, could construct the world's largest lithium-ion battery in 100 days to support South Australia's extensive renewable energy generation – and if his company Tesla failed to do so, the battery would be free [EA1]. For comparison, South Australia's neighbour state of Victoria had called for tenders six months earlier at the beginning of 2017, but were slowed by regulatory and financial hurdles (Parkinson, 2017). Tesla completed the task in South Australia within the 100 days and the battery was operational in December of 2017, successfully reducing electricity costs during times of peak electricity demand.

Technologies validated in such high-profile projects like South Australia's Tesla battery, pave the way for emerging cities without grid infrastructure to 'leapfrog' fossil fuel infrastructure and go directly to decentralised, renewable forms of energy with associated storage. Such local energy markets can operate between geographically related, interconnected agents who are both producers and consumers, empowering communities through cost reduction, and boosting the local economy as buying and selling is circulated within the community (Mengelkamp et. al, 2017a; 2017b) [EA11]. In the developed world example of South Australia, Tesla has now built on the momentum of one grid-scale battery, to 50,000 residential batteries for the State Grid at no cost to homeowners in return for electricity at desired times, thereby creating a 'Virtual Power Plant'. Here, the existing system is important when implementing technologies. But as the system changes, new possibilities will emerge and become favourable.

It is important that Governments set a fair playing field for entrepreneurs who are driving sustainable energy uptake, and who are competing against traditional fossil fuels [EA12]. Policies are often tailored towards current, rather than future, technologies. Governments can harness the finance and innovation of the private sector to further their own objectives if they set the right conditions, which is necessary given the global imperative for accelerating climate action. Innovative partnership models that represent the permeable collaboration needed for effective urban governance are being called for in the literature. The challenge can be that governments are presented with a multitude of new technologies, each of which with promises of boundless potential from their proponents, and they are not always able to identify which ones will deliver. Similarly, incumbent technologies may be tied to existing policy and/or industry agreements that dictate that entrenched models remain in place.

The development of energy-related technology in the industrial revolution has resulted in significant productivity improvements that have underpinned many of today's prosperous economies. As the examples in this chapter demonstrate, technological advancement alone does not achieve this. Entrepreneurial agency plays a major role in mainstreaming new technologies. The four case studies clearly depict a suite of approaches historical entrepreneurs applied. One distinction to be made is that technological advancement is not solely an entrepreneur-specific process; it can involve collaboration between research and development facilities, universities, incumbent firms, and entrepreneurs.

The current socio-technical systems change for sustainability requires the accelerated structuration of new energy technologies such as solar photovoltaics, electric trains, trams and buses, and decentralised electricity networks. Harnessing these new technologies is a priority for cities aiming to mitigate climate change and will be crucial as cities around the world undergo a low-carbon transition in the coming decades, not only for environmental prosperity but for economic and social prosperity also. Many of the technologies and trends of the new wave of innovation reduce environmental impacts, they can also generate economic advantage, higher productivity and better lifestyles for citizens. The earlier a city is in its stage of development, the more opportunity it has to leapfrog straight to sustainable technologies. This is critical, as historical energy transitions show large increases in consumption will occur as much of the developing world becomes electrified (Sovacool, 2016).

This chapter does not posit that entrepreneurship is the one-and-only solution. The key message here is that the entrepreneurial approach lends itself to systems change in the face of uncertainty. As each of the technological functions covered in the case studies undergoes regeneration to a low-carbon form, they will also need to become more integrated. Integration will occur through digitally-enabled 'smart' technologies converging with 'sustainable' technologies (Geissdoerfer et al., 2018). This revolution of digitization, distribution and automation is increasingly blurring the lines between what has traditionally been the responsibility of the state, and what social needs can be met by the private sector. This means there is both technological disruption and economic opportunity occurring at all levels: for individuals, businesses, cities and governments.

Rather than confining the 'entrepreneurial approaches' presented in this chapter as examples of the entrepreneurial agency of enterprising individuals to drive structuration of new technology in and for society, the objective of this thesis is to interrogate the potential for actors such as big industry, utilities, civil society, mayors, planners, and policy-makers to adopt the thinking and proactive approaches of 'entrepreneurs', and apply them to the way they respond to the challenges that cities and countries face. This form of entrepreneurial governance informed by the practice of entrepreneurship – that is, the process of applying agency to increase the structuration of innovations for systems change in the face of uncertainty - may prove essential to navigating the complex transitions in coming decades.

3.7 CONCLUSION AND CONTRIBUTION TO THESIS

Entrepreneurial agency has played a key role in major paradigm shifts in technology, energy and urban life throughout history. Entrepreneurship is at the core of innovation as distinguished by Schumpeter (1934), whose 'Creative Destruction' is a driving force of techno-economic paradigm shifts (Freeman and Perez 1988). In the 21st Century, systems change in the face of uncertainty is necessary to avert catastrophic economic, ecological and social consequences. And this change needs to resemble the techno-economic paradigm shifts akin to the historical cases presented in this chapter. The technologies exist to make this happen, it is the governance and implementation of these solutions that requires reinvention.

This chapter makes clear the potential that 'entrepreneurial approaches' offer in accelerating systems' transformation towards sustainability. Subsequent chapters of this thesis build upon this validation of entrepreneurial approaches by extracting insights from modern-day entrepreneurship literature and applying them to urban governance to inform the sustainable transformation of cities in the 21st Century.

In summary, this chapter makes the following contributions to the thesis:

1. Provides four short-form case studies across prominent historical technological transformations that were at the centre of socio-technical transformations.
2. Through thematic analysis, illustrates that systems change is a product of more than new technology, and is often influenced by entrepreneurial agency.
3. Provides discussion and insights from history that validate the role of entrepreneurial agency in socio-technical systems change, providing a foundation for further research into modern-day entrepreneurship literature to extract learnings for systems change driven at the level of business venture, and at governance level for the multi-stakeholder transformation of urban infrastructure.
4. Validates the role of entrepreneurship and entrepreneurial agency for historical industrial systems change, in this case for technologies related to cities and urban infrastructure. These types of socio-technical infrastructure transformations will be required to accelerate sustainability transitions in response to global carbon reduction imperatives.

The key contribution to the thesis of the examples of 'entrepreneurial agency' highlighted in this chapter is the validation of entrepreneurial agency as a driving force in socio-technical systems change. With entrepreneurial agency established as key to civil infrastructure transformation, the next chapter turns to modern day entrepreneurship theory to supplement this understanding to better inform urban governance approaches. It extends this concept beyond the individual entrepreneur to the provision of civil infrastructure at a systems level. A modern-day civil infrastructure case study is provided of the Willunga Basin Water Company to illustrate this approach.

CHAPTER 4

ADOPTING AN ENTREPRENEURIAL APPROACH TO URBAN INFRASTRUCTURE GOVERNANCE: A CASE STUDY OF THE WILLUNGA BASIN WATER COMPANY

4.1 CHAPTER OVERVIEW

This chapter extends the concept of entrepreneurial agency beyond individual entrepreneurship and applies it to the context of civil infrastructure for collective value creation. The chapter focuses on responding to the research question: Is the entrepreneurial decision-making logic of effectuation a useful construct for transformative urban governance approaches in the context of contemporary civil infrastructure?

The chapter begins by translating Wiltbank et al.'s (2006) framework of prediction and control from a business management context to an urban governance context. This translation draws on the previous two chapters. First, it uses the key dimensions detailed in Chapter 2 to show how the adapted framework can deal with uncertainty and facilitate systems change to address sustainable development challenges. Second, the chapter reinforces the role of entrepreneurial agency in socio-technical systems change throughout history, as established in Chapter 3. In assessing current urban governance models against this framework, the chapter highlights the need for more transformative governance models to be adopted in practice to cultivate systems change in the face of uncertainty.

Effectuation, a theory of entrepreneurial decision-making logic developed by Saras Sarasvathy (2001), is then contrasted against causation logic to represent the transformative approach that is needed to facilitate more effective and responsive urban governance. Effectuation is combined with Strategic Niche Management, as introduced in the literature review as a subset of sustainability transitions literature focused on niche innovations with low levels of structuration, to outline how SNM predominantly follows a causation logic, before developing an 'effectual' model applicable to urban infrastructure.

The chapter provides a civil infrastructure case study of the Willunga Basin Water Company. The case illustrates the applicability of effectuation as a decision-making logic for infrastructure governance. The discussion then details this new model of infrastructure governance which is presented as effectual urban governance; a concept articulated further in Part 2 of the thesis.

4.2 INTRODUCTION

The idea that entrepreneurial agency drives innovation is not new (Schumpeter, 1934). In a broader governance context however, particularly in the civil infrastructure and built environment sectors, research and practice place a much greater weight on the role of governments to support sustainable outcomes. As highlighted in Chapter 2, strategic niche management (SNM) has been a prominent governance approach within the sustainability transitions literature to support the increasing structuration of niche innovations aligned to sustainability. Significantly, strategic niche management can involve governments and policy makers but it is not confined to them, with various other actors such as businesses, co-operatives, university

researchers and civil society groups also undertaking SNM. Rather than governments attempting to create niches in a top-down fashion, niches are, and should be, steered from within (Schot & Geels, 2008). A key point in the SNM literature on the governance of sustainability transformation therefore centres around managing an inherent tension; providing enough support to niche innovations so that structuration within local practices increases to a point where they are capable of replacing existing socio-technical regime configurations, and at the same time, balancing this level of support so that these innovations can survive in the market without being reliant on support mechanisms such as government subsidies (Hoogma et al., 2002). While the SNM process is based on experimentation, and focuses on setting expectations, building networks and facilitating learning as key factors important to the success of a niche, it is important that niche support and management i.e. SNM, through scaling and embedding exercises, truly achieves an increase in the level of structuration of a given innovation - i.e. that user demand is generated throughout the process to enable the innovation to become disruptive (Christensen, 1997).

Over the past decade, and in response to criticisms that the concept of SNM has lacked practical guidance (Mourik & Raven, 2006), the SNM field of research has focused on transitioning from a research framework to a practical tool that can be applied to facilitate future transitions and sustainable structuration. As articulated in the literature review, the concept of structuration is not confined to emerging niches in the sustainability transitions literature. In fact, the very process of entrepreneurship at its essence, particularly in a context involving 'new innovation', is a process which aims to increase the structuration of a new innovation being commercialised by an entrepreneur. The entrepreneurial process has many similarities to the processes of SNM, with both being a process of applying agency. Entrepreneurship takes place within social systems, and entrepreneurs are agents who actively seek to shift existing structures in society to generate change predominantly, but not exclusively, for financial gain. Introducing new innovations is often met with resistance from incumbent firms and established structures within a socio-technical system, and successful entrepreneurs are strategic about navigating these challenges. Entrepreneurs may also face resource scarcity and uncertainty given the low levels of structuration surrounding the new innovations they attempt to bring to market. This thesis draws parallels between the entrepreneurial process and SNM to show how entrepreneurial processes can offer insights and enhance the processes of SNM which similarly seeks to manage the growth of socio-technical configurations to create new, sustainable social structures.

The literature review undertaken in Chapter 2 highlighted a number of types of 'entrepreneurship', including Social Entrepreneurship (Emerson & Twersky, 1996; Leadbeater, 1997; Wee-Liang et al., 2005), Intrapreneurship (Stopford & Baden-Fuller, 1994; Shane & Venkataraman, 2000; Ağca et al., 2012), Civic Entrepreneurship (Henton et al., 1997; Leadbeater & Goss, 1999), Academic Entrepreneurship (Balazs, 1996), Policy Entrepreneurship (Kingdon, 2003), and Institutional Entrepreneurship (Maguire, Hardy and

Lawrence, 2004; Garud, Hardy & Maguire, 2007). While historically, entrepreneurs have played a pivotal role in major technological shifts as explored in Chapter 3, these contemporary understandings and examples provide a holistic, multi-dimensional view of what it means to be entrepreneurial. Rather than narrowly defining entrepreneurship as the act of an individual starting a new company or being self-employed, as outlined in Chapter 2, entrepreneurship can be considered the act and processes of navigating uncertainty, creating opportunity with limited resources, and shifting socio-technical structures while creating economic value. It is this understanding that is drawn on for insights into accelerating system-change towards sustainability for enhancing and operationalising the SNM approach.

SNM, similarly, is fundamentally a governance process for facilitating the expansion of sustainable technologies across society despite restrictive selection pressures imposed by existing structured socio-technical regimes. This chapter argues that entrepreneurship and 'entrepreneurial approaches' can significantly enhance SNM as the similarities and lack of structuration in both contexts allows the entrepreneurship domain to inform governance approaches to effectively foster sustainability transitions.

4.3 SYSTEMS CHANGE UNDER UNCERTAINTY: SYNTHESISING ENTREPRENEURSHIP AND URBAN GOVERNANCE

In responding to the research question of this chapter, it is important to first determine relevant entrepreneurial and strategic management approaches which focus on systems change and uncertainty. This section translates Wiltbank et al's (2006) framework of prediction and control into an urban governance context, providing a framework to assess governance approaches for their ability to facilitate systems change under uncertainty.

4.3.1 Strategy Framework of Prediction and Control

There are two predominant schools of thought related to entrepreneurial opportunity. The first considers opportunity to exist external of the entrepreneur, and the entrepreneur identifies these opportunities and seeks to act upon them before others do (Kirzner, 1979; 1985). Here, prediction and adaptation are combined to deal with uncertainty, such as through competitive analysis. Taking this view, opportunities are exogenous from the entrepreneur. The second school of thought places greater agency with the entrepreneur, suggesting that entrepreneurs can influence the conditions and environment in which they operate, thus having the power to create opportunities regardless of the external environment (McMullen and Shepherd, 2006; Wiltbank et al., 2006). From this perspective, entrepreneurial opportunities are brought into being by the entrepreneur and their actions/agency, rather than discovered – and thus the world is

considered to be endogenous, or within one's control and able to be shaped (Mintzberg, 1994; Sarasvathy, 2001).

Traditional strategic management studies, which mostly sit within the school of 'opportunity as an external phenomenon within an exogenous environment' generally pose two fundamental approaches to dealing with uncertainty and determining a basis for action. As explained by Wiltbank et al. (2006):

> "Studies in mainstream strategic management boil down to two fundamental prescriptions for how firms can decide what to do next (Brews and Hunt, 1999): They should either try harder and predict better (rational strategies advocated by the planning school) or move faster to adapt better (adaptive strategies espoused by the learning school). Which prescription a firm is to follow depends upon how confident the firm is in its ability to predict changes in its environment."

A key feature of both approaches is the focus on the position within an exogenous environment, or the external cause or origin outside their control. What differentiates these two approaches to strategic management within an exogenous environment is the level of prediction they employ to inform action within this environment. However, as Knight (1921) posits in his seminal work on uncertainty, in situations of deep uncertainty, as especially present in complex systems or times of great disruption, predictive approaches to strategy development are not reliable, and therefore prediction as a basis for control is not viable.

Wiltbank et al. (2006) distinguish prediction of the environment and control of the environment as two separate dimensions, presented in Figure 4-1 below. In situations of low uncertainty, prediction and control can be synergistic, given that prediction can be relied upon. In situations with greater levels of uncertainty, prediction is not as reliable and approaches with lower levels of prediction are required. Figure 4-1 provides a taxonomy of strategic approaches across the dimension of Prediction and Control.

In the Figure:

- 'Positioning' approaches represent actions taken within an environment perceived to be exogenous of the actor. In other words, the system is perceived to be 'outside of the control' of the actor; the framework presents these approaches as being low on the dimension of control. These approaches resemble the first school of thought relating to entrepreneurial opportunity, where opportunity exists external to the entrepreneur, rather than being generated by the entrepreneur, and here the entrepreneur is an actor that responds to and capitalises on this external opportunity.

- ‘Construction’ approaches represent actions taken within an environment perceived to be endogenous of the actor. In other words, the system is perceived to be within the control of the actor, and the actor has the agency to intervene in the world and shape a new system. These approaches are presented as those with higher intent to ‘control’ the environment. These approaches resemble the second school of thought on entrepreneurial opportunity, where the entrepreneur, as an agent, is actively involved in generating new opportunities.

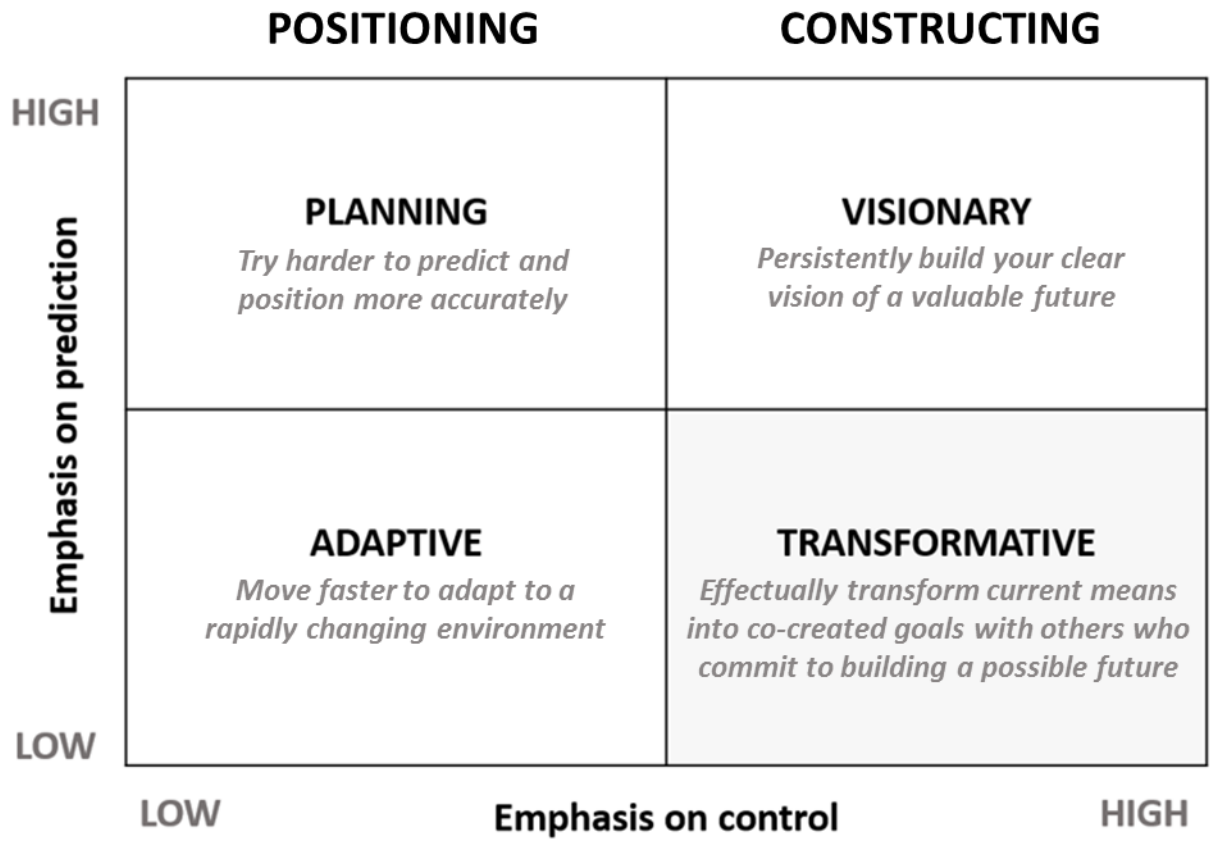


Figure 4-1: Framework of prediction and control (Based on Wiltbank et al., 2006)

In all cases shown in Figure 4-1, actors seek favourable outcomes – as Wiltbank et al. (2006) state, “the argument is simply that prediction is not the only point of leverage in achieving those outcomes”. Approaches that fall within the Planning quadrant that consist of ‘trying harder to predict and position more accurately’ may well be the best approach in an exogenous, predictable environment. On the other hand, attempting to influence or control an endogenous, unpredictable environment is positioned as a more viable approach as predictions of the future can be unreliable or may not lead to desired outcomes. In the framework above, the four distinct approaches can be described from the view of an actor as follows (Wiltbank et al, 2006):

- **Adaptive Strategies:** It is assumed the environment is unpredictable, and therefore planning horizons should be shortened, however the environment is outside the control of the actor. Investment is made in flexible strategies that effectively respond to challenges in the environment.
- **Predictive Strategies:** It is assumed the environment is predictable but, similar to Adaptive strategies, it is beyond the actor's control. Investment is made in predictive techniques that allow favourable positioning for the future.
- **Visionary Strategies:** It is assumed the environment is predictable but malleable and that an actor can intervene in the world to shape the system towards their vision of the future, shaping the environment to achieve their desired outcomes.
- **Transformative Strategies:** It is assumed the environment is unpredictable but malleable, and thus the actor seeks to shape the environmental factors through cooperation and goal creation with others to imagine possible futures extending from current means.

Rather than elucidating these approaches in the context of entrepreneurship and strategic organisational management, the next section translates them into the context of urban governance.

4.3.2 Urban Governance: A New Framework of Uncertainty and Systems Change

In this subsection, I translate Wiltbank et al.'s (2006) framework into an urban governance context in response to the research question of this thesis. A number of approaches to urban and infrastructure provision fall within the framework provided by Wiltbank et al. (2006) (Hart, 1992; Verreynne et al., 2016). However, as Linnenlueke et al. (2017) identify in their systematic review of urban and infrastructure planning approaches, the literature is "fragmented and does not yet fully address the sustainability challenges that stem from both planetary boundary violations and multiple stakeholder needs" (Whiteman et al., 2013; Steffen et al., 2015), i.e. it has not fully addressed the need for systems change for sustainability transitions. Linnenlueke et al.'s study (2017) places planning approaches at the level of organisation, rather than the broader levels of industrial systems, national and regional policies, or international agreements.

Each of Wiltbank et al.'s four strategic approaches are relevant to planning and governance in cities. As such, Wiltbank et al.'s (2006) framework of entrepreneurial and strategic management approaches is translated into an urban governance framework of uncertainty and systems change along the dimensions of prediction and control. Urban strategy, tactics and operations also occur along varying dimensions of prediction and control, which can also be considered as dimensions of (1) capacity to deal with uncertainty; and (2) ability to facilitate systems change. The following discussion re-frames Wiltbank et al.'s dimensions for an urban governance context.

Firstly, in the context of urban governance, prediction is useful when the future is predictable. As Knight (1921) distinguished, the process of converting uncertainty to risk allows for the identification of 'known unknowns' and allows predictions of the future to account for events that may be unknown, however can be quantified or accounted for. This process is constrained by uncertainty. Uncertainty is characterised by 'unknown unknowns', and in complex systems, uncertainty limits the usefulness of prediction-based approaches. Prediction is, after all, informed by past events and overwhelmingly, but not exclusively, it does not account for unexpected events and non-linearity in cause and effect relationships. As an example, researchers at Stanford University, University of Sydney and Northwestern University Illinois conducted a study that highlighted the 'failure of COVID-19 predictions' in 2020. They presented fourteen contributing factors including poor data input; incorrect assumptions; high sensitivity of estimates; limited contributing features incorporated into models; poor past evidence available; looking at only one or a few dimensions of the problem; groupthink; and lack of expertise in crucial disciplines (Ioannidis at al., 2020). The failed predictions of the pandemic are exemplars of how forecasting and prediction are not suited to conditions of heightened uncertainty. This prompted the observation that in the context of urban governance, prediction-based approaches are distinguished from non-predictive approaches in their capacity to deal with uncertainty; this forms the dimension of 'Effectiveness Dealing with Uncertainty' in the new framework.

Secondly, as established in Chapter 2, systems change in the context of urban governance involves applying agency to increase the structuration of preferred socio-technical innovations. The application of agency to influence structuration requires agents to have the ability to intervene in the world and produce effects, shaping the environment in which they operate. Wiltbank et al. (2006) distinguish between strategies within an 'Exogenous' or 'Endogenous' environment as the level of 'Control', differentiating between strategists who actively seek to shape the environment, or believe they have the capacity to, compared to those who respond to it. This parallels the two prominent schools of entrepreneurial opportunity – those that posit opportunity to exist in an exogenous environment independent from the entrepreneur, and those that posit that entrepreneurs themselves operate in an endogenous environment whereby they take an active role in creating opportunities. The latter is descriptive of the type of urban governance required to facilitate systems change towards sustainability, particularly because systems change requires acting outside of established path-dependencies and lock-in effects of established and unsustainable socio-technical regimes. An actor within an exogenous environment does not perceive an ability to facilitate systems change by generating opportunities outside of the exogenous environment that is subject to path-dependency. This prompted the realisation that in an urban governance context agents need to hold the 'Ability to Facilitate Systems Change'.

Each of Urban Governance typologies within the framework presented in Figure 4-2 along the dimensions of 'Effectiveness Dealing with Uncertainty' and 'Ability to Facilitate Systems Change' are further articulated below. Figure 4-2 presents the revised Urban Governance Framework of Uncertainty and Systems Change.

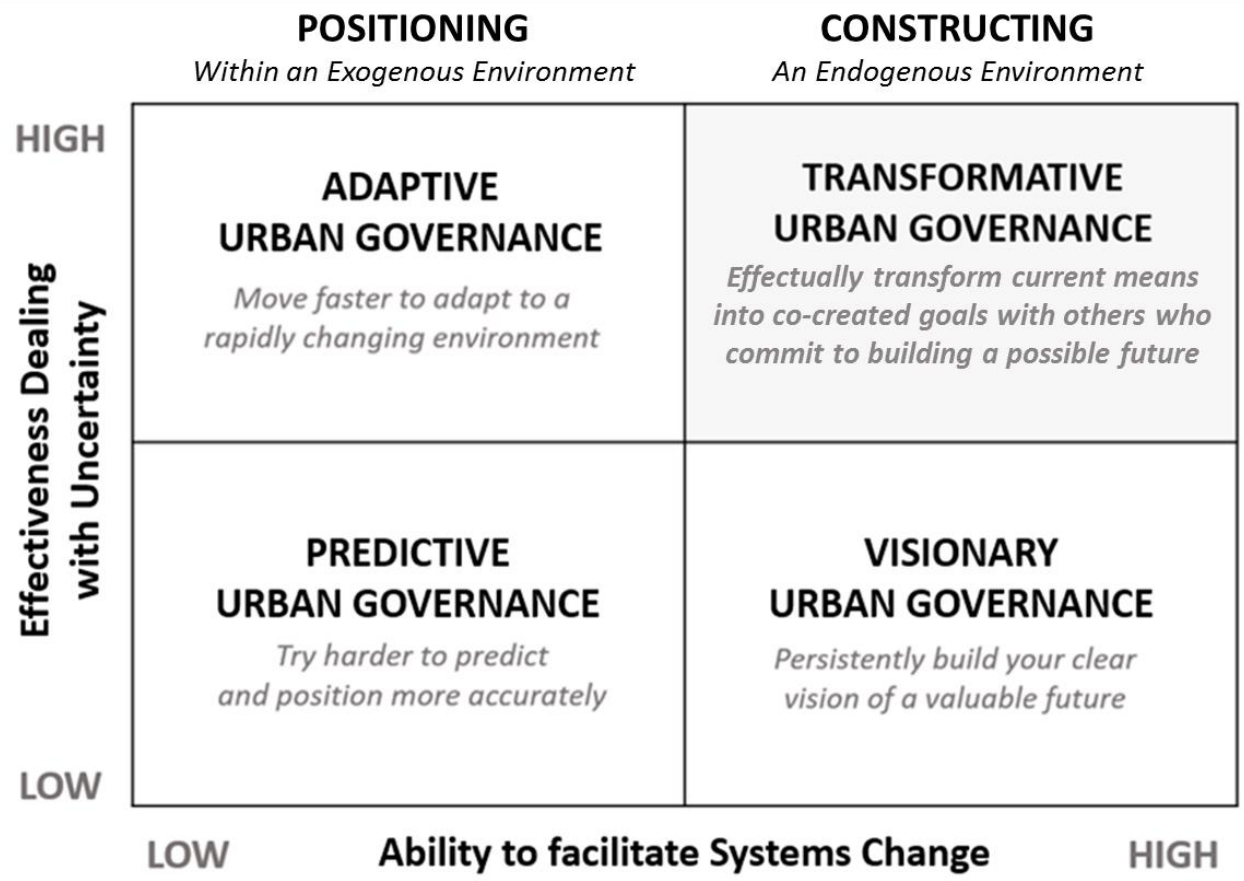


Figure 4-2: Urban Governance Framework of Uncertainty and Systems Change (Source: Author; Adapted from Wiltbank, 2006)

Predictive Urban Governance

Predictive urban governance is based on predictions of the future using available information, and the design of strategies that position for success within an exogenous environment. Such urban governance approaches often take historical data, events and system states as 'evidence' to inform the predictions generated about the future. A common tool used for predictive urban governance is forecasting (Jager et al., 2015; Takamatsu et al., 2014). This approach leverages rigorous analysis to develop deeper levels of insight, to form a basis for action that is taken in line with the predictions. This approach is well-suited to the analytical capabilities of engineers and technical experts.

An example of this approach that has come to dominate transport planning in Anglosphere cities for the past 50 years is the 'Predict and Provide' approach (Buchanan, 1963). Predict and Provide describes a planning approach whereby the extrapolation of existing conditions, as informed by historical events, create a projection of a predicted future and infrastructure is accordingly planned and supplied to support this future. The shortcomings of this approach have been predominantly discussed in the context of road-based transport investment and the associated side effects. In many Anglosphere cities that are often some of the most car-dependent in the world, predictions based on historical data unsurprisingly tell planners that in 20-30 years' time, traffic volumes will continue to increase substantially and more road space will be required to cater for this increased demand. These cities therefore prioritise the expansion of highways and allocate more urban space for the movement and parking of private vehicles.

However, these prediction-based models have proven to be flawed time and time again, due in large part to the principle of induced demand – whereby new demand results from an increased and lower 'cost' supply (American Association of State Highway Officials, 1957; Downs, 1962; Growther, 1963; Overgaard, 1966; Thomson, 1977; Newman & Kenworthy, 1989; Mogridge, 1990; SACTRA, 1994; Goodwin, 1996; Hills, 1996; Litman & Colman, 2001; Næss, Mogridge & Sandberg, 2001; Noland & Lem, 2002; Nicolaisen & Næss, 2011; Næss, Nicolaisen & Strand, 2012; Levinson et al., 2017). Despite providing additional vehicle lanes to relieve congestion, the new lanes are unable to provide lasting congestion relief, due to travellers' shifting travel times, routes, and modes when networks are changed, even slightly; this has resulted in ineffective prediction-based interventions in the urban transportation sector for decades (Downs, 1992). This effect can also occur when forecast-based public transit interventions, deployed in isolation of land developments, are undertaken to result in less-than-expected reductions in traffic congestion (Litman, 2017).

Prediction-based approaches are useful in many contexts, particularly when relationships between actions and outcomes are linear and predictable, or non-linear, but known. However, even in these in these scenarios where uncertainty is low, prediction-based approaches do not pro-actively facilitate systems change. That is, the larger issue in a 21st Century context is that this planning approach does not deal well with uncertainty, and by its very nature, locks-in the path dependencies of unsustainable systems thereby creating a self-fulfilling prophecy that follows the same trajectory of the past into the future. Cities today grapple with facilitating sustainable urban systems change in the face of factors such as climate change, natural disasters or global pandemics. In this uncertain environment, prediction-based planning using historical data increasingly promotes unsustainable regimes and does not account for non-linearity, feedback loops or sudden and abrupt changes (De Smedt, 2013; Folke et al., 2002). In addressing pressing ecological, social

and economic issues around urban transport planning, especially under conditions of uncertainty – predictive approaches have not proven suitable.

Adaptive Urban Governance

Adaptive urban governance is characterised by a focus on responding to changes to the environment as they occur and responding quickly to new opportunities that emerge from changes to economic, social or technological conditions (Rijke et al., 2012). Adaptive approaches see the environment as exogenous, and also acknowledge the future is uncertain and changing. Thus, rather than over-investing in any one predicted future, adaptive urban governance approaches opt instead for the ability to agilely respond and adapt to changes as they occur. In contrast to predictive approaches to urban governance, adaptive approaches prioritise a greater level of flexibility (Hodkinson et al., 2014).

In line with an exogenous view of the environment, and combined with a reluctance to commit too heavily to predictions of an uncertain future, adaptive governance is more reactive than proactive. Examples of adaptive governance are evident in global responses to COVID-19. For example, digital meeting room software has existed in industry for a number of years. However, the dramatic shift to working from home arrangements caused by the pandemic for the subset of the population with the opportunity to do so, particularly urban knowledge economy workers, resulted in a dramatic uptake of these tools to respond to the health risks of face-to-face interactions. While the ecological and economic benefits of such digital tools have been advocated for decades (von Weizsacker et al., 1995), these technologies only rose to recent prominence in response to changing conditions in a changing environment. There are many workers in cities that do not have the option to work virtually, however this adaptive response to COVID-19 exemplifies how one subset of the working population around the world has adapted to new conditions – in a way that could not have been predicted at the beginning of 2020 before the breakout of the global pandemic. We have seen the same type of governance around the world with cities responding to ecological disturbances created by climate change.

In literature and practice there is a push towards forms of adaptive governance that are more proactive (Olsson et al., 2004; McDonald, 2008; Daniell et al., 2011). This approach to governance draws on prediction to some degree, not to specify a certain path and go ‘all in’ on this prediction, but rather to acknowledge that change is a constant and to be prepared to respond. Scenario building is a tool commonly used in practice for adaptive governance. An example of adaptive government is the Dutch ‘adaptive delta management’ ex-ante approach to future flood risk (Linnenlueke et al., 2017). The Dutch approach is anticipatory instead of responsive, and explicitly recognises uncertainty about the future and takes these uncertainties into account in planning (Klijn, 2015). Their approach opts for more incremental

commitments and successive decision points over time rather than decision-making based on a long-term future state.

Like predictive governance, adaptive governance has its place, and is useful in many contexts, and in many cases is important (COVID-19 being a case in point). However, an adaptive governance approach remains reactive and stakeholders often do not seek to construct or control an environment that is seen as exogenous. This highlights the risks associated with an adaptive urban governance approach which include the scale and uncertainty of future events, and the difficulty of mobilising large numbers of actors simultaneously to respond. While adaptive governance is particularly effective for rapidly responding to landscape pressures induced by major global events - which are difficult to control or predict - it is not the immediate objective of adaptive governance to focus on shaping the exogenous environment.

Visionary Urban Governance

Visionary urban governance is based on building visions for the future and identifying gaps between the current state of the system and the vision as a method for identifying preferred strategic interventions. This approach views the environment as endogenous, meaning there is an ability to facilitate and shape the environment and factors influencing the state of the city, and create, rather than wait for the opportunities that the Predictive and Adaptive approaches perceive to be external. This field of urban governance involves a greater level of agency, and sees individuals, firms, governments, or community groups taking on the role of change agent. Visionary urban governance is based on goals and ambitions for the future, which like predictive approaches, seek to define a future state as the basis for action.

McLoughlin (1969, p. 85) provided an early description of the basis for visionary governance approaches: "the city of course is the system we wish to control, the desired states are expressed in the plan, we measure the actual state at any time by all forms of survey and can thus compare the actual conditions with those intended by the plan". Above, the example of 'Predict and Provide' infrastructure planning was used to describe a predictive approach to transport infrastructure provision. In response to the identified shortcomings of the Predict and Provide approach, city leaders are increasingly adopting a 'Vision and Validate' approach as distinguished by UCL Professor of Transport and Sustainable Development Peter Jones (2016). A Vision and Validate approach establishes the vision, with system interventions designed and implemented to align with it (Jones 2016). The Vision and Validate approach enables planners to break away from the technical analysis and quantitative predictions that dominate Predict and Provide and envisage a growth trajectory ungoverned by the past. It is more 'constructive' - or based on control - because policy makers proactively establish a vision for the future they wish to see, such as one that can more effectively address economic, social and ecological concerns.

While it is common for the rhetoric contained in the Vision to not always be reflected in what is implemented in reality, visionary urban governance provides the framework for change that is not defined by the past, giving this approach a greater ability to break out of path dependency that is created by past states of the system. The literature has only begun dealing with how to engage in visionary planning, however a significant step was made by Jones (2012) in articulating it as distinct from Predict and Provide (Budde et al., 2012; Cagnin and Loveridge, 2012; Linnenlueke et al., 2017). Extending this observation to the level of urban governance and combining it with an example such as the discrepancy between the 2015 Paris Climate Agreement required reductions, visionary national commitments, and the actual progress that has been made, it is reasonable to assert that visionary urban governance as defined here, particularly in the transport sector of Anglosphere cities, is in its infancy. Key gaps at present are the ability to define a vision, and to achieve structuration of this vision within urban systems, or have such visions and ambitions scale beyond niches to become embedded regimes.

Transformative Urban Governance

Transformative urban governance is characterised by an ability to deal with uncertainty while facilitating transformative systems change; this has been identified as a necessary form of governance to address the sustainability challenges of the future (Linnenlueke et al., 2017). Transformative urban governance, in the context of the Uncertainty and Systems Change urban governance framework, focuses on what is controllable, rather than trying to correctly position and plan based on predictions of the future. Transformative approaches view endogenous environment conditions as opportunities for actors across sectors to generate economic, social and ecological benefits. The approach is based on establishing stakeholder relationships and co-creating a sustainable future through collaborative human actions. The approach draws on input from a diverse range of stakeholders such as governments, private industry, community members, and members of the scientific community. Transformative governance places this collaborative approach at its core which contrasts to predictive and adaptive planning that does not focus on the inclusion of these diverse inputs, as they are guided by forecasting techniques or responding to events (Wiltbank et al., 2006).

Transformative urban governance approaches are required when a high level of uncertainty converges with a need for systems change, such as the need for the rapid decarbonisation of the global economy. While some cities respond with low-cost infrastructure investments that shift away from automobiles towards walking and cycling infrastructure (e.g. Bogota, Milan, Bordeaux and London), other cities announce infrastructure stimulus plans for more highways to serve a future that is an extrapolation of past trends (e.g. Adelaide, South Australia). These different plans and responses demonstrate why approaches with lower reliance on prediction are termed transformative – they are applicable in the face of uncertainty, and reduce

their reliance on prediction-based models based on past states of the system. As such, they break free of path dependencies that can result in multi-decade lock-ins of further unsustainable regimes.

However, a lack of conceptual clarity in the literature of what constitutes change as 'transformational' has limited the term's contribution to challenging the status quo in urban planning approaches (Brand, 2016; Hölscher et al., 2018). Transformation is commonly defined as change that is large-scale and at a societal level, involving social-ecological interactions (Brand, 2014; Folke et al., 2010; De Bruijn and Norberg-Brohm, 2005). Rather than 'transitions' which are more subject to path dependency and occur over long time periods (etymologically 'going across'), 'transformation' etymologically originates from a 'change in shape' and is more related to the shape, form or outcome of the system (Hölscher et al., 2018). The focus on the 'what', rather than the 'how', for transformative governance may contribute to the lack of clarity about its application. While Rijke et al. (2013) note some exceptions (i.e. Olsson et al., 2006; Adger et al., 2011; Herrfahrdt-Pähle & Pahl-Wostl, 2012), most efforts to provide guidance on governance for transformation lack specificity (Loorbach, 2010; Pahl-Wostl et al., 2010; van de Meene et al., 2011; Farrelly et al., 2012). This chapter and thesis more broadly contributes to addressing this gap in transformative urban governance approaches for systems change under conditions of heightened uncertainty by transferring the decision-making logic in entrepreneurial approaches to the urban governance context.

Urban Governance Typology Summary

Table 4-1 below summarises the four urban governance typologies distinguished in the framework of Uncertainty and Systems Change.

Table 4-1: Overview of Urban Governance typology within framework of Uncertainty and Systems Change

Type of Urban Governance	Capacity to Deal with Uncertainty	Ability to Facilitate Systems Change	Key Approaches / Frameworks / Logic	When to Use
PREDICTIVE URBAN GOVERNANCE	LOW	LOW	• Forecasting • Scenario Planning • Causation Logic *(entrepreneurship domain)*	In situations of low uncertainty, where the characteristics of the socio-technical system are to be maintained. Limitation is that path-dependency is embedded.
ADAPTIVE URBAN GOVERNANCE	HIGH	LOW	• Scenario Building • Back-casting	In situations of high uncertainty, when the characteristics of the socio-technical system are to be responsive to future events. Limitation is that a preferred future is not facilitated.
VISIONARY URBAN GOVERNANCE	LOW	HIGH	• Strategic Projection • Roadmapping • Transitions Management	In situations of (ideally) low uncertainty, where a vision for the future can be realised, where the socio-technical system requires systems change to a preferred future. Limitation is visions can be prediction-based.
TRANSFORMATIVE URBAN GOVERNANCE	HIGH	HIGH	• Effectuation Logic *(entrepreneurship domain)*	In situations of high uncertainty, where the socio-technical system requires systems change towards a preferred future. Limitation is lack of practical guidance on transformative governance approaches.

4.4 ENTREPRENEURIAL DECISION-MAKING LOGIC FOR SYSTEMS CHANGE UNDER UNCERTAINTY: EFFECTUATION

In the entrepreneurship literature, the entrepreneurial decision-making logic that represents a transformative approach - as defined by this framework - is 'effectuation'. Effectuation has predominantly been applied in the entrepreneurship and strategic management literature. This thesis proposes effectuation as a strategic approach positioned within the transformative domain, to inform 'Transformative Urban Governance'. It seeks to validate effectuation as an approach relevant to urban governance and elucidate the distinctions of an effectual approach to urban governance in contrast to conventional causation approaches.

When scientists began researching chess masters in the early 1970s in an attempt to understand the phenomenon of expert performance, they found that intelligence had no correlation with chess mastery (Chase and Simon, 1973; Simon and Chase, 1973; Doll and Mayr, 1987; Dew et al., 2009). As research into expert performance expanded into domains such as taxi-driving, medicine, and firefighting, the results were similar (Ericsson, 2006a; 2006b; 2006c). 'Expertise' is understood to result from more complex factors related to how problems are perceived, how information is stored, and how solutions are generated (Dew et al., 2009). The change in underlying cognitive systems that occurs for 'experts' as a result of deliberate practice and experience in a particular domain manifests as higher-level skills and knowledge that lead to superior performance, rather than IQ (Unger et al., 2009).

At the turn of the 21st Century, Saras Sarasvathy published the results of her work studying 'expert' entrepreneurs, a list of individuals sourced from 'Top 100 most successful entrepreneurs from 1960 to 1985' list; and Ernst & Young 'Entrepreneur of the Year' award winners, to understand their decision-making logics and solution building processes (Sarasvathy 1998; 2001). The result of Sarasvathy's work into understanding entrepreneurial expertise was the development of a theory of entrepreneurship she calls 'Effectuation' – a decision-making logic applied by expert entrepreneurs under conditions of heightened uncertainty. Sarasvathy's work challenged the traditional understanding of entrepreneurial decision-making and behaviour, with effectuation articulated as distinct from the more traditional school of thought around business planning and execution – 'Causation'. In contrast to the conventional view of entrepreneurship which considers entrepreneurial opportunities to be 'found' and exploited, Sarasvathy posits that opportunities are 'co-created' by entrepreneurs and their stakeholders (Sarasvathy, 2001; Sarasvathy, 2003; Read et al, 2009; Sarasvathy & Ramesh, 2019; Sarasvathy & Botha, 2022).

Since Sarasvathy published her work in 2001, there has been a significant amount of interest and research in the entrepreneurship field related to this concept (e.g., Goel & Karri, 2006; Mitchell et al.,

2007; Chiles, Gupta, & Bluedorn, 2008; Read et al., 2009; Dew, Read, et al., 2009; Wiltbank et al., 2009; Endres & Woods, 2010; Chandler et al., 2011; Harmeling, 2011; Brettel et al., 2012; Keskin & Markus, 2022). An array of studies over the past two decades have examined entrepreneurship from an effectuation perspective and gathered empirical evidence from expert entrepreneurs across multiple industries applying effectuation heuristics to deepen the understanding of effectuation as a decision-making logic in contexts of entrepreneurship, innovation and finance (Dew & Sarasvathy, 2001; Sarasvathy & Wiltbank, 2002; Sarasvathy & Dew, 2005; Read, Song, & Smit, 2009; Wiltbank, Read, Dew, & Sarasvathy, 2009; Dew & Sarasvathy, 2016;).

4.4.1 Entrepreneurial Decision-Making Logics: Causation vs. Effectuation

Sarasvathy (2001) distinguishes two opposing but substitutive logics that guide entrepreneurial decision-making during the venture creation process: causation and effectuation. Causation describes the goal-driven, rational decision-making, outcome-focused process applied by entrepreneurs when pursuing entrepreneurial opportunities. Causation is grounded in neoclassical economics and comprises the majority of entrepreneurship literature. Entrepreneurs adopting a causal logic identify a specific entrepreneurial opportunity, usually in the form of a desired goal, outcome or product, and focus on assembling the required resources based on prediction and planning to achieve their desired objective. Effectuation is characterised as 'non-predictive control'. In contrast to causation, entrepreneurs applying effectuation logic begin with what resources are available - such as identity, knowledge and networks - and build partnerships and collaborations with the goal of co-creating an outcome that is not pre-determined by the individual entrepreneur, but is formed through a collaborative process with customers as partners. While partnerships, and commitments by partners as a driving force in the co-creation of new markets and futures by effectual entrepreneurs – equally important is the effectual approach to responding to contingencies. Under effectuation logic, entrepreneurs seek to leverage contingencies, rather than be hindered by it, and as such this approach is well-suited to action under uncertainty.

It was not that some entrepreneurs used causation and others used effectuation, but that entrepreneurs switched between the two based on conditions. Sarasvathy observed that although causation logic was considered conventional wisdom, the type taught in Master of Business Administration (MBA) programs around the world, expert entrepreneurs more commonly applied effectuation. This was especially the case in situations of heightened uncertainty. Sarasvathy further observed that effectuation was commonly applied by expert entrepreneurs during new venture creation and growth under conditions of heightened or 'Knightian' uncertainty. Under Knightian uncertainty, expert entrepreneurs opted for non-predictive strategies that leveraged what was within their control and created opportunities with committed stakeholders. Rather than focusing on a pre-determined outcome, the effectual entrepreneur began with a general objective in mind and brought on-board those who would

conventionally be considered 'customers' as partners, focusing on controlling the controllable rather than predicting the unpredictable, and leveraging surprises and opportunities as they arose rather than seeking to avoid them through prediction. Such logic has particular value in contexts where there is no clear development path (Kaufmann, 2013).

As Sarasvathy (2009) describes:

> "Causal problems are problems of decision; effectual problems are problems of design. Causal logics help us choose; effectual logics help us construct. Causal strategies are useful when the future is predictable, goals are clear and the environment is independent of our actions; effectual strategies are useful when the future is unpredictable, goals are unclear and the environment is driven by human action. The causal actor begins with an effect he wants to create and asks, "What should I do to achieve this particular effect?" The effectuator begins with her means and asks, "What can I do with these means?" And then again, "What else can I do with them?".

Sarasvathy does not claim that expert entrepreneurs, or entrepreneurs that apply an effectual logic, do so exclusively and do not act in accordance with causation thinking at all. In fact, Sarasvathy posits that entrepreneurs shift between the two logics and apply both when and as required. The switch between the two logics can occur due to contextual factors such as levels of uncertainty, access to information, or availability of resources (Lennips, 2016). Sarasvathy's original study found that 63 percent of her participants used effectual rather than causal logic approximately 75 percent of the time (Sarasvathy, 2001). In other words, the majority of 'expert' entrepreneurs applied effectuation over prediction-based strategies, the majority of the time. A comparison of the two logics (causation and effectuation) is presented in Table 4-2-2 below.

Table 4-2: Comparison of Causation and Effectuation Entrepreneurial Logics (Sarasvathy, 2009)

Characteristics	Causation	Effectuation
Basis for taking action	**Should:** Start with pre-determined goals based on perceived optimal scenario. Focus on what should be done to attain this goal.	**Can:** Start with what's available: who you are, what you know, who you know. Focus on what can be done and push this forward.
Attitude towards risk	**Expected return:** Calculate a predicted upside potential and pursue the best opportunity.	**Affordable loss:** Calculate downside potential and risk no more than you can afford to lose.
Attitude towards others	**Competitive**: Establish transactional relationships with products and suppliers.	**Co-Creational:** Build a market together with customers, suppliers and even potential competitors.

Attitude towards unexpected	**Avoid surprises**: Use prediction and forecasting to avoid future surprises.	**Leverage surprises:** View unexpected occurrences as opportunities.
Underlying logic	**Prediction:** The future can be readily predicted. To the extent we can predict the future, we can control it.	**Design/Creation:** Using strategies for creating a future. To the extent we can control the future, we do not need to predict it.

The effectual entrepreneur, rather than heavily investing in a pre-determined solution they predict will be ideal for their pre-existing target market, reduces risk by assessing their affordable loss and shapes a new target market through collaboration. Rather than seeing contingencies that arise as roadblocks or challenges that prevent them reaching a predetermined goal, the effectual entrepreneur treats these contingencies as opportunities to steer the venture in a new direction. By including a range of stakeholders from the beginning, and including future 'customers' as partners from the start, effectual entrepreneurs co-create a product that is subject to greater demand, and simultaneously create a surrounding market and ecosystem. The effectual entrepreneur recognises the future is uncertain, and rather than relying on a strategy based on predictions of an uncertain future, they co-create next steps based on what they can do with the resources and partners they have.

4.4.2 The Principles of Effectuation

Following from Table 4-2, the five principles of Effectuation are presented below (Sarasvathy, 2009):

Principle 1: Available means rather than pre-determined ends

Effectuation logic focuses on what is available – 'available means' - rather than beginning with a predetermined outcome in mind. Effectuation takes the means as given, and focuses on creating effects; it does not take an effect as given and focus on assembling means to achieve such an effect. For individuals, available means fall within three categories: (1) identity; (2) knowledge base; and (3) networks. Entrepreneurs may ask themselves: Who am I? What do I know? Who do I know? More broadly, means could include a range of available resources i.e. local natural resources, materials, and environmental factors, industries and/or competencies.

Applying effectual logic, an entrepreneur makes decisions based on what is readily available, with preference given to actions that leverage available resources or networks over those that require acquiring new means to fabricate an approach that satisfies a pre-determined outcome. Sarasvathy (2009) provides the analogy of a chef who cooks a meal based on the ingredients available in the pantry - often leading to a more novel meal - rather than deciding on a meal as a pre-determined outcome, assessing what is missing from the pantry and going shopping for the necessary ingredients. With effectuation logic, decisions are made based on what is readily available, and preference is given to actions that can be taken which harness available resources or networks, over those that require acquiring new means. In a meta-analysis of existing studies, Read et al. (2009) found a significant and

positive correlation between means ('what I know', 'who I am', 'who I know') and new venture performance.

Principle 2: Affordable loss rather than expected returns

The predisposition towards risk of an effectual entrepreneur is focused on calculating what level of loss is 'affordable' as a basis for determining acceptable risk, rather than basing such decisions on expected returns. Effectual entrepreneurs are more likely to limit downside risk rather than focusing on upside potential. In this way, their decisions are safe within their own acceptable bounds, and large risks to achieve idealised returns are avoided. This principle overlaps with available means as decisions aim to creatively leverage underutilised or 'slack' resources available in the world to reduce early-stage funding, and options are chosen which create more options in the future. Read et al.'s (2009) meta-analysis found less correlation between affordable loss and new venture performance than, for example, the strategic value of available means.

Principle 3: Alliances and partnerships rather than competition

Effectual logic suggests that expert entrepreneurs build partnerships from the beginning of their ventures, and potential customers become key founding partners and stakeholders. This approach is particularly effective under uncertainty as pre-commitments from partners and stakeholders dramatically reduces uncertainty; as 'contracts' are formed regarding the direction of the collaboration, and stakeholders act consistently with these commitments over time, a future begins to emerge which is consistent with the agreement. In combination with the affordable loss principle, this strategy of collaboration reduces costs to the individual entrepreneur and establishes some certainty about the future. This principle departs from conventional corporate strategy oriented around competitive analysis and differentiation. The key distinction here is that rather than a primary focus on theorising in a vacuum through business plans and predictions of market demand before going out and speaking with potential customers and partners, the effectual approach entails prioritising input from potential customers from the very beginning of the new venture process. Not only do effectual entrepreneurs 'consult' with customers, take on their feedback, and iterate a product in-line with market demand, they seek to establish partnerships with customers that expand network resources and co-create the artefact jointly with the end-user. While there may be much interest in a new artefact from potential customers, the litmus test for those who are genuine self-selecting stakeholders is the level of commitment that an individual/entity is willing to make to the new venture. Through a series of commitments, a patchwork quilt of collaborative contributions form a more unique and novel product; one that has leveraged the resources of a collective rather than only the entrepreneur, and is inherently aligned to its end user or market. Read et al.'s (2009) meta-analysis found a significant correlation between partnerships and new venue performance.

Principle 4: Leverage unexpected surprises as opportunities to create greater value

Rather than trying to predict and avoid the unexpected or to achieve predetermined goals in spite of contingencies, effectuation suggests that expert entrepreneurs exploit contingencies and recognise that unexpected events present opportunities to maintain control of an emerging situation. At the core of this principle is the ability of the entrepreneur to recognise a surprise as an opportunity for value creation rather than an added barrier to achieving a predetermined outcome. Effectual entrepreneurs are open to the possibility that the final artefact to emerge from an effectual process may not look like what was initially envisioned. Through collaborative formation and effectual stakeholder contributions, in conjunction with adaptation to changing conditions within the environment, the effectual artefact adapts along the way. It is not the contingency itself that defines which ventures can leverage these occurrences for productive outcomes, it is the individual/firm's ability to identify these as opportunities. Contingency, and the leveraging of contingencies is central to effectuation logic and is a key reason why effectuation is well-suited to action under uncertainty. As Sarasvathy (2009) identifies: "Uncertainty is a resource and a process rather than a disadvantageous state".

Principle 5: Control what can be controlled and avoid basing decisions on predictions of an uncertain future

Taking an effectual approach to decision making given uncertain futures puts a focus on the controllable aspects of an unpredictable future; it does not try to predict an uncertain future and act upon these predictions. This principle of effectuation opposes a process where the future is assumed to be predictable, and predictions are made with actions and strategies designed with safety nets which account for the inherent uncertainty of any prediction. Instead, strategies and actions focus on aspects of the future that are within the control of the entrepreneur, particularly those elements which are a result of human action, and shape a desired future in this way. Rather than making strategic decisions based on predictions of the future, decisions are made based on what is within the 'control' of the actor and the broader partnership network. As commitments are made, they both expand network resources and cause a convergence of collective expectations.

The remainder of this chapter translates effectuation, as a decision-making logic falling within the 'transformative' domain of the prediction and control framework, into a civil infrastructure context. The remainder of the chapter illustrates the effectual approach in this context and discusses the implications for the governance of niche innovations. The principles outlined form the basis of a new approach to urban governance that adopts effectual logic, which is further detailed in Part 2.

4.5 SYNTHESISING EFFECTUATION LOGIC AND STRATEGIC NICHE MANAGEMENT

4.5.1 Strategic Niche Management and Causation

While SNM has been used in the sustainability transitions literature as an analytical tool to asses past transitions with the aim of informing insights for systems change towards sustainability, its application as an operational tool for transitions has been limited. As this subsection illustrates, it is clear that this development is aligned with causation logic. Mourik and Raven (2006) identify five steps involved in the creation of niches and projects, and three interrelated internal niche processes that determine the fate of a niche. They also apply a practitioner's lens to SNM to highlight limitations of the approach and call for future research to address key gaps limiting SNM's usefulness. Figure 4-3 below represents the steps and processes they identify.

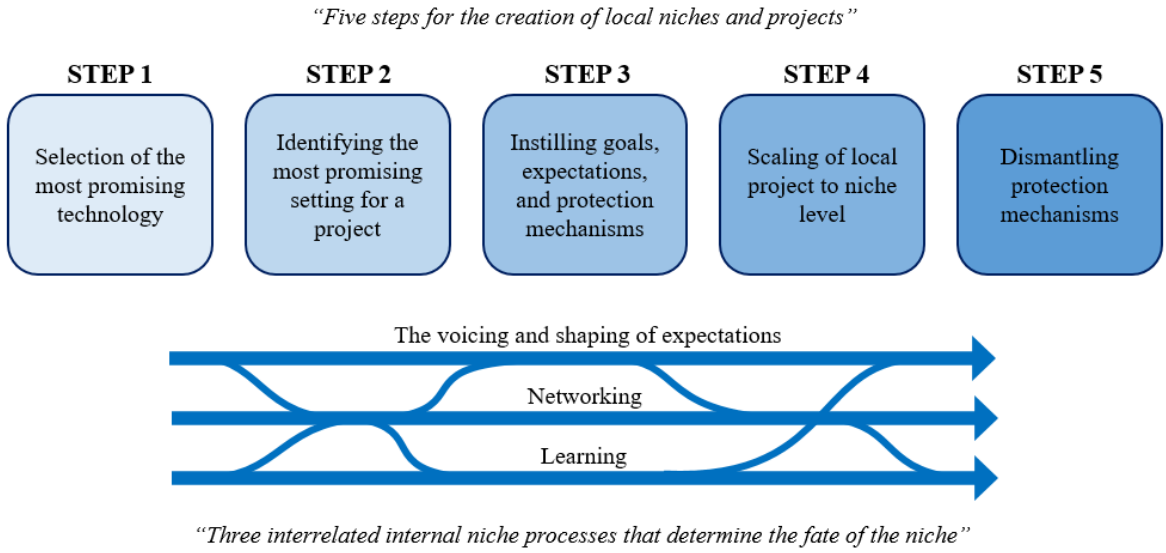


Figure 4-3: Strategic Niche Management process (Source: Author based on five steps identified by Mourik and Raven, 2006.)

The traditional SNM process places a strong emphasis on analysing and assessing innovations to assess the most promising; this analysis includes determining which settings are right to deploy such innovations; and which frameworks should be used to analyse the success of innovations and determine future steps. Viewing SNM through the distinction of causation and effectual logic shows that SNM takes a causal approach to identifying strategic networks where key players are identified through market analysis and carefully selected to achieve pre-determined outcomes. Mourik and Raven (2006) acknowledge that the application of SNM through a technology supply, or 'technology push' approach is clearer, however, do state that SNM focuses on the potential of creating niches through demand-pull

but lacks practical guidelines on how to do this. A SNM process resembling causation logic is more prominent, in that technology and environment are pre-assessed through analysis.

The first step in the SNM process is to select the most promising technology, ideally one that has some alignment to the existing regime in order to inspire stakeholders, but is open to radical changes at a later stage (Weber et al., 1999). Selection of this process through a SNM approach involves establishing a list of indicators to assess the technology, such as alignment to policy, user preferences, existing infrastructure, production and maintenance structures. Leonard (1998) and Hoogma and Schot (2001) devised a matrix to assess technologies. Such an approach is representative of analysis-based prediction approaches to selection of technology and market analysis to identify opportunities for strategic deployment. This approach reflects causation logic with the selection of technology against market preferences with a range of criteria and assumptions.

Once a technology has been selected, the second step is 'identifying the most appropriate setting for the local project, where advantages of the technology weigh more heavily than its (economic) disadvantages' (Kemp et al., 1998; Weber et al., 1999). Here it is generally assumed that (a) new innovations are not competitive on economic terms with established alternatives; and (b) it is the decision of the niche manager to determine in what application the technology has the most advantages. Consistent with causation logic, the basis for taking action is to establish pre-determined goals based on a perceived optimal scenario. From there, the focus is on what should be done to attain this predetermined goal. This is the same approach an entrepreneur applying causation logic takes when calculating a predicted upside potential and pursuing the best opportunity. The niche manager may ask themselves, 'now that I can predict the optimal application of this new technology, who do I need to bring on board to realise this'? This leads to the second component of the second step, which is establishing a network.

In-line with causation logic, networks are established in the SNM process after a solution - in the form of a new technology - has been selected, and a desired outcome, based on a hypothesis regarding a specific market opportunity, has been established. The niche manager now establishes a network and orchestrates participation in that niche to achieve the desired goal. While some authors (Caniëls and Romijn, 2006:11) call out the vagueness of the SNM literature for who to be doing what, Mourik and Raven (2006) elaborate that network establishment should include specific entities – insiders and outsiders, users and producers. In the establishment of the niche network it is recommended that user roles should be defined and protection mechanisms should be stablished (Mourik and Raven, 2006). This process is coordinated by the niche manager, however not all actors are willing to participate or commit to the project (Mourik and Raven, 2006).

Reflective of a causation logic, it has been suggested that competitive selection be applied in the formation phase of the network, with calculation models applied to demonstrate to actors that the predicted returns of a radical innovation is much higher that the short-term revenues of incremental innovation (Weber et al., 1999). This case is made to participants to encourage their participation. The risk associated with a predicted return-based approach to establishing networks is that relationships can become transactional. This is representative of a causal approach to network building, in that the network is established on a pre-conceived notion of who is required to fulfil the vision for the technology, rather than seeking self-selecting stakeholders who inherently understand the value of a new socio-technical configuration.

The third step, shaping expectations, is a key step in aligning network participants for collaborative effort. In SNM, the aim of aligning expectations is to create a 'community with a shared agenda' (Elmustapha et al., 2018; Geels, 2010), such that the new innovation becomes a means of achieving this agenda. A balancing act is required between setting expectations with a high enough level of stability to allow actors to contribute to a niche effectively, while allowing expectations to also be dynamic in what is an environment of uncertainty and experimentation (Raven, 2005; Van Lente, 1993; Hoogma, 2000). Practical guidelines on managing the process of voicing and shaping robust expectations is limited. Grounded in a technology-first approach where strategic networks are established to achieve a pre-determined goal, establishing expectations and coordinating the participation of stakeholders is challenging as the technology is new, potentially disruptive, and surrounded by much uncertainty.

Learning occurs throughout the stages of SNM and is crucial for the development of a niche. It is often considered the task of the niche manager to 'design' experiments that facilitate learning and extend it across the niche and between experiments. This is similar to a causal approach to entrepreneurship whereby a 'customer segment' is identified and experiments are conducted to tailor an artefact to fit the market. Learning processes are usually oriented towards maximizing the potential of the technology rather that the broader system change – however the extent to which a technology will be sustainable cannot be fully anticipated, as it is impossible to define all possible effects before implementations, and equally difficult to predict all secondary effects (Weber et al., 1999; Hoogma et al., 2002; Raven, 2005; Mourik and Raven, 2006). For this reason learning is essential to SNM, however is commonly limited to technology-oriented learning rather than system-oriented learning.

The fourth and fifth steps are scaling up of a local project to the 'niche' level, and then dismantling protection to promote the independence of the innovation with the intention of increasing its economic competitiveness. A common means of scaling from a local project to niche level is by installing public support measures. These critical fourth and fifth steps are the most lacking in guidance for practitioners in the wider literature. While the SNM literature has developed an approach to local project formation, it is less prescriptive in expanding this local project to a niche and then removing support. With the first

three steps in SNM resembling a causation process, there is an embedded assumption that (1) the right technologies are identified; (2) the right networks can be identified and established; and (3) an appropriate scope of learning occurs.

Key gaps in Strategic Niche Management are as follows:

- There is an assumption that selection of technology is undertaken by a niche manager, and that this niche manager is best-placed to make this identification of a sustainable technology.
- A set of indicators are established up-front to assess the appropriateness of a technology against a set of pre-defined considerations, including alignment to the existing regime to encourage support. It is assumed this prediction-based approach is appropriate for selecting a technology, however is based on the existing unsustainable regime.
- As a result of the two points above, SNM is predominantly positioned and applied as a 'technology push' approach, rather than a demand-pull approach.
- There is an assumption that selected technologies/innovations are not competitive with incumbent alternatives, which in many cases they may not be, however the solution is for the niche manager to select the most appropriate context for application to enable and facilitate appropriate support mechanisms.
- Once the optimal outcome in a perceived optimal implementation setting is established, a strategically identified network is identified who are considered to have the required attributes to make the niche a success.
- Because these stakeholders are identified on their attributes some may not be willing to commit to a project or have deep buy-in, with a niche manager attempting to demonstrate the potential value through modelling of expected returns associated with a radical innovation.
- There is a risk that network interactions become transactional and focused on cost-effectiveness. Building shared expectations is important however is more challenging when stakeholders have been sourced in the above way.
- Influenced by a technology-first approach, while learning is essential to niche evolution it can be overly technology-oriented, rather than systems-oriented – which can limit a technology's ability to scale and survive without protection mechanisms.
- Ultimately, the fourth (scaling a local project to the niche level) and fifth (removal of support mechanisms) steps can be inhibited – i.e. new technologies have limited scalability without support mechanisms.

I posit that the foundations for successful scaling (step 4) and removal of support mechanisms (step 5) are underpinned by the logic applied during the early stages of project/niche development. It is here that the foundations are laid for long term shared value creation, through networks that are self-selecting and with innovations that harness available means. As such, the answers sought by SNM as to how to

increase the scalability and competitiveness of a local project are not found after such a project has been undertaken through a causal logic, but in the logic by which a local project is orchestrated, and the shared value that is created to incentivise niche stakeholders to make ongoing commitments to drive the structuration of the new socio-technical configuration.

Viewing the strategic management foundations of SNM through Sarasvathy's (2001) distinction between causation and effectuation logic, it is clear that traditional SNM literature reflects causation logic. While the literature provides guidance on local project formation aligned to this logic, it is less clear on how to successfully scale a local project to the niche level and then subsequently remove protection mechanisms in order for a niche to survive. This prompts the question - what does the SNM process look like following an effectual logic, rather than a causal one? Does reconsidering the SNM processes in-line with an effectual approach, observed as a decision-making processes applied by 'expert' entrepreneurs – present an opportunity for more productive structuration of niche innovations to respond to sustainability challenges? What does this look like in a civil infrastructure context?

The remainder of this chapter focuses on making a contribution to the SNM literature by re-conceiving the niche structuration process through an effectual lens. The Willunga Basin Water Company is presented as a case study to illustrate how a sustainable civil infrastructure project increased in structuration following effectuation logic to transform the water infrastructure regime and broader economic prosperity of an entire region in South Australia. The case study and discussion responds to the gaps in SNM articulated above – specifically the nature of partnerships involving self-selecting stakeholders that drove structuration of the niche based on commitments from those stakeholders; the leveraging of available means to underpin technology selection; the facilitation of systems-based learning within the community; and how the expansion of network resources and convergence of expectations drive the structuration of a niche.

4.5.2 The Dynamic Process of Effectuation

The dynamic model shown in Figure 4-4 (Sarasvathy & Dew, 2005) represents the dynamic process of effectuation. The key 'steps' in establishing an effectual market are to focus on available means (Who am I? What do I know? Who do I know?) and prioritise interactions with other people to establish commitments from effectual stakeholders that provide resources and certainty about a future direction. The Figure illustrates the dynamic process which involves two concurrent cycles of acquiring means and converging the collective goals and expectations of the cohort of partners (Sarasvathy & Dew, 2005; Sarasvathy, 2008).

The process shown in Figure 4-4 is not prescriptive on whether or not this process begins with a specific opportunity identified: in some cases it may, in some cases it may not (Sarasvathy & Dew, 2005). What is more important is the available means, what is on-hand in the form of identity, material resources,

knowledge or networks that can be acted upon. However, these alone are not enough to determine a course of action. The effectual actor prioritises interactions with others, in the search for effectual stakeholder commitments, and these effectual stakeholder commitments represent the 'criteria' for network participation. Through effectual stakeholder commitments, new means are made available to the project/niche, and new collective goals are created.

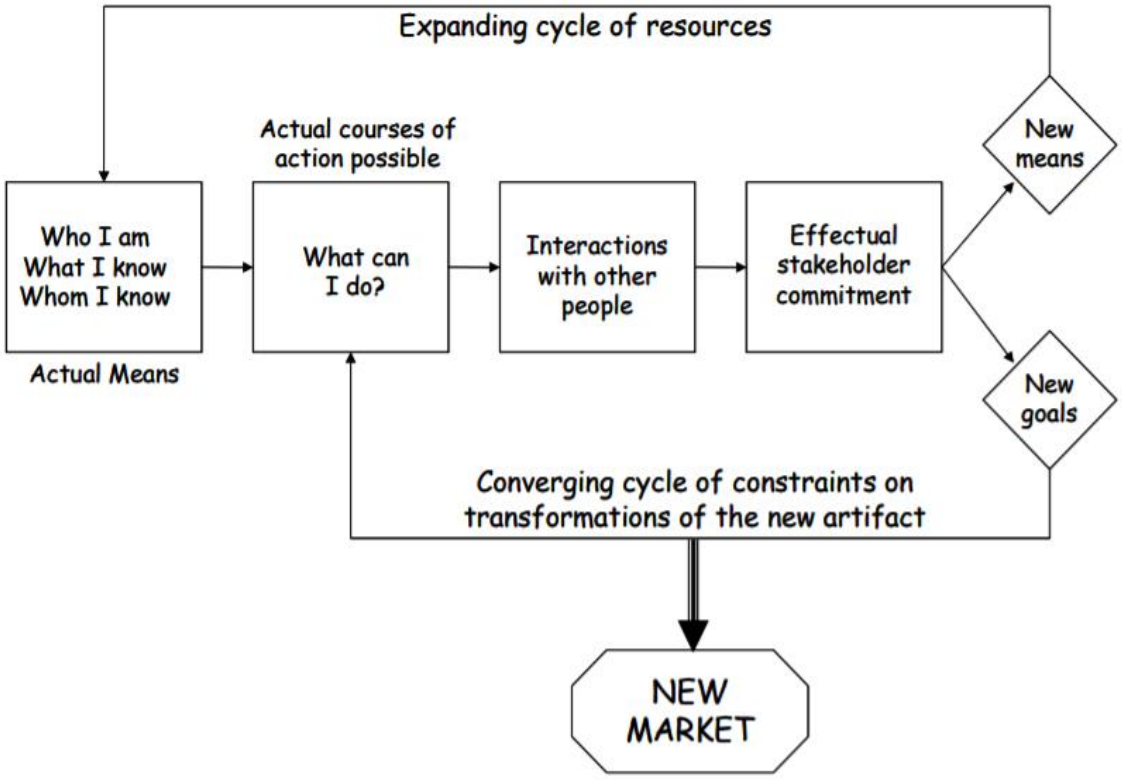


Figure 4-4: A dynamic model of the effectual network and the new market as an effectual artefact (Sarasvathy & Dew, 2005)

The case study of the Willunga Basin presented in the following section illustrates this dynamic process in the context of socio-technical infrastructure transitions and transformation.

4.5.3 Infrastructure Niche Structuration through an Effectual Lens: Case Study of Wastewater Re-Use in the Willunga Basin, South Australia

The Willunga Basin is located in South Australia, the driest state of the driest inhabited continent on Earth (Geoscience Australia, 2022). The Basin is home to world-renowned wine regions and tourism destinations such as McLaren Vale, whose successes have been underpinned by the availability of water provided by the Willunga Basin Water Company (WBWC) for the past two decades. The WBWC was formed in the mid-1990s, when the agriculturists of the Willunga Basin were facing increasing uncertainty as a result of water scarcity and regulation during an eight-year drought. At the time, while

there was available land to expand the production of the region's globally sought-after wine, there was a high level of uncertainty surrounding water supply, which inhibited investment in the area.

The WBWC addressed this challenge by implementing a wastewater reuse scheme that leveraged available resources, brought together competitors as partners, and focused on affordable loss rather than expected returns. The WBWC evolved based on effectual stakeholder commitments, and acted upon what could be controlled to generate certainty for the region. Retrospectively, these steps reflect the five key principles of effectuation. It was through an effectual approach that the WBWC transformed what began as a niche idea subject to much negativity and scepticism from local agriculturalists, into the prevailing socio-technical water regime in the region that has since underpinned economic prosperity in a range of industries. However, and as with many niches, incumbents of the established regime initially resisted this new socio-technical configuration. Despite the significant success the WBWC has achieved over the past 20 years, at the time of its initial conception as a new market niche, the incumbent water utility – the South Australian Water Corporation (SA Water) – was opposed to its creation.

The formation of the WBWC has been documented by various authors including Carter (2001); Institute for Sustainable Futures (2013); Thiyagarajah (2005); and Keremane and McKay (2008). This case study outlines the formation of the WBWC and the structuration of this niche over time into a prevailing socio-technical regime by following the dynamic process of effectual urban governance, shown in Figure 4-4. The narrative follows an 'iterative' process over two iterations of effectuation. The first iteration is divided into five subsequent steps:

1. Available means and subsequent possible actions
2. Interaction with actor networks and effectual stakeholder commitments
3. Taking effectual action
4. Converging cycle of niche structuration (expectations, actions and learning)
5. Expanding cycle of network resources

The second iteration is presented more generally, comprising the following overarching dynamic processes that drive niche structuration:

1. Expanding networks: Strengthened networks leading to new effectual commitments and projects
2. Converging expectations: Increasing structuration of practices and expanding network of resources

The five principles of effectuation, as defined earlier in this chapter, are coded throughout this process using the following abbreviations:

- **[AVM]** Available Means rather than predetermined ends
- **[AFL]** Affordable Loss rather than expected returns
- **[ALP]** Alliances and Partnerships rather than competition
- **[LVC]** Leverage Contingencies to create greater value
- **[CTRL]** Control rather than prediction

First Effectual Iteration

During the mid-1990s in South Australia, agricultural irrigators (predominantly wine growers) in the Willunga Basin region were facing water shortages as a result of an eight-year drought. The groundwater the irrigators relied upon was declining in both quality - becoming increasingly saline (an important metric for wine growing) - and quantity, as water was becoming increasingly regulated. Agricultural land in the area had become essentially worthless without water supply. This was limiting for existing irrigators and preventing the expansion of premium grape growing across regions such as McLaren Vale, which at the time, presented a major economic opportunity as the wines grown in this region were being recognised around the world. While there was global recognition and demand for McLaren Vale's wines, the water scenario at the time meant that growers could not meet this demand. The growers in the region needed a solution for irrigated water.

Available Means and Subsequent Possible Actions

Regulations meant that irrigators could only extract a limited amount of groundwater, with their other option being to pay for mains water for irrigating; however this was much more expensive and commercially unviable, while the marginal cost of extracting groundwater was practically zero as it essentially only required infrastructure and electricity for pumping.

At the same time, the discharge of wastewater from Christies Beach wastewater treatment plant into the nearby Gulf of St Vincent was an emerging problem for South Australia **[LVC]**. Nearby, approximately 10 km from the Willunga Basin, the treatment plant was emitting 9000 ML of treated wastewater into the ocean each year, produced by a serviced population of 150,000 people. The emission of wastewater into the Gulf was of concern for both the South Australian Government and SA Water.

This wastewater source presented a source of water that could satisfy the water needs of Willunga Basin and simultaneously solve an existing problem for the state **[AVM, LVC]**. A project was conceived by a group of irrigators to take the wastewater from SA Water's Christies Beach plant and supply it to the McLaren Vale wine growing region **[ALP]**. This proposal would divert water from entering the Gulf and provide (1) an environmental benefit and a big 'win' for the water utility and State Government who were responsible for managing the nutrient output into the Gulf; and (2) provide the irrigators of the Basin with a stable water supply that was needed **[LVC]**. Despite the benefits for the State, and the

support of the State Government for the scheme as it reduced the wastewater being discharged into the Gulf, SA Water was initially not receptive to the idea as it was inconsistent with the existing regime.

Interaction with Actor Networks and Effectual Stakeholder Commitments

The project, as conceived by the growers to meet their own water needs, had the support of the South Australian Government **[ALP]**. Regulations in South Australia meant the project still needed to go out to competitive public tender to allow other companies to propose how they may be able to provide the infrastructure to make the plan a reality. Multiple companies submitted a bid to deliver the infrastructure, however the consortium of growers submitted the most competitive bid and were awarded the rights to develop the project. Representing 'customers' acting as partners was a further fundamental component of their successful bid.

The proposed structure of the WBWC enabled a number of tax and finance mechanisms to work in favour of the consortium of growers as it would not be a third party delivering the project and then selling them the water. As shareholders of the company, the investors were also purchasers of water from the scheme, and each put in amounts proportionate to the amount of water they planned on withdrawing from the scheme **[ALP, CTRL]**. The financing package put together by the irrigators, with leadership from an ex-investment banker member of the group who became chair of the WBWC, took advantage of tax incentives available to agricultural producers in the State. The recipients of the value created by the project were much better-placed to competitively bid for the project – displaying the benefit of having these parties involved up-front.

Taking Effectual Action

The Willunga Basin Water Company 'WBWC' was formed in August 1997 as a joint venture between irrigators in the region; they banded together to provide the investment to construct the pipe linking the wastewater treatment plant at Christies Beach with the McLaren Vale wine region **[ALP, LVC]**. The AUD $20 million start-up cost of the company and the distribution network was borne wholly by a group of 15 irrigators.

While there was no reliance on Government funds, initially the government provided investor and irrigator confidence by signing a 30-year agreement for the secure supply of water, with an additional 10 years available **[CTRL]**. SA Water, who are ultimately guided by the government as a public water utility, agreed to provide the wastewater at no cost for the contract's initial period as it was a resource they needed to find an alternative use for **[AVM, AFL]**. This was a key part of bringing SA Water onside. Rather than WBWC being responsible for treating the water, the company agreed to transport it to irrigators, who then further treated it using sand or disc filters prior to irrigation **[AFL]**.

Initially, the broader community perception of using wastewater to irrigate crops was not positive. This was characteristic of the structuration of the prevailing socio-technical regime, and its associated

cultural norms and user preferences, being misaligned to the innovation proposed by this new niche. Research suggests that wastewater reuse projects often fail because there is a lack of community involvement (Po, Juliana & Nancarrow, 2004; Hurlimann & McKay, 2006; Keremane & McKay, 2008). However, the initial 'customers' in this case were the partners in the venture, meaning the business operators understood customer needs as they were part of the local viticulture community **[ALP, AFL]**. It also meant that the project had enough knowledge to 'get going' – and was able to bypass the experimentation processes often involved to convince new customers before the project could begin.

Converging Cycle of Niche Structuration

Initially, the 15 investors were the only users of the treated water for irrigation as other viticulturists in the region were worried the wastewater would risk the health of their crops. The main issues with wastewater generally are related to health and safety (Bitton 1994, pp. 371-3; Environment Protection Authority 1996; National Health & Medical Research Council 1999); water quality; suitability of crop to be irrigated with treated wastewater; and consistency/reliability of water supply (Metcalf & Eddy 1991).

The infrastructure delivered in the first iteration of effectual action involved supplying water via the pipeline scheme to the irrigators for their own use, however they did secure a supply agreement of wastewater larger than this amount (given the favourable conditions of the supply agreement) in the case that future expansion of the scheme occurred **[CTRL]**. The new pipeline and irrigation approach was a great success for the initial users, and information dissemination and learning was facilitated within the community through discussions and seminars – based on the crop successes of the 15 partner customers.

After one year, the initial negative perceptions/expectations of wastewater reuse were overcome within the wider community. One year after the project began, the WBWC's network expanded to service third party growers. Information provision to all new irrigators who joined the network was paramount throughout this process, particularly around health and hygiene risks. The two-stage rollout of the irrigation network between the initial investors and third-party growers minimised both technical and investment risk **[AFL]**.

Expanding Cycle of Network Resources

With a reliable supply of wastewater, guaranteed by the minimum 30-year contract secured with SA Water, and the 'proven success' of the initial phase of the project, the WBWC were confident they could expand the business to serve a broad customer base. New users were charged an access fee per ML they intend to use, paid over a 6-year period. This fee is paid regardless of whether they use their agreed volume – which ensures that WBWC's costs are covered and no demand prediction is needed

each year **[AFL, CTRL]**. The demand from an increasing number of third-party growers to join the scheme has been significant.

Both SA Water and the City of Onkaparinga also invested in the further expansion of the WBW network. Given the variability of the demand from year to year depending on variable climates, storage capacity is a key constraint on the expansion of the network. By partnering and trading with and between SA Water and the City of Onkaparinga to find mutually beneficial solutions, the WBWC has positioned itself to draw on the resources of its partners to achieve strategic growth.

Second Effectual Iteration

Over the course of 20 years, the use of the WBWC's wastewater has grown from a water supply network for a group of 15 investor-irrigators, to a new regime throughout the region that now supplies water to over 225 irrigators. Today, the WBWC supplies 6,500ML of recycled water per year to the region. Due to the partnerships that have been forged throughout the process, the scope of the WBWC's projects, as well as the resources, have expanded and these can now be leveraged by the WBWC from its partner organisations.

Strengthened Networks and Expanded Resources Leading to New Effectual Commitments and Projects

The legitimacy of the WBWC has grown significantly over time. The WBWC has become a major regional water supplier, alongside SA Water and the City of Onkaparinga. The three entities are equally committed to water security for the region, with the WBWC supplying 60 percent of the region's water. WBWC sources water from both SA Water and City of Onkaparinga, and leases storage from them. In return, WBWC delivers approximately 100ML of pressurised water into the municipality's network – including for a golf course, two reserves and a local school.

The City of Onkaparinga's 'Water Proofing the South' initiative is focused on future water security of the region, of which reclaimed water plays a major role. The WBWC have been engaged to supply water as part of this initiative. Stage 1 includes 174ML storage capacity to store water during the winter to be used in summer for irrigation. WBWC's collaboration with SA Water has also expanded, with an Aquifer storage and recovery scheme implemented in Aldinga, offering an additional 400ML water/year.

The WBWC has also commenced an expansion project to supply capacity to 8,100ML per year, underpinning water security for the region and building on the current supply of 6,500ML per year. In 2020, WBWC completed another 600ML storage dam in preparation for the 2020/2021 irrigation season. The WBWC continues to expand, and as of 2020 are in discussions with irrigators in the Blewitt Springs region, who currently rely 100 percent on stressed aquifers for their water supply – an unsustainable model.

Increasing Level of Structuration of Practices Resulting in an Embedded Socio-Technical System

Relationships continue to be strengthened and the network continues to expand. With this, comes new resources and opportunities for expanding the offerings of the WBWC. There is now a significantly different tone within the community compared to the initial perception of reclaimed wastewater. In the words of one interview participant, there is a 'line out the door' of irrigators seeking to be signed onto the scheme. The constraints of the system are now on the supply side, rather than demand, given the initial infrastructure was designed to meet the needs of 15 irrigators rather than an entire region. Although the water is more expensive than groundwater, the certainty that it provides growers to make sound forecasts and investment decisions is considered well worth it as the constraint of water scarcity has been mitigated. Estimates put the now current bulk value of wine produced in the region at approximately AUD $200 million per year.

The scheme has had significant economic benefits; it has also diversified the market with a growing number of organic and biodynamic vineyards. The region is simultaneously gaining a reputation for sustainability. For the businesses increasingly focused on sustainability, recycled water fits with their ethos and does not compromise their accreditations. "Now you find that the community's bragging because they're sustainable". "We are getting a reputation for sustainability and that's where the [Willunga Basin scheme] fits in really well".

Summary

Over the course of its development, the Willunga Basin wastewater reuse scheme faced a number barriers that new socio-technical niches commonly face. Initially, incumbent entities were not supportive of the scheme, as they perceived the new proposal to be encroaching on the established regime – given they were the primary water provider in the region and state more broadly. It was not just incumbents that were not positive towards the scheme - the idea of using recycled wastewater was initially not favoured within the Willunga Basin community. Within a year however, wastewater reuse represented a niche innovation and had established user preferences, cultural acceptance, and a local track record to validate its potential.

Civil infrastructure is often capital intensive, and in the case of the Willunga Basin, the government was not providing the funds to deliver the infrastructure. Even though the initial scheme did require government support in the beginning, and this was consistent with the ethos of strategic niche management, the process was still kick-started by a group of growers to meet their own water needs.. The government's supply of subsidised water to the scheme was an example of harnessing available means and addressing a pain point that existed at the time – the release of wastewater into the gulf. In terms of capital and initial customer offtake agreements, the WBWC exhibited effectual logic by bringing together a group of self-selecting agriculturalists who, on the one hand, could be considered

competitors, but instead rallied together to initiate effectual action to introduce the scheme at a scale that met their own water consumption requirements. The structure of 'customer as partner' created by the self-selecting group of initial stakeholders meant that the initial users of the water supplied by the scheme were those who were involved from the beginning and were willing to make commitments for effectual action. By acting on stakeholder commitments rather than over-extending and borrowing money to implement a grander scheme from the outset, the project's first iteration of effectual action allowed for learning by doing in some aspects of business management for the WBWC, as they were not previously in the business of water supply. In conjunction with broader community, this learning influenced a convergence of expectations among the region regarding what shared values could be created through the expansion of the scheme.

The structuration process followed a dynamic model of effectual urban governance, in that each stage of effectual action was based on commitments from self-selecting stakeholders who expanded the resources available to the niche and further converged expectations. While the initial water was supplied at no additional cost to those that funded the first iteration of effectual action, as the niche increased in structuration, users paid up-front fees (to again reduce up-front risk and reduce reliance on prediction and forecasting about future demand scenarios). As the structuration of the niche increased, new networks were formed with larger self-selecting stakeholders such as local municipalities participating, with agreements resembling partnerships much more than transactional dealings being signed– such as water storage leasing agreements from partners that in return have specific reserves and golf courses watered by the WBWC. Even the incumbent, SA Water, has expanded its partnerships with the WBWC to jointly supply more water to additional townships across the region.

The application of effectual logic in the development of the Willunga Basin wastewater reuse scheme is summarised in Table 4-3 below.

Table 4-3: Examples of the application of Effectuation logic in the Willunga Basin case study

Effectuation Principle	Example from the Case Study
Available Means rather than predetermined ends [AVM]	• The Willunga Basin Water scheme made use of wastewater that was being discharged into the adjacent Gulf of St Vincent that was considered a problem for the state. • SA Water agreed to provide the water at no cost for the contract's initial period as it was a resource to find an alternative use for. • The Joint Venture partners (irrigators) invested in the pipeline themselves paying amounts proportionate to their own use.

Affordable Loss rather than expected returns [AFL]	• SA Water agreed to provide the water at no cost for the contract's initial period as it was a resource to find an alternative use for. • Rather than WBWC being responsible for treating the water, the company just transports it to irrigators, who treat it themselves using sand or disc filters prior to irrigation. • A two-stage rollout of the irrigation network between the initial investors and third party growers was adopted which minimised both technical and investment risk. • This fee is paid by WBWC customers regardless of if they use their agreed volume or not – which ensures that WBWC's costs are covered and no demand prediction is needed each year.
Alliances and Partnerships rather than competition [ALP]	• Project was undertaken as a joint venture between irrigators in the region who banded together to provide the investment to construct the pipe. • The 'initial customers' in this case were the partners in the venture, meaning that community (of which they were apart of) outcomes were central to the project. • Customer needs were understood and able to be quickly incorporated back into further iterations of the initiative. • Partnerships with SA Water and City of Onkaparinga, all focused on water security for the region, has allowed continual expansion of scope for reclaimed water use.
Leverage Contingencies to create greater value [LVC]	• Discharge of wastewater into Gulf of St Vincent was considered an issue for South Australia, however provided an opportunity to get a 'win-win' (more-so than desalination). • SA Water agreed to provide the water at no cost for the contract's initial period, as it was solving a key problem for them as they were responsible for managing the nutrient output to the Gulf. • Government were supporters of the venture and endorsed the scheme given the avoidance of discharge into the Gulf.
Control rather than prediction [CTRL]	• The investors of the company were also purchasers of water from the scheme, putting in proportionate amounts based on the amount of water they planned on withdrawing from the scheme. • The Government provided investor and irrigator confidence by signing a 30-year agreement for the secure supply of water, with an additional 10 years available. • The initial investors intention was to expand supply over time, however they began by using the treated wastewater themselves. • The scheme charges irrigators based on an agreed volume, and the fee is payed regardless of if they use this volume. This ensures that WBWC's costs are covered and no demand prediction is needed.

4.6 DEFINING AN EFFECTUAL APPROACH TO THE STRUCTURATION OF INFRASTRUCTURE INNOVATIONS: DYNAMIC MODEL OF EFFECTUAL URBAN GOVERNANCE

The previous case study illustrated infrastructure niche dynamics through the lens of effectual logic. The Willunga Basin wastewater reuse scheme, delivered by the WBWC, is an example of how effectuation logic can drive the structuration of a new, sustainable socio-technical infrastructure niche to create a new sustainability regime. Framing the emergence of a new socio-technical water regime through an effectuation lens offers new insights to inform sustainability transition efforts that often meet challenges when developing new innovations. These insights aim to support their increased structuration and regime transformation potential through a dynamic model of effectual urban governance.

The dynamic model of effectual urban governance proposed here adopts effectuation logic, as exemplified by the case study. While the case study presented a 'successful outcome', the focus of this discussion is on the process and principles upon which the structuration of niche innovations can be increased. As Sarasvathy (2009) states, effectuation is not about becoming a 'successful entrepreneur' per se, it is about 'how to do entrepreneurship well'. In the same way, it is important for the primary insights emerging from this work to focus on the process of urban infrastructure governance that can be translated to different local contexts, as is being called for in the literature (Pierre, 2014; May and Marvin, 2017). It is increasingly recognised that governance insights must not be project-specific or too rigid in their methodology; instead, there is a need for principle-based and adaptable approaches to different institutional and policy contexts where projects take place.

This first part of the research has restructured the elements of Sarasvathy's dynamic model to create the dynamic model of effectual urban governance shown in Figure 4-5 below. The model represents an approach to SNM that follows an effectual logic, rather than causation logic. It incorporates the key SNM elements of expectations, networks and learning. This section outlines the elements of this dynamic model.

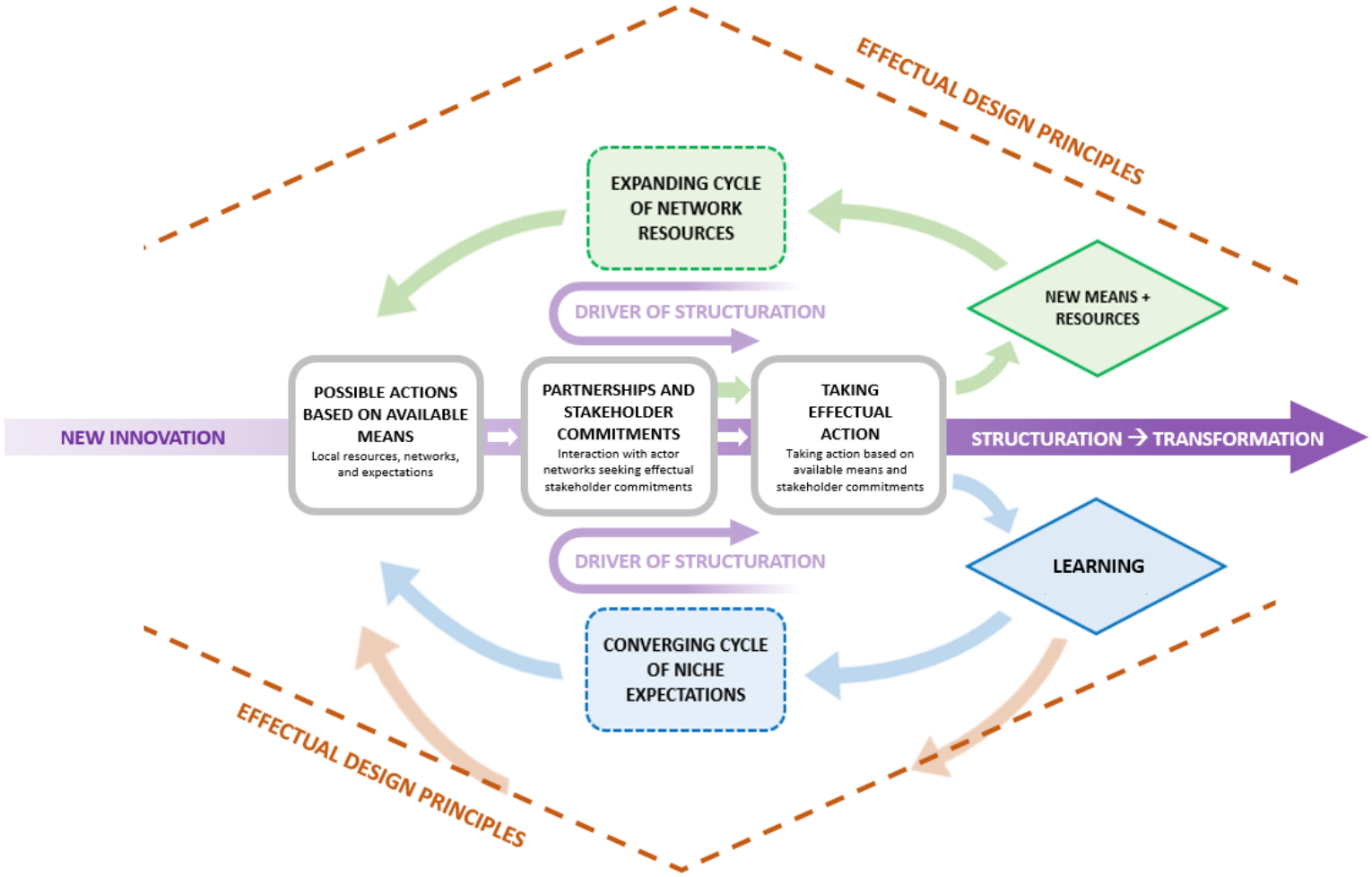


Figure 4-5: Dynamic model of Effectual Urban Governance, combining Effectuation and Strategic Niche Management

(Adapted from dynamic model of Effectuation presented by Sarasvathy, 2009; and key Strategic Niche Management elements Geels and Raven, 2006)

The fundamental objective of niche support is to increase the level of structuration of niche innovations to facilitate system change towards sustainability. By definition, the increased structuration of new innovations is the differentiating factor between which innovations remain a niche, and which innovations emerge to form a new socio-technical regime, as explored in Chapter 2. Because niche innovations in a socio-technical transition context are defined as new ventures, and can be broader and involve innovations such as policy or behaviour change, the creation of 'new markets' as an output of the effectual process has been represented as 'structuration of a new innovation' in an SNM context. These concepts are connected, as the creation of a new socio-technical regime involves changes to the social and technical elements that comprise a market; it is the increase in structuration of these new practices that is needed for a new market to emerge. For communicative purposes the concept of structuration has been used as the objective and outcome of the effectual urban governance process to provide a more direct focus on the driver of socio-technical transitions predominant in the literature.

In contrast to the conventional SNM process that begins with a new innovation, the effectual approach to SNM, see Figure 4-5, is deliberately agnostic to what stage of the process a new innovation is introduced. As such, it is applicable in cases where a specific innovation has been identified to be supported, and in cases where a problem is identified and solutions are to be generated. This resembles the context of new venture creation, whereby the effectual process can begin with an innovation or identified market opportunity as a starting point, or it can occur without an exogenous market opportunity pre-identified, and the very process itself can lead to the generation of new opportunities and markets (Sarasvathy & Dew, 2005). As discussed in Chapter 3, many of the technologies required to meet global sustainability objectives already exist. The missing link is arguably the processes by which these innovations are structured across economies. In an urban governance context, niche managers are focused on building a new venture that in an entrepreneurial context may be established around a single innovation, rather than inducing sustainability transitions and transformations that involve a diverse fabric of urban infrastructures and social norms. The reality in this context is that a new socio-technical regime may involve a number of innovations or technological capabilities that may or may not already exist. As the process of structuration through effectual action increasingly occurs, innovations that may have been new when starting out, or did not exist and were created through an effectual process become more established – and become available means in each subsequent iteration of the dynamic effectual cycle.

Despite leveraging new innovations, the majority of civil infrastructure is provided in response to a need. In the case of the Willunga Basin, the water shortage crisis. Transport infrastructure is provided to respond to connectivity and accessibility needs. Electricity infrastructure is supplied to meet society's demand for energy. Waste management infrastructure is required to process increasing volumes of

discarded materials. Infrastructure investment, and particularly those involving public funds, is justified based on the ability for infrastructure to respond to an identified need or problem.

Civil infrastructure is expected to deliver benefits for society, and by definition, innovations that are introduced to enable sustainability transitions are expected to be sustainable. Effectual urban governance, however, does not begin with a pre-selected innovation/technology for implementation in the same way that traditional SNM does. Instead, the first question is: what is available locally? As evident in the Willunga Basin example, if a niche begins with this question rather than a focus on which technology is the best fit based on a pre-conceived outcome, there is potential to leverage and value-add to what already exists. The Willunga Basin case study clearly shows that solutions that are generated through an effectual process create significant local value. They can also be 'unique' in the context of what has been done before. However, there was an overarching aim – to ensure the Willunga Basin grape growers received a stable water supply. By leveraging what is available, there is an inherent level of 'structuration' embedded in any solution – i.e. some component of the innovation, process, inputs, or networks already exist in the context in which the niche is being developed.

As effectual urban governance does not start with the most promising sustainability technologies as a pre-requisite, it is important to ensure sustainability transitions actors meet their fundamental objective of bringing about outcomes aligned with sustainable development. This raises the possibility that developing a solution based on effectuation logic, one that is not focused on pre-determining a specific outcome, is at risk of being steered off course by actors who have the resources to commit to the niche in a way that diverts effectual action away from sustainability. In the context of urban sustainability transitions, effectual design principles are proposed to guide public infrastructure innovations. Effectual design principles are proposed as broad principles that guide and inform the development of the niche. These principles guide the processes involved in the evolution of the niche and should be established at the early stage of an effectual endeavour with early niche stakeholders. Importantly, the principles should be broad and outcome-based, but not so prescriptive as to inhibit innovation, or to the level of detail that they pre-define the form or function of a solution; within these 'boundary conditions', or agreed and established expectations, the process of effectual urban governance is free to generate innovative solutions.

It should be noted here that in applying effectual logic to existing concepts within the SNM literature, 'expectations' replaces 'goals'. In this understanding, expectations and goals represent the same concept within existing SNM terminology. While the word 'expectations' is somewhat at odds with the very notion of effectuation as effectual processes are not about taking action based on 'expected' return or 'expected' outcomes but are based on what is available and within an acceptable loss threshold, the language is used here to increase the model's pertinence to the existing body of socio-technical transitions literature. As expectations reflect broader socio-technical preferences and norms, and as they

grow more rigid, the market of the niche becomes more embedded. The convergence of expectations in an effectual SNM context thereby represents the development of a community of stakeholders with a shared purpose and agenda, which becomes more clearly defined as effectual action is taken and learning ensues. The types of expectations which relate to purpose and goals, stem from and re-inform the design principles upon which the niche is developed. Further, and reflecting the converging cycle of niche expectations, 'learning' arises as a dynamic process from effectual actions and informs subsequent possible actions, as new information is revealed within the niche that influences expectations and goals. Murphy et al's (2020) work with the Toquaht Nation, a Canadian First Nations community provides an important example of the importance of engaging with communities to embed community views of the world into the effectual co-creation process.

Through effectual action and subsequent learning, effectual expectations converge. The convergence of expectations is one of the key driving dynamics of structuration over time. Returning to socio-technical transitions theory – without demand, niches do not survive. In the case of Willunga Basin, the community was initially reluctant to participate in the scheme. By using the available resources and building legitimacy through effectual action and communication of the benefits, the self-selecting stakeholders enabled learning among the wider community that expanded the customer base and led to the further expansion of the wastewater reuse scheme. In other instances of effectual action, as new actors join the network after multiple effectual iterations, and as the socio-technical configuration achieves some level of structuration, it is expected that the 'norm' has been established and that new actors will contribute to the scaling of the niche rather than significantly adapting its core intent.

The above synthesis of effectuation logic and strategic niche management establishes that driving the structuration of niche innovations through effectual urban governance does not follow a conventional strategic niche management approach. Rather, it consists of two processes. These are the converging of expectations, and the expansion of network resources. The steps/considerations in these processes include:

- Establishing effectual design principles at the outset of niche development, whether this be in response to the identification of a new innovation, or in response to an identified problem/need or strategic vision/objective. Effectual design principles should be broad and outcome-based, without being prescriptive about a particular 'desired effect' that constrains the process of effectuation based on available means. Example of effectual design principles may be (a) achieve a reduction in greenhouse gas emissions; (b) improve neighbourhood amenity and liveability; (c) improve safety of road users.
- Avoiding directly transferring expectations from one project where a specific technology or innovation may have been successful, to another. The focus is on available means as a basis for action, and allows local context, resources and networks to shape the expectations of a local

project. The success of a specific innovation in a different context may contribute to available means in itself, i.e. connecting with individuals involved in previous niche structuration efforts who are willing to share feedback and learnings from their experience; this may empower or accelerate the learning that can occur within a new niche, however could impede local value creation if this is the only starting point.

- Allowing expectations to be dynamic and shaped by stakeholders who 'buy-in' and commit to the niche. Expectations, in an effectual urban governance context, are more tactical compared with effectual design principles, which are higher-level and outcome based, and may involve the form and function of solutions that begin to emerge. As new commitments are made, the shape of the niche evolves, as do the expectations surrounding it.
- Avoiding establishing expectations on forecasted predictions of an 'expected' future. Expectations in an effectual urban governance context are goals-based, goals being generated locally and contingently and aggregated to a larger shared purpose rather than entirely top down, thereby serving to unify a niche with a shared purpose. They are not predictive, they do not promise a 'potential upside' to entice new stakeholders to the niche; instead they focus on what is controllable and allow the niche to be built outwards from available means.
- Encouraging technology and solution providers to remain open and flexible to niche feedback. If technology-first expectations are established that take a particular innovation as 'given' – with no room for iterative adaptation – there is a risk the niche will not align itself with social and cultural expectations and be unable to survive beyond a niche support stage. Effectual urban governance prioritises the establishment of authentic product-market fit through iterating with customers as partners; thus technology providers must be willing to go on this journey of exploration with users.
- Following from the point above, given that a technology may change and evolve throughout the process of niche development, avoiding being fixated on a specific technology, as is the case with SNM approaches, but instead be needs-oriented, guided by effectual design principles and view technologies/innovations as available means that form the basis for effectual action, and that may need to adapt in response to changing socio-technical conditions.

The second process that complements the convergence of expectations to drive the structuration of niche innovations is the expansion of network resources. Figure 4-5, defines two distinct steps of (1) establishing partnerships/networks (self-selecting stakeholders) and (2) effectual action.

Urban projects occur in diverse multi-stakeholder environments. It is necessary to distinguish between the processes of undertaking consultation, seeking partnerships and co-creating based on commitments – from the second distinct step of effectual action, or implementation.

Establishing networks and fostering effectual stakeholder commitments through an effectual urban governance approach consists of:

- Facilitating niche development through an effectual urban governance approach requires approaching potential partners. However, rather than fabricating a network to suit a desired end goal through market analysis, partnerships established through effectual urban governance will be with self-selecting stakeholders who are willing to make effectual commitments in-line with the effectual design principles of the niche.
- Taking a 'customer as partner' approach means engagement with the community is prioritised from an early stage of a project. Representatives of the residential and business community are given opportunities to engage with ideas from an early stage. The objective of the governance entity is to create an open and inviting environment for participants to engage. While know-how, innovation and resource contributions may come from private sector network participants, for example, community engagement at an early stage may be best suited to shaping effectual design principles that are aspirational and relate to their specific context. This way, early consultation is not solution-focused and does not revert to a causation logic but remains needs/problem focused with subsequent innovations developed by the network through commitments and then tested with the community in-line with the effectual design principles.
- Facilitating regular opportunities to negotiate effectual commitments through some form of stakeholder platform, or a specific actor within the network (i.e. government). This is because new actors are joining regularly and expectations are continually shifting. Effectuation places negotiation between committed stakeholders at the core of determining the future of the niche.
- Diversity of stakeholders represents an asset to the niche, particularly from different sectors. Explored further in Part 2 of the thesis, multi-sector participation in a niche broadens the structuration of the niche beyond a single silo. Again, the criteria for self-selecting stakeholders in an urban governance context is that (a) they are willing to make commitments to drive the structuration of the niche; and (b) their expectations and commitments are aligned to the local effectual design principles established for that niche.

In the context of urban infrastructure transitions, 'effectual action' will commonly represent the undertaking of an urban project at varying scales. Taking effectual action based on network commitments means that the scale and form of a project is defined on a case-by-case basis. The intention of making the distinction of effectuation action (as elucidated in Chapter 8), is to assert that unlike traditional causation-based decision-making processes, the 'first step' in taking effectual action within an effectual SNM process does not necessarily need to embody the final product. It may, for example, be one step in the direction of structuration that is taken based on affordable loss not expected returns. From this exploration of affordable loss, learning occurs, and new 'available means' are added to the

niche as new infrastructure, new habits or norms, or new user perceptions and further subsequent investments may be made. Taking effectual action then induces learning processes and galvanise network commitments, establishing the means available for a subsequent effectual iteration.

As Figure 4-5 depicts, learning is an inherent driver to the convergence of expectations within a niche. Learning arises from effectual action. Unlike conventional SNM, effectual governance of socio-technical niches does not strictly focus on a new technology; the shaping, design and decision-making processes of effectual action and SNM experimentation thereby differ. While both produce learning that highlights opportunities to move forward within the niche, effectual action is a more collaborative and commitment-based process. This approach embeds an element of structuration in the element itself by leveraging available means and allowing partner commitments to expand the resources available to the niche. Partnerships and networks are explored further in Chapter 8. It therefore follows that learning is not a technology-centric process but more broad and focused on developing the network and the niche through evolving goals and expectations. In avoiding the design of an 'experiment' that can often lead to quantitative performance evaluation of new technologies, effectual governance is more aligned to second-order learning that involves how niche stakeholders and the broader community perceive a new socio-technical configuration and how the 'demand side' social elements of socio-technical transitions can be refined and aligned based on commitments. In some cases however, effectual action may not achieve outcomes that galvanise stakeholder commitments or reinforce the niche direction. There may be user backlash or negative outcomes of effectual action. In this case, available means are once again revisited as the basis for a subsequent effectual iteration, but they may be significantly altered and/or involve different participants and/or different expectations.

With this said, as was the case in the Willunga Basin case study, communication of benefits plays an integral role in the evolution of perception, goals and expectations around a niche innovation. The Willunga Basin community was initially hesitant about treated wastewater as an agricultural input. However, community information sessions to communicate the benefits enabled second-order learning within the community that altered expectations and facilitated the expansion of self-selecting stakeholders. This suggests that while an effectual approach in an infrastructure context does not avoid measuring benefits/performance metrics or remains 'outcome agnostic' and focused on means, the process of taking action and the quantification of benefits are brought about in an effectual way. The learning that occurs within a niche is very much a product of the early-stage decisions that shape the artefact creation/implementation. If a causal process is taken to pre-determine a technology, and if specific metrics that are to be measured and conveyed are based on a pre-conceived hypothesis, the learning will often be limited to the specific realm of enquiry. Rather, starting with available means and effectual commitments and as a result, lesser certainty about the 'end product', facilitates a more open and flexible style of learning and future development trajectories remain open to possibility.

Facilitating learning through an effectual urban governance approach consists of:

- Following a collaborative and commitment-driven approach to effectual action, broadening the focus of learning to encompass technology performance, the social function and network impacts of a socio-technical configuration.
- Demonstrating value enables broader learning among stakeholders and potentially expands the pool of self-selecting stakeholders open to participating in the niche. Opting for problem and means-oriented performance metrics, rather than solution-oriented performance metrics. For example, ensure effectual design principles are broad and do not constrain innovation, so that different technological solutions can be compared and generate new and different ideas.
- Learning is iterative as each subsequent effectual iteration influences the dynamic process of effectual action based on stakeholders' commitments. When new stakeholders engage, the network broadens and new learnings may be generated; all learnings are important and should be communicated. While there may be a core set of partners willing to make the commitment to drive the next iteration of effectual action, there is still benefit in broadening the network and obtaining new users and partners for scaling of the niche.
- Engaging in an effectual process requires being genuinely prepared to receive feedback from the network and take action based on new means and commitments that arise from effectual action. Unlike 'Predict and Provide', effectual urban governance allows for broad input from early in the process and allows an infrastructure development process to be influenced by users of the system.
- As contingencies arise they are leveraged as opportunities rather than seen as de-railing niche development. By reducing reliance on prediction and forecasting, the impact of contingencies counter pre-conceived expectations for the future. Contingencies serve to change the context, means and learning occurring in the niche and forms the basis of the next iteration of effectual action.

4.7 CONCLUSION AND CONTRIBUTION TO THESIS

This chapter applied effectuation logic from the entrepreneurship/strategic management literature to SNM in the context of the governance of urban infrastructure transitions. The synthesis of effectuation logic and SNM illustrated the potential for effectuation logic to inform system change efforts under conditions of heightened uncertainty.

The dynamic model of effectual urban governance proposed here incorporates the key SNM elements of expectations, networks and learning, and these dynamics were articulated through the lens of effectuation logic rather than a causation-driven approach which focuses on technology first and focuses on assembling pre-determined stakeholders. Effectuation logic responds to the need for flexibility and co-creation in the structuration of niche innovations. The effectual approach to SNM was demonstrated using the case study of WBWC, to highlight socio-technical regime transformation and how this process happened dynamically over time.

This Chapter thereby makes the following contributions to this thesis and to the literature:

1. Responds to the thesis research question by developing a novel framework of urban governance that synthesises entrepreneurship and urban governance concepts:
    a. Draws on Wiltbank et al. (2006) framework of Prediction and Control, developed in the context of strategic management/entrepreneurship.
    b. Translates this framework into the context of urban governance, by defining the substitution of Prediction with ‘Capacity to Deal with Uncertainty’ and Control with ‘Ability to Facilitate Systems Change’.
    c. Within this new framework of Urban Governance along the dimensions of Uncertainty and Systems Change, presents an urban governance typology consisting of Predictive Urban Governance; Adaptive Urban Governance; Visionary Urban Governance; and Transformative Urban Governance.
    d. Utilises the developed urban governance typology to guide the subsequent literature review on practical urban governance approaches, with an explanation provided for each type of governance the defining features, examples in practice, and the limitations.
    e. Identify gap in ‘Transformative Urban Governance’ approaches as rationale for the application of effectual logic to the urban governance domain.
2. Applies the entrepreneurial decision-making logic ‘Effectuation’ to socio-technical systems change domain, specifically Strategic Niche Management, a sub-domain of this research field focused on supporting the emergence of niche innovations that hold promise for transforming prevailing socio-technical regimes.

3. Presents a dynamic model of effectual urban governance, which incorporates key elements of strategic niche management, as a dynamic process based on effectual logic rather than causation.
4. Validates the dynamic model in a civil infrastructure context by presenting a case study informed by semi-structured research interviews with project participants.
5. Presents a dynamic model of effectual urban governance.
6. Summarises key insights for SNM across elements of expectations, networks and learning informed by effectual logic and the infrastructure case study.

Key concepts of effectual urban governance are further elaborated in Part 2. Part 2 focuses on the urban transport sector as the 'civil infrastructure illustrative case' for further articulating the usefulness of effectuation logic to inform urban systems change. The insights generated in this chapter provide an alternative lens to view the strategic management of socio-technical niches for sustainability transitions, which in the literature has been a process informed by what can be considered 'causation' logic. Given that SNM is an extension of strategic management thinking applied to a broader systems change context, a broader discussion focused on the principles and logic underpinning these approaches is essential, particularly as the field moves from an analytical research tool to a more holistic and operational model for practical application. In distinguishing effectuation logic as one such approach to the structuration of innovations, this research provides a new perspective for the SNM field, shows how the principles and practices of entrepreneurship can be applied in a much broader societal context.

PART 2

PART 2 OVERVIEW

Part 2 of this thesis further illustrates the elements of effectual urban governance in a civil infrastructure context. It focuses on illustrating key elements of the dynamic process presented in Chapter 4. The discussion is further supported by practical case studies and examples; and extracts from research journal papers, industry research and practitioner research workshops that I have developed over the course of this research project.

The dynamic model of effectual urban governance presented in in Part 1 was developed through:

- A multi-disciplinary synthesis and discussion of the literature on entrepreneurship, urban governance and sustainability transitions. The synthesis articulates the parallels between new venture/market creation in an entrepreneurial context, and the structuration of niche innovations in a socio-technical transitions context to facilitate transformation towards sustainability **(**Chapter 2**)**.
- A historical analysis of technology/infrastructure transformation with a focus on the role on entrepreneurial agency in facilitating systems change. This analysis validates the role of entrepreneurship in facilitating change in civil infrastructure regimes (Chapter 3).
- Articulating the gap in urban governance approaches across the dimensions of uncertainty and systems change, building on the strategic management work of Wiltbank et al (2006). The identification of transformative urban governance as a key gap in current approaches provides the basis for first, translating Sarasvathy's effectuation logic to the strategic niche management domain in a civil infrastructure context. Following the case study of the Willunga Basin Water Company, a dynamic model of effectual urban governance was presented to respond to the need for facilitating urban systems change while dealing with heightened uncertainty (Chapter 4**)**.

Part 2 of this thesis **(**Chapters 5-8**)** begins the process of translating and applying effectuation logic to the civil infrastructure domain as a decision-making logic for both public and private sectors.

Part 2 focuses on the following four elements of effectual urban governance:

1. Effectual design principles: This element articulates the guiding design principles that ensure initiatives undertaken through effectual urban governance (i) align with the values and objectives of the communities they seek to serve; while (ii) responding to global sustainable development imperatives. A discussion on smart mobility exemplifies these principles. See Chapter 5.

2. Available means and value creation: This element considers available means and resources to establish the basis for action, rather than working with pre-determined outcomes. Such an

approach helps to reduce uncertainty and leverage slack resources while simultaneously providing opportunities for greater value creation. See Chapter 6.

3. Partnerships and effectual stakeholder commitments: This element advocates the creation of partnerships from the beginning of an effectual process, i.e. the early stages of infrastructure planning, and seeking effectual stakeholder commitments to reduce uncertainty and galvanise resources for niche support. See Chapter 7.

4. Effectual action: The element of taking action builds on the culmination of the guiding design principles, available means, partnerships, commitments and affordable loss. These considerations, in combination, inform the action taken rather than endeavouring to validate/invalidate causal assumptions. The first stage of effectual action may not be the final product, but taking action early enables socio-technical learning which allows for adjustments of niche characteristics to align with demand, and for the iterative development and structuration of that niche over time. See Chapter 8.

This second part of the thesis, building on the case study presented in Part 1, uses urban transport as an illustrative case of effectual urban governance. The term 'Transit Activated Corridors' (TACs) is used throughout this second part of the thesis to describe the integrated planning of public transport and land use corridors (Newman et al., 2021). Delivering public transit is often an exercise in transport provision and in holistic city shaping. Transit activated corridors embody an approach to infrastructure development that considers land development, economic agglomeration and social benefits as key drivers and outcomes for an urban transit project.

As discussed in the early chapters of Part 1, cities around the world are increasingly looking to provide high-quality transit services as a means for transport provision and as a driver of sustainable change and economic development. At present, urban governance approaches in Anglosphere cities could be optimised to more effectively deliver these outcomes. This second part of this thesis illustrates the potential of effectual urban governance processes to deliver transit activated corridors and facilitate sustainable social and economic development.

CHAPTER 5

EFFECTUAL URBAN GOVERNANCE:

EFFECTUAL DESIGN PRINCIPLES

5.1 CONTEXT

Effectual urban governance is a collaborative, means-based solution building process that optimises the socio-technical fit of innovations. Using this approach, innovations are tailored to the needs of users, which is a core characteristic of an effectual approach to urban governance and one that leverages the demand-side pull of markets to out-compete market alternatives and increase the potential for the innovations' 'disruptive' scalability (Christensen, 1997). An effectual approach to urban governance fosters the co-evolution of new technologies and social practices to facilitate the scaling of innovations that are able to survive in the market without ongoing support mechanisms. Effectual urban governance thereby draws on lessons from entrepreneurial agency to focus on the interrelatedness of social and technical change; it does not take a 'technology-push' approach that relies solely on the merits of a technology as many factors may lead to the failure of a technology beyond its relative technical performance (Schot and Geels, 2008).

As discussed in Chapter 3 and Chapter 4, there has been a lack of application of the entrepreneurial method to a civil infrastructure context. It is generally accepted that the fundamental objective for a capitalist entrepreneur or private sector entity is to create shareholder value. Notwithstanding the many exceptions of sub-disciplines of entrepreneurship that are driven by environmental or social objectives (as discussed in Part 1- Section 2.3 and 2.4), it cannot be assumed that following the 'entrepreneurial method' will inherently result in desirable environmental and/or social outcomes. Nor is it assumed that following the 'entrepreneurial method' will result in negative environmental and/or social outcomes.

In the context of urban infrastructure, it is expected that solutions – whether they be funded by the public or private sector - will deliver economic and social value, and increasingly, sustainable environmental value. The prediction, forecasting and planning that occurs prior to funding an infrastructure solution is largely done to justify the infrastructure investment based on these (public) benefits. In advocating a move toward an effectual approach to urban governance, it is important to ensure that the delivery of public value is not sidelined in the process.

Strategic Niche Management (SNM), in the context of conventional sustainability transitions literature and niche innovations, is explicit about the requirement for innovations to be 'sustainable', as a precursor for them to be selected for niche support (discussed in Part 1 – Chapter 2 and Chapter 4). Effectual urban governance requires a similar, yet distinct, stance whereby the process of urban innovation should be oriented towards driving the creation and structuration of niche innovations that offer potential to contribute to sustainable outcomes. Traditional SNM approaches mostly focus on supporting preferred 'sustainable innovations' in their early stages; this is to provide them with a stronger chance of influencing regime change towards sustainability by engaging users throughout the development of new sustainable innovations in ways that accelerate their mainstreaming. Effectual urban governance as an approach to niche structuration does not take the selection of a preferred

innovation as a starting point, and instead allows for collaborators to have influence over the expectations, goals and development trajectory of the niche based on their own means and commitments. Therefore the embeddedness, or 'pre-requisite' of sustainability in niche development that is assumed in SNM as a result of innovation pre-selection does not explicitly hold for effectual urban governance.

Due to the recognised imperative for sustainable development, many technologies with support mechanisms are considered inherently more 'sustainable' than incumbent technologies in the applications or sectors in which they exist (for example, renewable energy technologies, low emissions transport technologies, waste recycling innovations). However, there are also many innovations emerging that are 'sustainability agnostic' (for example, artificial intelligence or blockchain technology). If such sustainability agnostic technologies were implemented with sustainability priorities they could significantly contribute to sustainability objectives. When implemented without sustainability design principles embedded in the process however, there is a risk that unsustainable socio-technical regimes are further entrenched. An approach to infrastructure development and delivery that follows the principles of effectuation could be applied to innovations that are both 'sustainable' and/or 'sustainability agnostic'. While promising, it is acknowledged that this may also lead to outcomes which do not align with sustainable development. How then, do niche innovations uphold the principles of sustainable development (and broader societal good) without pre-defining solutions or inhibiting innovation? The explicit inclusion of effectual design principles into the effectual urban governance model addresses this question.

Articulating guiding design principles for an infrastructure project, when done collaboratively at a strategic level, presents an opportunity to define a bounded realm of possibility within which sustainable, and effectual innovations, may develop. Such innovations may include increasing public transport use, encouraging mixed-use urban development, providing cleaner water for communities, or reducing waste that is sent to landfills. Such guiding design principles do not specify characteristics of any technologies or solutions; rather, they represent outcome statements that align the development of the infrastructure solution to broader societal objectives without specifying any pre-determined form or function of potential solutions. This chapter argues effectual design principles, as part of effectual urban governance processes, set boundary parameters within which effectual innovation can happen in urban contexts while preserving and enhancing social value. To illustrate this point, this chapter takes 'smart mobility' as one case of socio-technical change currently occurring in cities around the world. It first outlines the rise of smart technologies in cities. It then highlights some of the challenges of incorporating smart mobility options into existing mobility approaches – and the risks of further entrenching unsustainable approaches. It then illustrates how the principles of design and available means from an effectual approach to urban governance can influence the outcomes of urban transport developments.

5.2 ILLUSTRATIVE CASE: SMART MOBILITY

5.2.1 Smart Mobility Overview

Globally, digitisation continues to grow rapidly, with implications for governments, businesses and citizens. In the transport sector, there are a number of emerging technology paradigms such as Mobility as a Service (MaaS) that are underpinned by a new wave of digital technologies and infrastructures. These emerging offerings characterise 'smart mobility', a subset of the broader 'smart cities' movement that is enabled by the application of Information Communication Technology (ICT) in urban infrastructural settings. Many of the technologies that enable these new 'smart' applications represent technologies that are inherently sustainably agnostic, with the outcomes being subject to the priorities and principles that govern their implementation.

What constitutes 'Smart'?

The concept of 'smart cities' and 'smart technology' has existed for decades. The term 'smart cities' was first used in the 1990s to describe the impacts of ICT technologies on the infrastructure of cities (Alawadhi et al, 2012). Albino et al., (2015) identify 23 different definitions of a smart city in the literature since the year 2000. They note, "the use of the term smart cities is proliferating in many sectors with no agreed upon definitions". Nor is there a single agreed template for framing a smart city (O'Grady and O'Hare, 2012).

It is generally accepted that 'smart cities' and all of the subsequent definitions and approaches, are interlinked with the increasing application of ICT (Washburn et al., 2010). The concept of smart homes, smart energy grids and smart mobility, for example, are enabled and augmented by increasingly-powerful ICT capabilities. This ICT-enabled enhancement of functionality is the general context for using 'smart' terminology in the literature and in practice.

'Smart city' technologies are increasingly being promoted for their potential to address urban challenges (Yigitcanlar et al., 2019). The promise of more efficient transport networks being delivered through unprecedented connectivity, on-demand and autonomous vehicles, and increased safety is a powerful example of smart city technologies and one that is appealing to city governments. To be smart however, these emerging technologies need to address fundamental issues in transport systems and shift cities towards sustainability, rather than further embed unsustainable urban practices.

'Smart' is not synonymous with 'Sustainable'

As discussed in Part 1 of this thesis (Section 2.3.2 and Section 4.3.2), fossil-fuel based automobiles have come to be the central mode of transport in Anglosphere cities. Since the mid-twentieth century, many cities have adopted a car-based planning approach that has led to 'automobile dependence' (Newman and Kenworthy, 1999). Issues facing urban transport systems stem from regimes that rely on

modes of transport that are not spatially efficient (e.g. private automobiles), are polluting (petroleum-based propulsion) and facilitate land use that is wide-spread and low density. Cities that introduce 'smart technologies' continually aligned to automobile dependence, risk these new technologies amplifying the characteristics of the existing socio-technical transport regime. The resulting congestion, travel times, pollution and sprawl are problematic.

Viewing system change through the lens of socio-technical transitions theory highlights the importance of broader agency factors to address sustainability challenges, rather than just relying on technology alone. New or smart technologies and innovations provide opportunities for disruptive regime changes towards sustainability, due to an ability to bring about a new paradigm of accompanying social norms. To achieve sustainable outcomes however, the process of implementing these innovations must be aligned with sustainability.

Albino (2015) notes many 'smart city' innovations claim to include sustainability, efficiency and social outcomes. The extent to which the implementation of such initiatives has promoted these outcomes – or if the opposite has occurred – is unclear. For example, a study in California found that Uber vehicles on the road have an average passenger occupancy of 0.66 – or in other words, they are empty 34% of the time (Currie, 2018; SFCTA, 2017).This finding prompts the questions: In a world of on-demand and autonomous car-based travel, what level of additional 'traffic' will be created by empty vehicles that are simply on the roads between dropping off Passenger A and collecting Passenger B? Will current congestion issues be exacerbated by a new fleet of empty vehicles, circulating from one location to another to find their next passenger? This is just one of the risks posed by augmenting car-based transport systems with 'smart city' technologies.

The degree to which 'smart city' visions are the product of marketing efforts by technology corporations has also been raised (Hollands, 2015; Albino et al., 2015; Luque-Alaya and Marvin, 2015). Lyons (2018), citing Luque-Ayala and Marvin (2015), notes "current understandings of [smart urbanism] lack a critical perspective compounded by an undue emphasis on technological solutions that disregard the social and political domains". Hollands (2015) raises concern about the influence of commercial interests in driving the smart city agenda and an accompanying under-appreciation for any broader social and urban development consequences. These concerns are particularly pertinent in the context of effectual urban governance, which in an effort to more effectively deal with uncertainty, could enable private actors with available means and a willingness to make commitments to unduly influence the development trajectories of urban solutions.

Sustainability *can be* an outcome of smart technology application. However, technologies that are often grouped under the 'smart city' umbrella can be agnostic in achieving both positive sustainability outcomes and the desired optimal levels of 'smartness'. Ultimately, it is the enabling technologies, the solutions that are built on them, and the associated social institutions and practices that emerge with

them that govern the degree to which they produce sustainable outcomes. As a technological enabler within a complex socio-technical system, technologies do have the potential to drive radical sustainability regime change. Accordingly, smart technologies are often presented as a silver bullet to cities' woes (Luque-Ayala and Marvin, 2015). While 'smart' technologies are undoubtedly one of a number of avenues to facilitate sustainability transitions (Geerlings et al., 2012) they need to be aligned and managed with sustainability objectives at their core or they risk embedding unsustainable regimes more deeply. In the case of transport, evidence from cities around the world suggests that a smart mobility agenda with automobiles as the central transport artefact will further embed the existing automobile-dependent regime (Pangbourne et al., 2018; Metz et al., 2017; Wadud et al., 2016; Pyper, 2014; McMahon, 2017).

As identified in the previous section, 'smart' does not inherently equal 'sustainable'. Creating regime change towards sustainable transport in Anglosphere cities requires a shift from 'automobile-dependent' design principles towards 'transit-oriented' design principles. To illustrate the distinction between these two development trajectories, I discuss smart mobility through the lenses of two opposing socio-technical configurations:

- **The automobile-dependent city:** Low density, urban sprawl with private vehicles as the predominant mode of transport.
- **The transit-oriented city:** Higher density, mixed-use land development oriented around high performance public transport.

These two models are used to illustrate how design principles and available means can influence outcomes. As detailed earlier, each model articulates values and broad objectives of the communities they seek to serve. In reality, city transit systems are complex and comprised of a patchwork of overlapping development patterns and infrastructure policies and legacies. The two configurations above illustrate two opposing development trajectories that would, ultimately, give rise to two distinct sets of design principles in an effectual urban governance approach. The difference between automobile-dependent and transit-oriented mobility systems is illustrated in Figure 5-1 below.

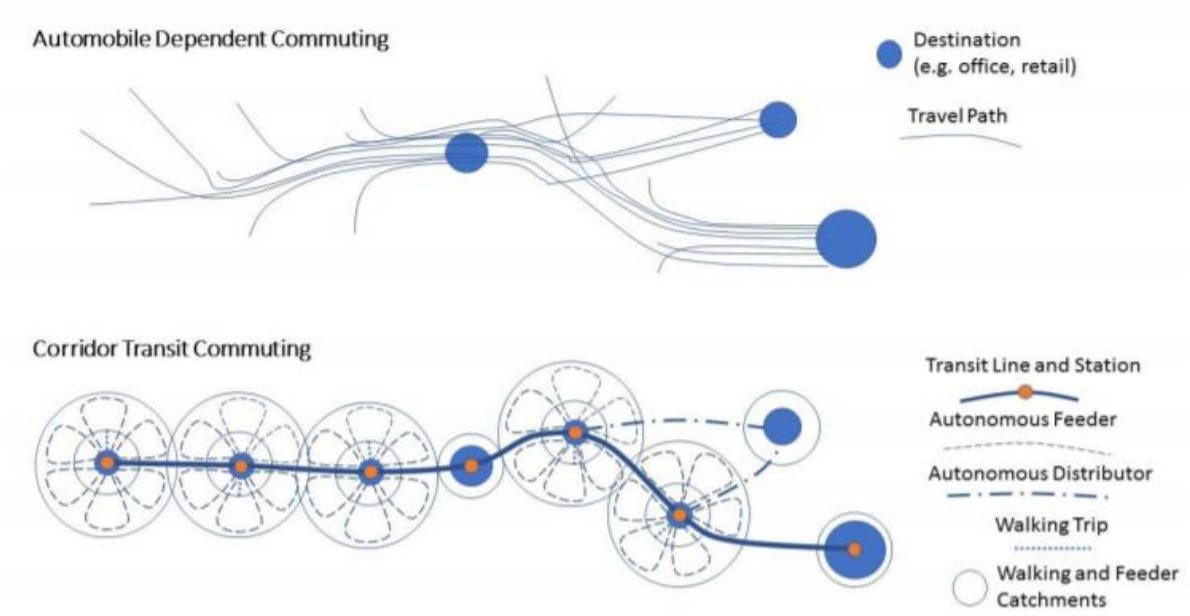


Figure 5-1*: *Comparison of traditional 'automobile dependent commuting' to 'Transit Activated Corridor commuting' with quality transit lines, last mile connectivity and integrated stations underpinning development. Source: Adapted from Glazebrook & Newman, 2018.

The approaches cities take to achieving a more balanced and multi-modal transport system, such as a the transit-oriented city, and those that reinforce the role of private vehicles, such as in an automobile dependent city, can be discerned through focusing on their policies that are aimed at reducing vehicle emissions. In the United States, Todd Litman (2021) distinguishes between policies focused on 'Clean Vehicles' and those focused on 'Vehicle Travel Reductions'. Litman defines Clean Vehicle strategies as 'Technologies and policies that reduce emission rates per vehicle-mile', and Vehicle Travel Reduction strategies as 'Travel Demand Management and smart growth policies that reduce total vehicle travel'. Although the United States has an embedded regime of automobile dependency, Litman's review of emissions reduction policies reports a stronger emphasis on 'Clean Vehicles' i.e. maintaining automobile dependence while reducing the carbon intensity of these vehicles, than on reducing vehicle kilometre travelled.

Table 5-1 provides examples of specific emissions reduction strategies that fall under automobile-dependent and transit-oriented approaches to city mobility.

Table 5-1: ***Emission reduction strategies representative of Automobile-Dependent and Transit-Oriented Transport Regimes (Adapted from Litman, 2021).***

Automobile-Dependent Transport Strategies Clean Vehicle Strategies (Litman, 2021)	**Transit-Oriented Transport Strategies** Vehicle Travel Reduction Strategies (Litman, 2021)
'Aim to achieve sustainability outcomes by reducing the emissions of private vehicles, without fundamentally shifting the design principles that govern the transport regime'	*'Aim to achieve sustainability outcomes by fundamentally shifting the design principles that govern the transport regime'*
• Shifts to more efficient and alternative fuel vehicles (e.g., electric and hydrogen). • High emitting vehicle scrapage programs. • Efficient driving and anti-idling campaigns. • Switching to lower carbon and cleaner fuels. • Inspection and maintenance programs. • Resurface highways. • Roadside 'high emitter' identification	• Multimodal planning (improve walking, bicycling, public transit, ridesharing, etc.) • Smart Growth policies that create more compact and multimodal communities. • Transportation Demand Management programs (commute trip reduction, freight transport management, etc.) • More efficient road, parking and vehicle pricing. • Vehicle parking policy reforms.

5.2.3 Available Means Facilitating Smarter Mobility Options

Effectual urban governance can be considered a process of co-creating urban artefacts from means. As explicitly stated in the model presented in Chapter 4, this process is driven by stakeholder commitments that work to reduce uncertainty. In the context of smart mobility, this subsection identifies key emerging smart mobility means and smart mobility artefacts (or solutions/applications) available in the sector.

Means for Smart Mobility: Examples of Emerging 'Sustainability-Agnostic' Technologies to Enable Smart Mobility Solutions

There are many ICT technologies that have an increasing number of applications to the urban transport sector. The technologies listed here can be considered 'sustainability-agnostic', in that they present opportunities to contribute to both sustainable and non-sustainable transformations. This depends on the design application and the available means to build them. In the transport sector, digital infrastructure and devices and smart tools and capabilities are 'available means' in the design and implementation processes.

Digital Infrastructure and Devices

Digital infrastructure forms the basis for data to be collected and information to be shared. It is key to smart cities. The tremendous surge in digital infrastructure has been integral to the emergence of smart city concepts. Examples of digital infrastructure are:

- ***Mobile Devices:*** Portable devices such as smartphones mean that citizens are interconnected with each other and their infrastructure. Citizens are able to engage with smart city systems through their devices, allowing a greater level of efficiency that is tailored to the users' needs. This 24/7 connectivity also means that greater amounts of data are being collected from smartphones and their applications, and this data is being used by companies to help inform and develop smart city solutions.
- ***Internet of Things (IoT) Sensors:*** Sensors have long been used in transport systems, such as to detect vehicles waiting at traffic lights or detect a train approaching a station. However, sensors are becoming much more wide-spread. Internet connectivity means sensors are now able to communicate in real-time to provide greater levels of insight on the state of the transport system. These insights enable transport authorities, and private operators, to more accurately understand and effectively manage the system and also empower citizens to make better travel decisions.
- ***Wireless Connectivity and the Cloud:*** Wireless connectivity and information transfer has significantly increased the potential for new capabilities to be developed that track movement of people and vehicles in real time, and at a greater level of detail (rather than only relying on centralised points of data collection such as stationary cameras or sensors). Wireless communication between people, vehicles and infrastructure forms the backbone for many smart city applications. Quickly processing this data in cloud-based systems reduces reliance on local infrastructure.
- ***Distributed Ledger/Blockchains:*** Trusted distributed ledgers such as Blockchain provide a range of functionality to transport systems (Hargroves et al., 2019). Blockchains are distributed systems of information that facilitate the transfer of value between parties without the need for an intermediary. 'Smart contracts' allow for automated agreements that can execute when certain conditions are met. The technology is currently being developed to assist authorities with vehicle registration, underpin micro-payments between shared vehicles and users, and provide interoperable multi-modal transport payment currencies.
- ***Cameras:*** Security/CCTV cameras can underpin a range of smart city insights. Many cities already have a number of cameras installed, for example, traffic cameras and/or security cameras. Traditionally, these cameras have been for security, however due to new capabilities such as AI-powered 'Computer Vision' they are becoming smart city sensors in their own right, able to produce data on flows of people and traffic.

Smart Tools and Capabilities

Smart tools and capabilities represent technologies and processes that collect, transmit and process the information collected into meaningful outcomes. The application of smart tools and capabilities requires much more intentional thinking about the types of outcomes that will be prioritised and produced for users. Examples of smart tools and capabilities are:

- ***Big Data Analytics:*** The installation of vast amounts of ICT infrastructure results in huge amounts of data being collected – this is termed 'Big Data'. This data creates the opportunity for decision-making to be informed by never-before-seen levels of information and insights. The analysis of Big Data often seeks to perform analysis across large volumes of data, which may have seemingly little direct relationships. Big Data perspective allows new linkages and patterns to be discovered.
- ***Artificial Intelligence (AI):*** Artificial Intelligence stands to enhance the computational and decision-making capabilities of many industries. It is being rapidly developed across many avenues of transportation such as acting as the 'brains' behind self-driving autonomous vehicles to real-time network prediction and optimisation. AI has the ability to harness big data analytics and make decisions to improve the efficiency of the network. Trained using historical data and comparing this to current states of the system, the data that is input (which can be contributed to by IoT sensors among other sources) is important in ensuring the accuracy and validity of AI tools.
- ***Integrated Platforms and Dashboards:*** Digital platforms and data dashboards can integrate different modes and data insights into a format that is easy to interpret and use. In mobility, 'Mobility as a Service' offerings (which provide a number of specific functions or applications), can integrate shared transit options, on-demand ride hailing services, and last mile options including shuttles, scooters and bicycles into a single user interface. By doing so, users are able to see different mobility options for their travel, choose a combination of particular modes based on time and cost, and make a single, integrated payment. Such platforms will integrate many technological capabilities, such as those described above, and stand to become the interface through which a city's transport system is coordinated.

Artefacts of Smart Mobility: Examples of Emerging Smart Mobility Applications

Drawing on the digital infrastructure and smart tools and capabilities identified in the previous sub-section, Table 5-2 provides a list of emerging applications in the Smart Mobility sector. There are a wide range of applications being developed and/or have been implemented aligned to both the 'smart automobile dependent city' and the 'smart transit-oriented city'.

Table 5-2: Emerging Smart City Applications in the Mobility Sector

Emerging Applications Aligned to the Smart Automobile Dependent City	Emerging Applications Aligned to the Smart Transit-Oriented City
• Real time updating and optimisation of traffic signals based on traffic conditions (Maryland Department of Transportation, 2017). • Monitor safety measures and inform warning systems (Cohen, 2012). • Real-time management responses to traffic jams created by traffic congestion (Mullich, 2013; Solomonow, 2012; Integrated Media Systems Centre, 2016). • Provide information on mobile phones or public signs to improve traffic conditions for motorists. • Update motorists on expected trip times to destinations based on changing traffic conditions. • Provide motorists with real-time route suggestions to avoid congestion (Google, Waze). • Flexible and adaptable speed limits. • Smart parking sensors providing private automobiles with real-time information on availability of parks (Here Mobility, 2020). • Enhanced logistics efficiency including real-time validation of authenticity of cargo and real time trip routing (NTI, 2018). • Perform predictive congestion management and alerting network users and managers when congestion conditions are imminent (Clinton, 2015; Integrated Media Systems Centre, 2016). • Monitor network and asset characteristics such as vehicle data, engineering data, and natural hazard data, to inform pre-emptive maintenance (Cohen, 2012). • Assist with traffic management and congestion prevention by identifying network flow interruptions (SCC, 2016; Lu et al., 2014; Highway Engineering Australia, 2015). • Monitor vehicle behaviour to create a baseline profile of safe vehicle behaviour, which can be used to identify irregular and unsafe behaviour (Hossain, 2012).	• Monitor location of public transport vehicles within network to provide real-time schedules, arrival and departure times, and location of approaching vehicle (Harmony & Gayah, 2017). • Monitor speed and separation distance of transit vehicles to inform safety measures and warning systems (SEPTA, 2015). • Monitor energy efficiency of transit vehicles to optimise driver behaviour (Shenzhen Bus Group). • Modify traffic light duration to allow pedestrians with restricted mobility longer time to cross the road (Dynniq, 2020). • Passenger counting to inform real-time trip planning and routing (Eurotech, 2016). • Digital fare collection across multiple agencies and modes of transport (Genfare's 'Genfare Link' application). • Provide greenway and priority to cyclists (Siemens Mobility, 2020). • Inform transit riders of local services on route such as shops or restaurants (Digi, 2020). • Prediction of public transit vehicle arrival times, delay or congestion (Fujitsu, 2016; Tan et al., 2008; Chien et al., 2002; Jeong et al., 2004). • Prediction of demand levels, locations and timing using mass transit data analytics (Siemens Mobility, 2020). • Dynamic bus operation optimisation to reduce excess wait times for public transit (Gkiotsalitis, 2016). • Optimisation of public transport vehicles required for schedule coverage (Mendes-Moreira, 2015; Khiari et al, 2016). • Public transit vehicles capable of intelligent driving and autonomy to reduce operating costs and increase safety (UITP, 2017). • Public transport on-board information and communications systems to provide network and travel time updates (Siemens Mobility, 2020).

• Enforce traffic regulations through visual and other means; including breaches in lane use, breach of traffic signals, weight limits, and allowable vehicle types. • Provide priority to emergency vehicles. • Ability to establish identification and streamline vehicle ownership documentation and registration to reduce associated transactions (US DoT, 2018). • Facilitate congestion zone charging, road user charging and collection of tolls and charges in real time (Noordegraaf, 2009). • Remove intermediaries and improve the efficiency and level of customer service of ride share services (NBC, 2015).	• Intelligent charging of transit fleets (Shanghai Bus Group; Shenzhen Bus Group). • Accident risk prediction based on driver profiling to inform proactive driver training interventions (NEC, 2014). • Smart travel assistants for journey planning and real-time public transport assistance (Axon Vibe, 2019). • Customer assistance tools and support systems e.g. Chatbots (Ono, 2018). • Flexibly change the prioritisation of traffic modes (Siemens Mobility, 2020).

The solutions listed in Table 5-2 draw on the same ICT infrastructure, however each can have significantly different implications for a city depending on the objectives under which they are developed and implemented.

These examples show that while technology, and available means more generally (available means are much broader than just ICT technology – however these technologies have been used in this chapter to illustrate one example of available means in the context of smart mobility), are enablers for sustainability transitions, they are a means not an end, as the end-state artefact/s or applications are influenced by the broader socio-technical system.

5.2.4 The Importance of Design Principles for Effectual Urban Governance

As demonstrated in the previous section, the same 'means' can be shaped and applied to develop smart mobility applications that are aligned with differing socio-technical regimes. The design principles that guide the development of solutions will influence the types of solutions that are developed. From the outset under a causation logic, 'prescriptive' design principles based on a preferred outcome are distinct and in contrast to effectual design principles which are instead more akin to 'desired outcomes' without being overly prescriptive about the types of solutions that should be pursued.

Based on the smart mobility means and solutions collated above, Figure 5-2 conceptualises the relationship between design principles, artefacts/available means and outcomes produced through the process of solution development. The Figure conceptualises the relationship between design principles and outcomes, with the process of innovation translating and using available means to produce artefacts. The process model of effectual urban governance, as developed in Chapter 4 (or other processes for developing innovations), occurs within and across the 'processes' depicted in the framework shown below. The applications and solutions that are developed are influenced by the design principles that guide the innovation process.

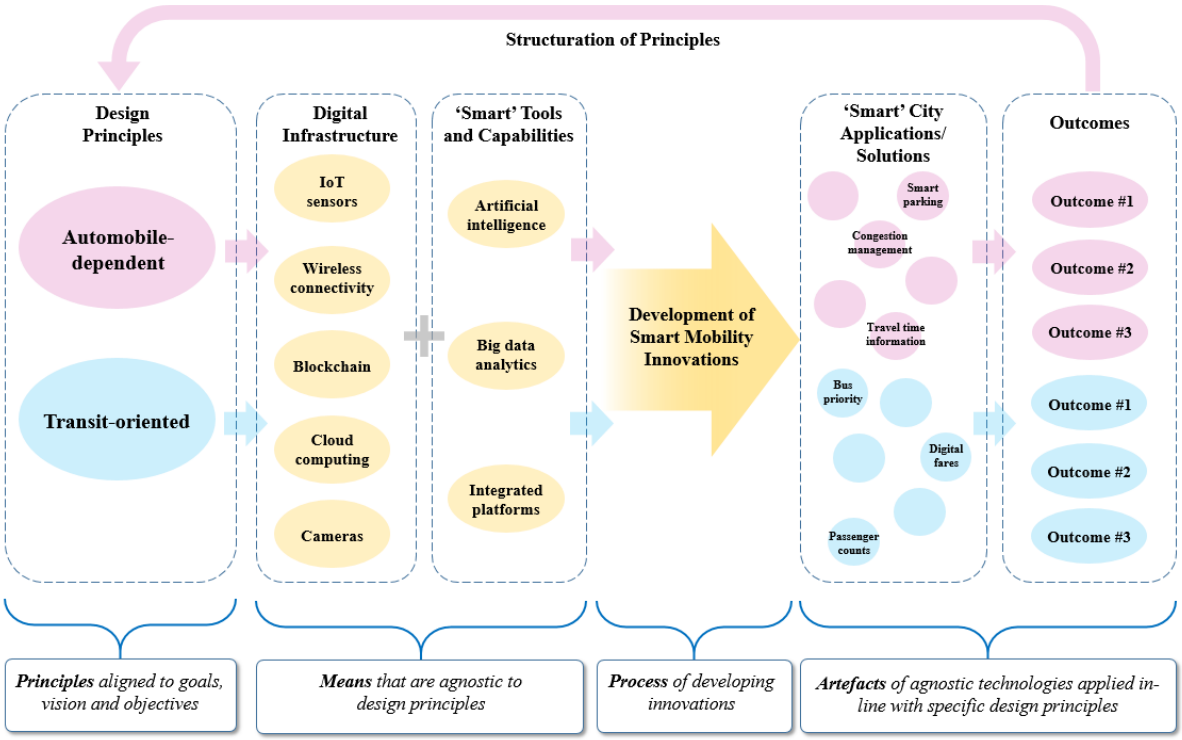


Figure 5-2: Conceptual Framework for Principles, Means/Technology, and Artefacts/Outcomes in Smart Mobility

Figure 5-2 conceptualises:

- The relationship between design principles and the processing/production of artefacts (smart city applications/solutions) and the associated outcomes of these artefacts, and the subsequent reinforcement of practices ('structuration of principles') that results from a particular set of design principles.
- The distinction between sustainability or sustainability-agnostic means that can be leveraged to achieve different futures depending on the guiding design principles established by a niche.

In practice, the transit-oriented and automobile-dependent city are not mutually exclusive. Cities will, have, and/or are in the process of implementing a combination of the applications across both categories found in Table 5-2. Some cities may not pursue smart transit systems. For city planners and/or entrepreneurs seeking to reduce uncertainty and act based on stakeholder commitments to improve urban mobility, any of the smart applications may represent viable cost effective opportunities. However, an effectual approach to urban governance, bounded by effectual design principles, is more holistic. In this approach, interventions planned and funded by governments must meet the imperative for sustainability transitions and also consider social value and ecological limits.

Without articulating the socially-acceptable bounds of innovation when it is a publicly planned and funded innovation, there is risk that effectual urban governance may not provide a cohesive contribution to meeting societal goals.

Effectual design principles align decision-making logic in governance processes involving public infrastructure, with broader societal good. These are not causal pre-determined ends, or mode-specific transport solutions. Rather, they are outcome-led design principles that broaden opportunities to develop creative urban solutions when compared with traditional predict and provide transport planning methodologies, while embedding social and environmental value creation in the process. The introduction of effectual design principles addresses a key gap that arises when applying effectuation theory directly to urban governance; this is the translation of a predominantly private sector or 'entrepreneurial' approach to value creation, to an approach that is suitable for urban governance processes to deliver public benefits.

In the transport sector in Europe, Sustainable Urban Mobility Planning (SUMP) has emerged to more effectively tackle the complexity of cities and promote more integrated and planning processes (Eltis, 2016; Newman, 2020). Table 5-3 summarises the shift in focus of SUMP compared to traditional transport planning which is more aligned to a causal 'predict and provide' approach than the SUMP methodology which reflects a more integrated and interdisciplinary approach.

Table 5-3: Summary of Guidelines for Sustainable Urban Mobility Planning compared to traditional Transport Planning (Eltis, 2016; Cited Newman, 2020).

Traditional transport planning	→	**Sustainable Urban Mobility Planning**
Focus on traffic	→	Focus on people
Primary objectives / desired outcomes: Traffic flow capacity and speed	→	Primary objectives / desired outcomes: Accessibility and quality of life, as well as sustainability, economic viability, social equity, health and environmental quality
Modal-focused	→	Balanced development of all relevant transport modes and shift towards cleaner and more sustainable transport modes
Infrastructure focus	→	Integrated set of actions to achieve cost-effective solutions
Sectorial planning document	→	Sectorial planning document that is consistent and complementary to related policy areas (such as land use and spatial planning; social services; health; enforcement and policing; etc.)
Domain of traffic engineers	→	Interdisciplinary planning teams
Planning by experts	→	Planning with the involvement of stakeholders using a transparent and participatory approach
Limited impact assessment	→	Regular monitoring and evaluation of impacts to inform a structured learning and improvement process

The SUMP methodology provides an example of how a more effectual approach can be taken to developing transport projects. It also shows the role of design principles or 'desired outcomes' in shaping solutions without being prescriptive about the types of solutions that should be pursued. Key tenets aligned to effectual urban governance that are embodied by SUMP guidelines are a non-mode specific approach (i.e. not narrowing the solution space to traffic interventions), interdisciplinary planning teams, and the involvement of stakeholders throughout the process.

It is evident from Table 5-3 that this shift in thinking promotes innovation. The shift towards a more integrated and holistic view of transport planning expands the scope of possibilities that can be developed. Other effectual design principles that could arise for Sustainable Urban Mobility Planning projects, to guide the solution development process include:

- The project should increase population access to jobs.
- The project should increase population access to everyday services.
- The project should support economic growth.
- The project should improve safety of the transport network for all road users.
- The project should contribute to a reduction in greenhouse gas emissions.
- The project should support the more diverse travel needs of women.
- The project should seek to unlock integrated land development opportunities.
- The project should contribute to improving urban air quality.

Effectual design principles like these do not specify the form or function of solution. They are outcome-oriented and provide a guiding compass for effectual stakeholder commitments to collaboratively shape urban solutions for the public good while embedding social and environmental value in the process.

5.3 CONCLUSIONS AND CONTRIBUTION TO THESIS

This chapter highlights the need to embed design principles in effectual urban governance process. It uses smart mobility as an illustrative case to demonstrate that available means can be leveraged for a multitude of possible artefacts. It also highlights the risks of limiting innovation design and implementation processes to self-selecting stakeholder commitments with the main risk further embedding socio-technical regimes that are not aligned to a sustainable future.

This chapter has addressed a key challenge that arises when taking effectuation and translating it to the context of urban governance. For entrepreneurs, addressing uncertainty through self-selecting stakeholder commitments creates a robust basis upon which to grow a business. However, in the context of urban governance, achieving social and environmental value are key outcomes that must also be considered when developing urban interventions. Therefore, effectual urban governance requires effectual design principles that can guide innovation towards social and environmental objectives. As highlighted through reference to Sustainable Urban Mobility Planning, the introduction of design principles to guide planning of urban infrastructure expands the realm of possibilities of an urban infrastructure undertaking.

This Chapter makes the following contribution to this thesis and the literature:

1. Interrogates the concept of 'smart cities' and challenges the assumption that smart is by default sustainable, and applies a socio-technical perspective on sustainability transitions, smart cities and entrepreneurship.

2. Collates evidence of emerging smart mobility applications from across the world and categorises them based on their alignment to two diverging mobility futures, namely the automobile-dependent city and the transit-oriented city. Both apply the same 'smart' ICT technologies however with different design principles as a basis and different outcomes.

3. Enhances effectuation theory, particularly as it applies to urban governance, by making the case for the inclusion of effectual design principles aligned to sustainable development. Embedding the social and ecological dimensions imperative for urban interventions that impact human life addresses a limitation of effectuation theory to inform governance for systems change towards sustainability.

CHAPTER 6

EFFECTUAL URBAN GOVERNANCE:

VALUE CREATION BASED ON AVAILABLE MEANS

6.1 CONTEXT

When determining a starting point or 'basis for action', a key principle of effectuation is a preference to "begin with a set of available means, rather than pre-determined ends" (Sarasvathy, 2009). When establishing a new venture, expert entrepreneurs begin with what is available - in the form of resources, networks and their own ability. Under this model, preference is given to actions which harness and build upon available resources or networks.

Effectual urban actors begin with what is locally available, seeking to connect with existing cultures, competencies, or initiatives. There is recognition that in complex systems, transferring best practice can prove not to be best practice at all (Madanipour et al., 1998; Walloth, 2016; Heraurd, Kerr and Burger-Helmchen, 2018). By beginning with what is available, rather than a pre-conceived idea of what should be, effectual urban governance projects and solutions can better reflect the increasingly distributed and complex nature of cities, especially as urban projects are complex across multiple dimensions (Heraurd, Kerr and Burger-Helmchen, 2018). One dimension of complexity is that urban projects impact and involve a range of diverse urban stakeholders who have different knowledge, preferences and decision-making procedures. A second dimension of complexity, is that urban projects, particularly large infrastructure projects, are a 'bet on the future' (Heraurd et al., 2018). This is in the sense that a piece of infrastructure should remain useful as new technologies and practices evolve around it over the decades to follow. However, it is also the case that infrastructure shapes the evolution of the city and urban life around it, thereby forming a reciprocal relationship where providing new infrastructure maybe an exercise in betting on the future, and simultaneously, an exercise in shaping it.

Effectual urban governance calls for a collaborative, co-created vision that is shaped by effectual stakeholders; it aims to increase the structuration of niche innovations through effectual stakeholder commitments, projects and learning. This is not to have engineers or policy makers pre-determine what outcome is preferable for the city or community in a top-down fashion. This process begins with assessing available means and using them as a basis for shaping a project that is able to maximise value creation through buy-in and contributions by self-selecting stakeholders. As commitments are made and projects are delivered, new resources become available, both through an active process of seeking out 'slack resources' (Sarasvathy, 2009), and by achieving greater buy-in and subsequent commitments from local actors with resources at their disposal – as discussed further in Chapter 7 (Effectual Urban Governance: Partnerships). Beginning with available means is a crucial element in incorporating the benefits of bottom-up urbanism into effectual urban decision-making.

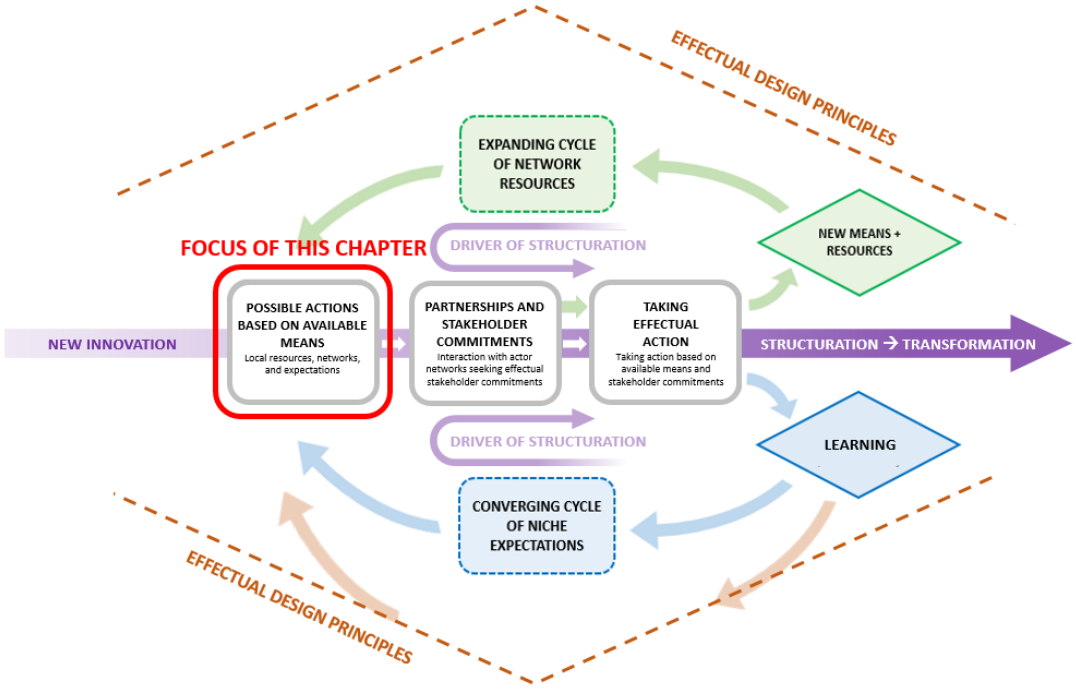


Figure: Dynamic model of effectual urban governance – with Available Means the focus of this chapter

6.2 THE TENSION BETWEEN TOP-DOWN AND BOTTOM-UP PLANNING

The majority of urban projects do not begin from a clean slate, but instead seek to influence the evolutionary trajectory of the area where they occur (Heraurd, Kerr and Burger-Helmchen, 2018). Given the complexity of urban projects, and the long-lasting impacts they have on communities, the involvement of urban stakeholders in planning processes has been raised as a critical area of focus to improve how projects address the true needs of the communities they serve. Criticism of traditional top-down planning has highlighted a lack of appreciation for local communities and conditions when formulating plans and executing urban projects as they rely predominantly on expert technical opinion rather than citizens' input (Sabatier, 1986; Murray et al., 2009, p. 444). For example, technical standards are central to the top-down planning process. As Pissourios states, "In particular, standards are part of ways of thinking and strategy-making processes; underestimate the preferences of local communities; and replace public participation and judgement with experts' knowledge" (Pissourios, 2014). To achieve scalability and disruption – innovations must be shaped by demand in order to gain traction. Translating this to the context of urban projects, success is linked to a project's ability to meet local needs.

However, top-down processes also have their benefits. As Hardin (1968) articulates, when individuals act in their own best interest, shared resources are often depleted to the detriment of the broader group – this is known as the tragedy of the commons. Society faces grand challenges, particularly related to climate change and sustainable development, for which coordination at a higher level than the individual or local community is required. In the 1990s, with the emergence of the communicative approach to planning – or 'communicative planning' – planning shifted to incorporate bottom-up processes, in that there was a greater focus on gathering stakeholders and seeking their input on planning decisions (Innes, 1995). More recently this approach has been called collaborative planning (Linnenluecke, 2017).

A more bottom-up planning model has made urban planning much more political. Progress can be crippled by local actors, albeit by design (with protection mechanisms in place to prevent top-down governments taking irrevocable action), whereby conservative members of the population are opposed to progress or development in their local area, and therefore actively seek to block project proposals that are representative of sustainable urbanism (for example, higher density development).

In contrast, China's approach to urban planning and economic development is much more top-down – and has resulted in significant progress and urbanization over the past half century. For example, the city of Shenzhen has achieved the phenomenal feat of converting its entire bus fleet of 14,000 buses to electric as of 2019, as well as its taxis, due to very clear top-down government ambition, support and

alignment with a national industry strategy (Lu et al., 2018). This has been replicated in other cities across China with astounding levels of electric bus uptake.

Challenging questions arise from the tension between these two approaches:

- How does society respond to grand complex challenges such as climate change and sustainable development, while balancing nuanced community interests?
- How best can city planners appreciate the increasingly distributed nature of cities and the variation between local contexts?
- How does society unlock the ability to make progress quickly and effectively, when it can be stalled by the 'loud minority' who are opposed to change?
- How can demand-drivers be leveraged to accelerate the uptake of sustainable innovations, rather than supply-push solutions that may be sub-optimal?

Effectual urban governance aims to address these questions, at least in part by providing insights from entrepreneurship literature. Effectual urban governance is not a purely top-down or bottom-up approach to planning and delivery of projects. Effectual urban governance provides a framework for collaboration between governments, citizens and businesses to constructively deal with urban challenges and proactively shape better urban futures. After all, governance is not just what governments do – it places agency with all urban stakeholders. 'Available means' – whether that be existing visions, policies, history, local actors, networks, or materials – are the starting point for an effectual process.

6.3 THE BASIS FOR ACTION: CAUSATION VS. EFFECTUATION

Participants in urban projects must make choices under conditions of complexity, uncertainty and resource constraints. Effectuation-based decision making is much more focused on available resources, what can be controlled or exists and can be acted upon. Conversely, causation-based decision making is more focused on a pre-determined outcomes, and causation processes are focused on obtaining the required means to create this end. A property developer operating through causal logic may set out to build a structure that has been selected from a catalogue of innovative designs that are location agnostic. On the other hand, the effectual property developer first focusses on understanding the local context and becomes aware of the means available, e.g. the history of the site, the local guiding norms, character and culture of the surrounding area, the local strategic ambitions and policy, nearby travel attractors and activities of citizens, relevant infrastructure and finance. The effectual developer is intentional in not allowing too many pre-conceived notions about the final solution determine the early stages; instead, relevant parties are invited into the process to foster the emergence of a project that is suited to its environment.

On a broader scale, urban regeneration through a causal process may seek to demolish existing buildings and structures and re-build new ones based on industry-leading design guidelines. In contrast, urban development through an effectual lens may seek to build upon the existing character and incorporate local actors into this process, regenerating the area while maintaining its heritage. This approach is not about denying what exists and starting anew, but rather looking for elements that can be leveraged and built upon. This is a focus on evolving rather than erasing what exists. This focus on evolution is important in complex systems, and effectual urban governance seeks to enrol actors to play a role in steering this evolution.

The provision of urban rail projects in cities is more reflective of causal logic than effectual logic. Transport modelling is based on predicting flows of people, estimating public transport requirements and assuming that transit provision will encourage post-rail development by the private sector. Following this methodology, the rail is broadly publicly funded. However, taking Australian cities as one example, it is apparent that compared to the rest of the world, the land development that is assumed to follow around transit nodes often does not eventuate. In contrast, Australia's initial tram lines of the early 20th Century focused on identifying land availability and development opportunities, and leveraging private sector partnerships to collaboratively provide transit infrastructure and land development, resulting in successful public-private partnerships with private funding for public infrastructure (Davies-Slate & Newman, 2019). This historic approach started with available means – being land development opportunities – rather than transport system optimisation.

Much like the tram lines of the early 20th Century, effectual urban governance requires understanding the local context, and shaping integrated infrastructure systems with partners. Available means form the basis of the opportunities that can be pursued.

6.4 THE RELATIONSHIP BETWEEN AVAILABLE MEANS AND VALUE CREATION

Effectual urban governance focuses on what can be controlled to create value rather than acting based upon predicted outcomes. As articulated by Sarasvathy (2009), this means focusing on the controllable aspects of an unpredictable future rather than actions based on predictions of an uncertain future. The conditions of uncertainty and unpredictable futures are a key feature of entrepreneurial environments (Knight, 1921). Similarly, they are key features of the complex systems in which many urban projects take place, particularly within a global climate or political context. As identified in Chapter 2, in his seminal work on uncertainty, Knight (1921) posited that uncertainty constitutes the ultimate source of profit for the entrepreneur. The 'unknown unknowns' that, by their very nature, characterise uncertainty are a product of a knowledge gap within the market, and knowledge of a specific domain can create the opportunity for novel and unique solutions to be created.

In his global best-selling book The Blue Economy, Belgian sustainability entrepreneur and Professor Gunter Pauli, reiterates the importance of starting with what is locally available when undertaking projects in complex systems (Pauli, 2009; Pauli, 2017). His Blue Economy model is based on entrepreneurial practice around the world. The model extends the 'Circular Economy' model and places a stronger focus on complex systems, their interrelated nature and the subsequent opportunities for economies of scope rather than economies of scale. In essence, Pauli's (2009) model suggests that rather than taking a 'core competency' approach that is representative of causation logic, entrepreneurs can create the most value by focusing on what is available and generate multiple interrelated benefits by diversifying their production portfolio based on underutilised resources, for example, the waste stream from one process as an input for another. By creating complementary processes that often leverage underutilised resources as inputs greater value is created through synergy. Drawing many insights from how nature itself operates, Pauli (2009) argues that when dealing with complex systems, starting with what is locally available is key to maximising value creation, and much of this value is spread across a number of interrelated value streams.

Pauli's (2009) work strongly resembles a shift in decision-making logic from causation to effectuation. Pauli (2009) presents 112 case studies from around the world spanning various sectors including manufacturing, agriculture, food, buildings, housing and energy. He states, "the approach looks anew at what is locally available, from that which was once thought of as waste product or weed, to infrastructure of assets that have been phased out and left unproductive". In the same way, Sarasvathy (2009) posits that 'slack resources' can be leveraged to create greater value in entrepreneurial ventures and should be a core focus when identifying available means. Similarly, effectuation logic also holds leveraging contingency as a core principle, whereby entrepreneurs look at unexpected events, or underutilised assets, as opportunities rather than constraints. In applying an effectual urban governance approach in the context of cities, leveraging available means constitutes a cornerstone for action and innovation.

A focus on available means presents the opportunity to get started and build traction for new initiatives, it may also ensure that value is added through leveraging and enhancing local contextual factors. Further, it can uncover potential value creation opportunities that may not be blatantly obvious but stand to deliver significant benefits when acted upon. Effectual entrepreneurs use this logic, often in conditions of heightened uncertainty, to seek commitments from stakeholders and reduce uncertainty. The best entrepreneurs acknowledge that their hypothesis about the world or a particular market is just their own. The best entrepreneurs also do not hold onto their own hypothesis at all costs, but instead turn to their potential customers and partners to look for answers.

Entrepreneurs test, experiment and learn with the intention of uncovering unique insights and means that are embedded with the complexity and uncertainty of the system. Mining the market for means, the

unique insights uncovered by the entrepreneur through interaction and networks are the 'hidden gems' that represent value in an uncertain world. In the case of the Willunga Basin Water Company, discussed in Chapter 4, the wastewater discharge into the Gulf of St Vincent was leveraged to create a secure water supply to underpin decades of economic prosperity for the region. This also created the added value of dealing with the environmental concern of wastewater discharge into the Gulf.

Effectual urban governance, just like entrepreneurs who develop artefacts based on their customers' needs, provides a framework for the creation of unique solutions that have the potential to unlock multiple sources of value beyond what is traditionally considered the primary objective by the technical experts. As Pauli (2017) states, "the import of external solutions renders the local communities blind to the wealth that they have locally". To reiterate the point made at the beginning of this section, transferring best practice into a complex system like a city, without an appreciate for local drivers and preferences, can prove not to be best practice at all (Madanipour et al., 1998; Heraurd, Kerr and Burger-Helmchen, 2018; Walloth, 2016).

6.4.1 Creating Value with Available Means in Practice

This section provides four examples of value creation based on available means to demonstrate this principle of effectual urban governance in an infrastructure context. Two of the examples drawn from Pauli's (2009) The Blue Economy exemplify leveraging available means for economic regeneration and the provision of infrastructure for bio-chemical manufacturing and energy in a regional context. By starting with what is locally available and focusing on economies of scope rather than economies of scale, these initiatives uncover hidden gems and capitalise on multiple opportunities. Following these two cases in regional regeneration, the other two examples highlight the value in applying effectual urban governance to urban transport projects in the same way that entrepreneurs apply the approach in other contexts.

Two Cases in Regional Regeneration

Regional Case 1: Biorefinery in Porto Torres, Sardinia, Italy

Novamont are an Italian company who are recognised as global pioneers in the production of biopolymers (to produce bioplastics) and leaders in the supply of biochemicals to customers all over the world. Their story began in 2013, with the opening of their first facility in Porto Torres, Sardinia, Italy. At this time, the Sardinian region was suffering from declining economic opportunities – with their major petrochemical facility struggling to maintain supply due to the loss of low-cost petroleum from Libya after the Arab Springs uprising. The region had also turned away from its traditional agricultural production to focus on tourism, despite having 175,000 acres of fertile agricultural land. However, following the 2008 financial crisis, tourism also diminished. In 2013, petrochemicals had

become unprofitable, tourism was low, and the farmers in the area were being subsidised by the European Union not to farm.

Novamont identified that a significant portion of the petrochemical facility – which at the time was considered a stranded asset – could be used to process biological feedstock to create biochemicals. However, it appeared there were no immediate agricultural crops or sufficient population to provide the feedstock. Novamont investigated the available means and discovered that throughout the surrounding once-agricultural land grew a native artichoke thistle that was growing rampant due to the absence of agricultural production (scientific name: Cynara Cardunculus). This thistle was capable of being processed into protein, animal feed, bio-plastics, bio-lubricant, herbicides and elastomers. Better yet, being a perennial, the thistle required no tilling, fertilisers, irrigation or pesticides.

By taking an approach that was based on available means while also leveraging contingency, Novamont had recognised two pivotal slack resources in the form of the retired petrochemical facility - a stranded asset - and the naturally occurring weed. The petrochemical group responsible for decommissioning the facility, entered a joint venture with Novamont to repurpose the retired facility to process the naturally abundant thistle, developing a partnership, rather than being competitors, and driving niche structuration, as further discussed in Chapter 7. By identifying and utilising available means, what was once a petrochemical site processing 2.5 million tonnes of petroleum fuel and naptha into 700,000 tonnes of chemicals, became a biorefinery processing 360,000 tonnes of thistles into valuable bio-chemicals that are used to produce 350,000 tonnes of bio-plastic, elastomers and functional chemicals and exported around the world.

Following causation logic, Novamont would have likely taken their research from the laboratory using a specific organic feedstock and searched for a suitable location where this feedstock was abundantly available and could be purchased cheaply. Novamont may have then developed a business case for the facility and designed a production facility, secured investment and proceeded to maximise production and reduce inefficiencies over the course of the project life. By taking an effectual approach and being guided by available means, particularly in the form of slack resources, Novamont uncovered available means that underpinned a stronger business model than would have been possible through a causal logic, and stimulated newfound economic prosperity for a region in decline. This outcome represents maximising stakeholder value, not just shareholder value.

Regional Case 2: Renewable Energy and Water in El Hierro, Canary Islands, Spain

Another case study that demonstrates effectual governance and the value of starting with available means when developing infrastructure solutions for sustainability transitions is the island of El Hierro in Spain. The island of El Hierro is the smallest of the Canary Islands. It has historically suffered from a shortage of water, resulting in the emigration of thousands of the island's inhabitants for jobs elsewhere which has long threatened the island's livelihood. In addition to the water crisis, the island

was spending USD $10 million each year to import diesel fuel for power generation. The island of El Hierro was all but abandoned in strategic national plans at one point and was facing the bleak possibility of needing to re-locate its inhabitants. To avert this, stakeholders took guided design principles and aligned them to sustainability, with a focus on self-sufficient agriculture and eco-tourism. The island leveraged its available means of abundant seawater (being an island), wind, and a volcano and through collective action merged its energy and water companies, with the population co-owning the new entity.

By aligning with the principles of effectuation and seeing contingency as an opportunity rather than a constraint, leveraging the existing costs spent on diesel fuel imports for financing of a USD $100M renewable energy program. This investment was not introducing new costs for the utility company, as repayments were a diversion of established diesel fuel costs towards more sustainable technology (controlling what is controllable, as per an effectual approach). The introduction of five major wind turbines generates 11.5MW of electricity for the island of approximately 10,000 people, with excess electricity used to desalinate water, which is then pumped to the top of the 700m volcano and stored in a reservoir in the volcanic basin that was sealed for the purposes of the project. The 700m high reservoir creates a hydropower reserve that is activated for power when wind activity is low. The system seen in Figure 6-1 below uses physics and available means, primarily the height differential as a means of storing energy and desalinating water – and as a result no batteries are needed.

Figure 6-1: Wind and hydropower station on location. (Javier Morales, El Hierro; Cited in Driesenaar, 2019).

This case study draws parallels to the effectual governance process demonstrated in the Willunga Basin in South Australia (Chapter 4). It also demonstrates the benefit of starting with available means as a

cornerstone of effectual urban governance. As a result of leveraging existing costs for finance, available resources in wind, and coupling this system with saltwater desalination, the island now has double the water at half the cost. Through co-ownership of the energy system, €23,5M is circulated back into the local economy each year. The island has reinvented itself as a home of sustainable, organic agriculture, underpinned by the newfound availability of affordable freshwater. It has the biggest area dedicated to the production of pineapples in the entire Canary archipelago. The island now has dairy and cattle industries and an award winning winery. By leveraging available means, discontinuing the import of diesel fuel and redirecting these funds towards self-sufficient energy production and water desalination an array of subsequent industries was made possible.

Both the Sardinia bio-refinery example and the El Hierro integrated energy and water example demonstrate the value of beginning with available means when planning and implementing infrastructure initiatives. Effectual urban governance poses that early-stage planning processes for urban infrastructure should begin with assessing available means and using these as a basis for subsequent partnership discussions and investment commitments. These case studies also highlight how the effectual principle of 'leveraging contingency' can unlock far greater value. The two case studies are exemplars of how synergy, based on available means rather than scale based on conventional business models, creates broad stakeholder value beyond any single business.

Two Cases in Urban Regeneration

Urban infrastructure can also turn to available means as a basis for value creation. In the case of transit projects, value is created across multiple dimensions, and thus available means should be considered across multiple streams. Transit projects create economic value through greater density and agglomeration impacts, improving productivity and innovation, promoting the sharing of common resources, creating knowledge spillovers and learning, and giving rise to new industries (Mori & Nishikimi, 2002). Transit projects also create integrated urban development opportunities, particularly land development opportunities in the form of higher density, commercial mixed-use centres within their station precincts. They create opportunities for electric mobility hubs powered by renewable energy and integrated buses and taxis, as achieved in Shenzhen, China and they can facilitate innovation in the sharing economy through smart mobility and micro-mobility initiatives. Thirdly, and importantly, transit projects underpin the creation of social value by providing workers with greater access to opportunity and upskilling, improved accessibility and social interaction, and health and environmental benefits. A focus on these value streams beyond the core 'travel time savings' from perceived congestion reduction and opens different views of what is possible.

Urban Case 1: South Lake Union Streetcar, Seattle

The South Lake Union Streetcar is a streetcar project that was constructed in 2007 as an initial 1.3-mile route from Seattle's downtown retail core to an inner commercial and industrial neighbourhood close to the city centre that was identified to have significant redevelopment potential. The streetcar line was first and foremost built as an economic development project to unlock land value and development potential in the area. A focus on available means in the form of underutilised land and the subsequent value creation potential, led to half of the USD $52.1M project cost being paid for by the private sector, rather than government (Ohland & Poticha, 2009). These costs were borne by property developers who recognised the value that public transport connectivity could create for the surrounding land. Specifically, Vulcan's initial 7,500 housing units and almost 2 million square feet of biotech and mixed-use projects – almost all of which are built to Leadership in Energy and Environmental Design (LEED) green building standards (Ohland & Poticha, 2009).

Significant sustainable development has occurred, and continues, around the streetcar route. Streetcar projects in the United States have evolved from solely transport projects to economic development projects that facilitate broader economic value.

Vulcan Real Estate Company, and other private interests were the major proponents of the streetcar route compared to others that had been proposed, due to the associated land development opportunity. This potential made them willing to contribute to the costs of the streetcar and the subsequent public-private partnership delivered much-needed public transit infrastructure and economic and social value. This shift to an effectual urban governance approach focused on envisaging a complex array of available means (underutilised land) and value creation (mixed use transit-oriented development) – rather than traditional, and more simplistic predictions of potential transit passengers and travel time savings. In contrast, a transport-centric lens that provides no opportunity to appreciate the multi-faceted set of value creation opportunities possible by leveraging available means allows little-to-no options to attract private capital for such infrastructure undertakings.

Urban Case 2: Redevelopment of Pearl District, Portland

Portland's Pearl District is considered one of the most successful urban redevelopment projects in the industrialised world (CDBC, 2015; Dujon et al., 2013). The provision of the Portland Streetcar in 2001 underpinned the transformation of the area and is an example of an effectual urban governance approach. At the end of the 20th Century, the Pearl, as the area was known, was a neglected de-industrialised area which had suffered from withdrawn investment. The planning of the streetcar route through the district focused on maximising the value creation based on the available means – running through large areas of ex-industrial land with significant development potential. The physical characteristics of the area, such as block size and surface area of the streets, were retained. The Pearl is now one of Portland's premier residential, commercial and entertainment areas, with employment in the area growing by 4.6% annually. The local community, developers and landowners were involved

in this project from the very beginning, and together were able to collaboratively comprehend and unlock the value from the available means.

Due to the development potential of the underutilised land (the value creation potential of the slack resources), funding contributions from the private sector through a Local Improvement District Levy and Tax Increment Financing made this project possible given the private sector stood to benefit financially from this project. In the words of Rick Gustafson, Executive Director of Portland Streetcar Inc., developers were "falling over themselves" to agree to the levy (Sustainability Victoria, 2011). The streetcar project cost US $103.15M – with approximately 20% paid for by the private sector. Since its construction, over US $3.5B of private finance has been invested in development within a two-block distance of the streetcar route, creating broader value for the city with more people living and working near public transport services. This demonstrates the integrated value that can be created through transit activated corridor projects.

An effectual urban governance approach begins with available means as a basis for action. Ken Johnsen, Principal of firm Shiels Obletz Johnsen who had managed both the Portland and Seattle streetcar projects, explained the two most important lessons learned. The first was that the private sector can, and should, commit funding to such projects with the understanding they stand to significantly benefit from increased property values and development opportunities – reflective of the effectual urban governance principle of forming partnerships early and seeking effectual stakeholder commitments. The second was to keep the project simple and fast. "It's not a $1 billion light rail project. It's not a ten-year effort", "It's ready-fire-aim! Just do it! The tendency is to grapple these projects to death" (Ohland & Poticha, 2009) – reflecting the effectual urban governance principles of 'taking effectual action'.

While the success of these two urban projects is evident from the case studies provided – the effectual urban governance principles and approach they used are not mainstream or standard practice across the world. Effectual urban governance provides a framework for conceiving and co-creating such opportunities that captures the key elements needed to create the urban value described in these case studies. This research advocates the effectual urban governance principle-based framework and processes developed in this thesis are translatable across geographical contexts to inform urban value creation and regeneration projects in cities across the world.

6.5 VALUE CREATION FOR TRANSIT ACTIVATED CORRIDORS

The effectual urban governance approach to integrated transit corridor creation is focused on available means and underutilised slack resources as a basis for action. Effectual urban governance in this context, and as depicted in the case studies above, is about much more than transit provision. Rather, it uses transit provision as a tool to unlock economic and social value along a corridor, and by incorporating

partners early in the process, it creates opportunities for co-contributions that can improve the viability of the infrastructure proposal and address global calls for public private partnerships to address the significant urban infrastructure funding gap (United Nations, 2016; Wu & Mehta, 2020; Avellan et al., 2021). This section first illustrates the types of value that can be created through a transit activated corridor process. It then distinguishes the value creation and value capture processes to make explicit the value of an effectual urban governance. The role of acting based on available means to maximise value creation, as a key component of this process, is then detailed.

6.5.1 Value Creation through Transit Activation

Transit provision creates value for a city in several ways. By enabling the increased utilisation of land adjacent to transit stations, and by enabling the efficient movement of people, accessibility benefits lead to land value uplift and to economic agglomeration benefits. Economic productivity is increased, integrated infrastructure developed and social capital opportunities are greater in these economies. This is represented in Figure 6-2 below.

Figure 6-2 illustrates the distinction between transit activation, or the factors that underpin and make possible the economic value that is created as a result of transit provision, and the drivers of economic value creation that themselves generate the economic value. The core contribution that transit makes to activate a corridor is two-fold; transit firstly enables the spatially efficient movement of large quantities of people; secondly it enables the increased utilisation of land. Without the ability to move large amounts of people efficiently, dense precincts are not viable. Similarly, by enabling dense land development adjacent to stations, more people are able to access the convenience of transit as their primary mode of travel. The distinction between transit activation and transit's drivers of economic value creation is important in informing, and understanding, an entrepreneurial approach to value creation based on available means.

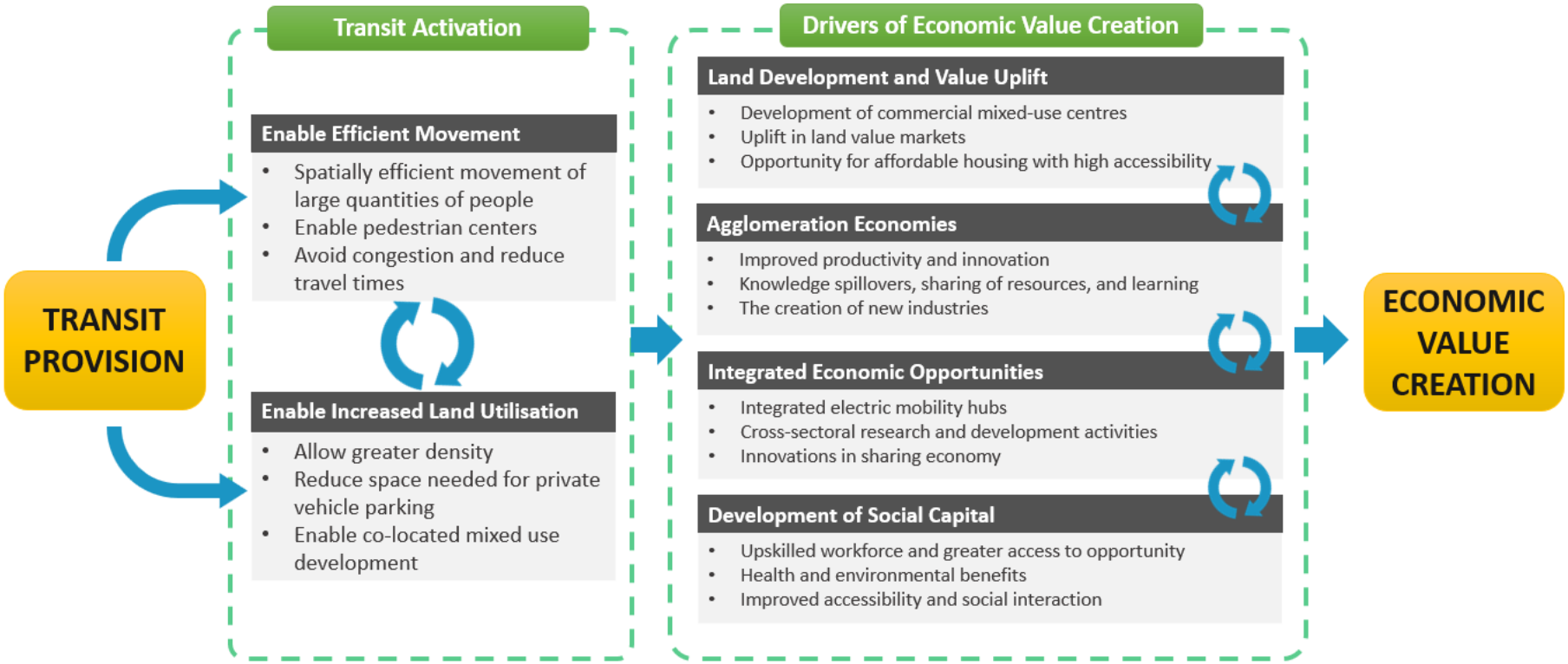


Figure 6-2: Representation of economic value creation through a transit activated corridor process

6.5.2 The 'Value Capture' Planning Process

While examples of transit corridor projects from around the world consistently indicate that economic value is created through the provision of highly efficient public transport systems, cities have forgotten the once conventional process of entrepreneurial planning that seeks to leverage such value creation for collaborative infrastructure delivery, leveraging the resources and innovation capacity of the private sector to achieve public benefits. This was the approach to railway delivery in the 19th and 20th Century discussed in Chapter 2. Modern transport infrastructure planning is steered by government transport agencies with a primary focus on delivering travel time savings as a measure of economic value creation. Other economic value creation, like land development potential or industrial agglomeration are considered 'wider economic benefits' – they can be estimated and quantified however they are often seen as periphery benefits that are assumed to materialised 'after the fact'. While all transit projects usually create this value, those historically planned by government agencies do not concretely capture this value to subsidise government funding as they are not focused on the proactive maximisation of this value in an entrepreneurial way. In essence, this traditional approach does not lend itself to the creation of effective public private partnerships for closing the global urban infrastructure funding gap.

Traditionally, transit planning processes begin with models of prediction and forecasting. These models determine where the bottlenecks and pain points are within the transport network, where urban growth is expected across a metropolitan area, and make a judgement on the best place to provide transit infrastructure as a transport tool for enabling the movement of people. While the movement of people is important, it is a means to an end, in that people do not travel for travel's sake – they travel to reach useful destinations and opportunities.

The nature of transit as an economic value creation instrument means that in conjunction with transit provision, additional value and opportunities are created along a corridor, as was the case in Seattle and Portland. The transport planning discipline has come to recognise the need to capture some of the economic value that is created by transit systems, especially in response to combatting the competing funding priorities of governments across all sectors. The value capture approach is a means of recouping some of the costs spent on transit. The process can be represented by the flowchart below in Figure 6-3.

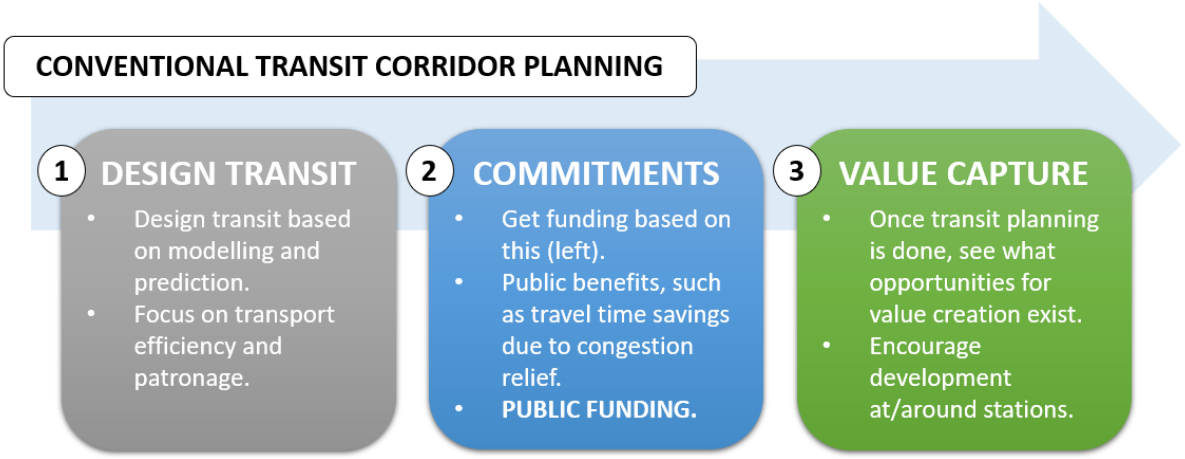


Figure 6-3: Conventional transit planning and value capture approach (Adapted from Newman et al., 2018)

With or without value capture, conventional transit design projects follow the same planning process. This process is representative of causation logic, in that analysis is undertaken up-front to identify the 'preferred solution', which forms the basis for the design, stakeholder engagement, business case, funding, and all subsequent activities. Simplifying this to three stages, the process is as follows:

1. **Transport Planning and Design:** The optimal route for the transit system is determined based on travel time savings. Such processes seek to identify options which perform best across multi-criteria analyses that are focused on transport benefits, and economic, environmental and social benefits. These processes are government-driven and when wider economic benefits are considered they are considered as a potential value capture opportunity post-delivery. This stage of the process culminates in the transit agency, usually in isolation, determining its ultimate preferred transit corridor routing option.
2. **Funding Commitments:** The preferred transit option established in (1) above forms the basis for a business case and funding commitments. Public funding is the primary funding source for such a project, with the project optimised to align with public funding objectives. This is not a problem in isolation. In the broader context of competing government funding commitments that has given rise to a global infrastructure funding gap (United Nations, 2016; Wu & Mehta, 2020; Avellan et al., 2021), adequate transit systems cannot be delivered to meet Sustainable Development Goal (SDG) objectives like SDG 11: Sustainable Cities and Communities where integrated transit systems and transit-oriented development are essential. Nevertheless, this stage of the process culminates in public funding for a project.
3. **Value Capture:** Following the planning process, land development and associated economic activity is generally encouraged. However, as the third step in the value capture process, once the project has been funded and delivered value may or may not be created. Generally, land prices will increase, which may even preclude some development from occurring, and generally

the benefits of proximity to transit and the associated accessibility are appropriately reflected in land value. Once the transit project has been funded and delivered, value capture is considered as a means of recouping capital costs and operational costs of the project. In the majority of infrastructure projects in Australia, for example, value capture is not used at all.

The order of events described in Figure 6-3 delivers infrastructure through public sector funding, justified by transport efficiency benefits. Inherently this is not a negative outcome, given that public infrastructure is being provided for public benefit. However, the reality is that national, state and city governments are facing infrastructure funding constraints. The 21st Century city does not seek to build more sprawling suburbs at low densities, leaving its citizens no choice but to drive long distances each day to access opportunities. This situation has been described as 'transport poverty', where disadvantaged socio-economic groups living in outer suburbs of Melbourne are trapped in a cycle of high private transport costs and no access to efficient public transport (Gleeson & Randolph, 2002; Currie & Dellbosc, 2013). To address this, the 21st Century city must find ways to regenerate its urban areas around efficient public transport to secure its social, economic and environmental future.

The public-led, value capture model outlined above is a fully public sector capital mechanism for funding urban rail (McIntosh et al., 2014; McIntosh et al., 2015). However, and perhaps most importantly, it is still a prediction-based approach that does not guarantee that the development that is forecast during the initial planning phase of the project will actually be delivered. Nor does it provide a basis for urban transformation at the scale needed. To facilitate that there needs to be a wider change in the way government transport planners perceive the types of developments that can occur that also enable the recuperation of funds through value capture. This change in contrast to current approaches is not a pre-commitment from self-selecting stakeholders made at the outset who are the very actors who have the ability to bring the development into effect.

6.5.3 The Untapped Drivers of Value Creation

The value capture approach to developing transit corridors remains an example of public-sector driven infrastructure provision. The approach undertakes transport planning as the primary objective with land development and other integrated benefits as an add-on. In regard to facilitating systems change and dealing with uncertainty, this approach is limited in its ability to facilitate transformative urban systems change due to the planning process that is transit-first; with other considerations made afterwards. The early-stage corridor planning process lacks a focus on the drivers of economic value creation, despite the significant potential to leverage these opportunities for partnerships and commitments. In contrast, transit activated corridor projects identify and optimise value creation aspects of the transport project from the start of the planning process that can shape a new future.

As one example, Figure 6-4 below highlights levels of infrastructure investment in different sectors and includes real estate alongside core infrastructure sectors such as transport, energy and water. It is apparent from the figure that global real estate investment, driven by the private sector, dwarfs other infrastructure modes. Transit provision has a positive effect on land value markets due to increased accessibility and opportunity to maximise land parcel utilisation (Siripanich et al., 2019; Berawi et al., 2020), as done in the Seattle and Portland case studies. This model is not commonplace despite the glaring opportunity for coupling real estate and infrastructure development through transit provision.

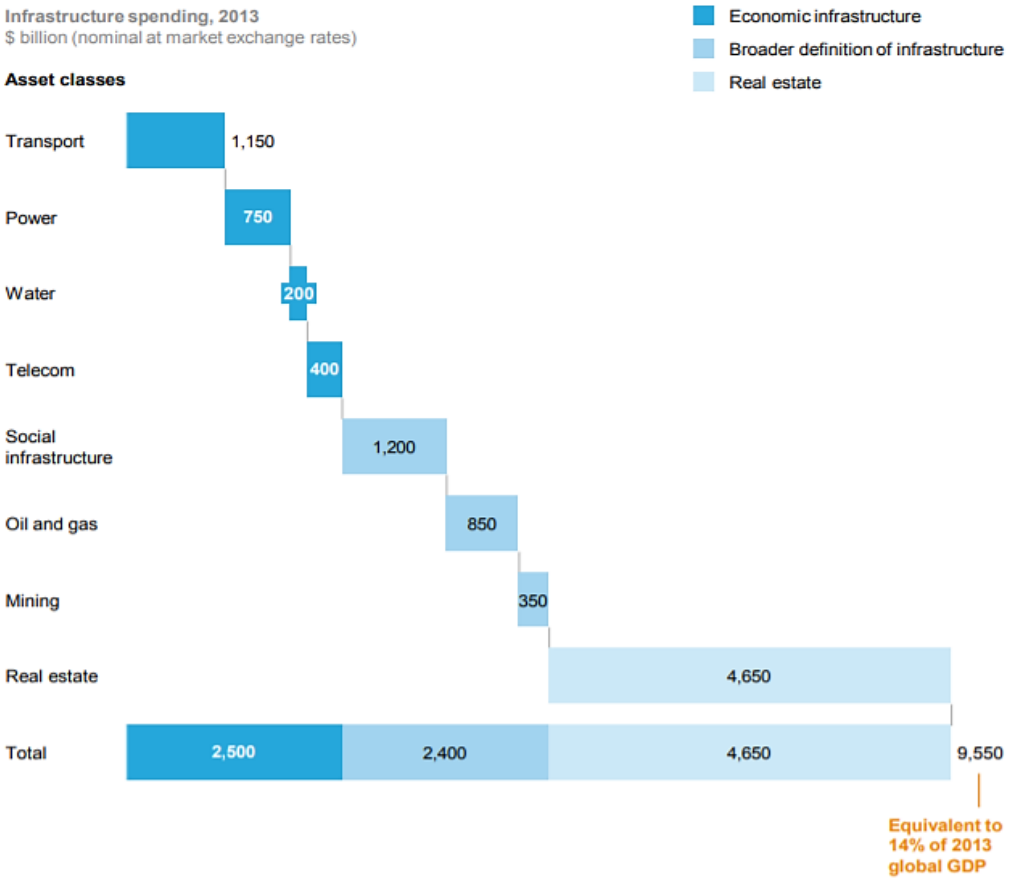


Figure 6-4: Global infrastructure spending compared with real estate investment (Source: IHS; Euroconstruct; IMF; World Bank; OECD as found in McKinsey Global Institute analysis, 2016).

The coupling of real estate development and transit provision has been applied in some parts of the world. The 'joint development' approach to value creation exemplifies the principles of effectual urban governance, particularly where partnerships and effectual stakeholder pre-commitments form the basis for infrastructure development. The most prominent examples that reflect the principles of an effectual urban governance approach to transit infrastructure provision based on land development opportunities are in Asian cities – such as Hong Kong's 'Rail-Property (R+P)' model (Hong and Lam, 1998; Cervero and Murakami, 2008); the 'Land Consolidation' model used in Taiwanese cities (Lam and Tsui, 1998); and Tokyo's 'Land Readjustment' model (Farrell et al., 1994; Tsukada and Kuranami, 1990; Kuranami et al., 2000).

These Asian cities, motivated by high densities, growing populations and strong demand for urban development, recognise the value creation opportunity that well planned transit presents. Their model engages private sector partners early in the planning process, particularly property developers. The details of each are location-specific however the general principle is that land developers are presented with the opportunity to develop around transit stations, a density and liveability opportunity that does not exist in automobile-centric precincts. The provision of new transit creates this opportunity. Therefore, these developers are willing to contribute to the costs of the railway as they are confident they can recoup their costs through subsequent development. This approach is not prediction-based, but instead opts for commitments from the private sector up-front, better allocating risk. In these cities, railway provision would likely lead to significant development regardless of if a public-led or collaborative planning approach was taken. The difference here is that the drivers of economic value creation (land development, agglomeration economies) are tapped into at the beginning of the planning process to secure private funding for the project, rather than following the value capture process presented in Figure 6-3. In this way, risks and rewards are fairly allocated and mitigated.

Other drivers of economic value creation can be leveraged to deliver integrated public infrastructure such as electric mobility hubs. Santiago, in Chile, has emerged as a global leader behind China in the rollout of electric buses. In 2016, a consortium of public, private, research institutions and civil society was established to foster the rollout of electric mobility in Chile. Cross-sector dialogue has enabled business model innovation, with Chile's largest utility company Enel Chile pioneering a new business model for electric buses in partnership with a bus operator. The buses have been purchased by utility companies - not transit companies - and are leased to the bus operators. This is an example of electric utility companies financing transit innovation, due to the overlap between the electricity sector, the utilities' core business, and electric mobility hubs. These types of partnerships make complex electrification and transit corridor projects less cumbersome on any one department as shared value can be created with risk and rewards distributed appropriately; this also allows different partners to play to their strengths.

The agglomeration and social benefits generated by transit can be incorporated early in the planning process through the involvement of businesses and communities who stand to gain from accessibility benefits such as density. A study by Rawnsley (2014) suggests that increasing effective job density by 50 percent can increase labour productivity by as much as 175 percent due to the creation of knowledge economy jobs. Similarly, density plays a role in facilitating innovation, with one study showing that the doubling of spatial employment density can increase the intensity of patent creation by 20 percent (Carlino et a., 2007). This makes knowledge economy firms and universities relevant partners for transit activated corridor projects. The City Deals approach pioneered in the United Kingdom (which is detailed in the next chapter) demonstrates how different sectors can collaborate to identify (a) their goals for the project; and (b) the investment they are willing to commit to a project which may be

beyond monetary. Such effectual processes focus on shaping projects based on the drivers of economic value creation and establishing commitments from private and community sectors. The commitments reduce uncertainty and allocate risk appropriately in realising and creating value.

6.5.4 Beginning with Available Means

Leveraging the drivers of economic value creation presents an opportunity to deliver infrastructure in partnerships, reducing reliance on government funds. As stated previously, to do so, the planning process needs to change. As evident in the four of the case studies presented earlier in this chapter, effectual urban governance opts for identifying slack resources to create more value, or those available means that are currently underutilised and form the basis of the most opportunity. Identifying available means is much more suited to generating effectual stakeholder commitments (discussed further in Chapter 7 – Partnerships), which reduce uncertainty by converging expectations and contribute to the expansion of network resources.

Figure 6-5 below illustrates the effectual urban governance approach to transit activated corridors, whereby value creation potential forms the basis for planning.

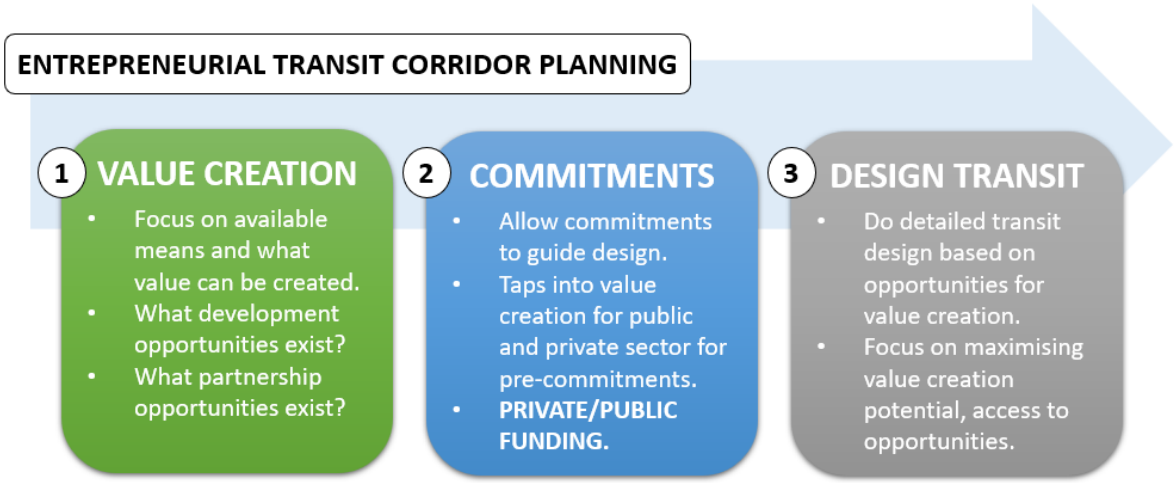


Figure 6-5: Effectual urban governance approach to value creation through transit provision (Adapted from Newman et al., 2018)

The planning process in effectual urban governance approaches begin by identifying what is available, what partners are willing to collaborate, and what opportunities for value creation arise out of these ingredients. As depicted above, simplifying this to three stages entails:

1. **Focus on Available Means for Value Creation:** The effectual urban governance process to create transit activated corridors begins by asking: What exists to form the basis for value creation? Is there underutilised land, infrastructure, or partners that are willing to make commitments for a certain future? Structuring the planning process around available means seeks to forego the initial tendency to rely on transport modelling to deliver a preliminary

transport solution. Instead, an economic corridor project looks broader to what opportunities exist for strategic urban development and the facilitation of agglomeration economies. By including such opportunities that arise organically based on what is available, there is greater opportunity for private contributions. This stage of the process is interactive, collaborative, and requires discussion and identification of opportunities.

2. **Get Commitments:** The effectual urban governance process seeks to establish partnerships early in the process, identify opportunities for value creation and through the process of effectual stakeholder commitments from partners, begin to design the details of the initiative. If commitments can be made based on available means, this forms the basis for the 'patchwork quilt' that begins to take shape. This stage of the process is interactive and may involve stakeholder workshops and negotiations. There may be local governments and private sector consortiums that are supportive of a transit line that connects a number of key identified precincts with opportunity for development. Based on these opportunities, much more of the commitment base is sourced from the private sector in a joint development fashion, meaning that development is integral to the project and not just an afterthought.
3. **Transport Planning and Design:** With the drivers of economic value creation aligned with available means, the outline of the project has satisfied major hurdles in public-private collaboration and is set up around commitments from the private sector. The transport planning and design exercise should seek to both satisfy the commitments that have been made while also maximising the transport benefits for communities along the corridor and between key nodes identified. Measuring the accessibility provided by the transport network connects transport and land use without needing to 'predict' where people wish to travel. By optimising the value creation potential and the accessibility potential of the transit line, transport planners can ensure that 'transit activation' occurs to facilitate economic and social benefits along the corridor.

Starting with available means firstly allows for value creation to be maximised. The additional value that is created through an effectual urban governance approach is what makes private sector involvement most compelling. After all, the identification of available means and perceived opportunities is not only the role of governments in this process – but for partners to actively engage in proposing also. This partnerships dynamic is discussed further in the next chapter.

6.6 CONCLUSION AND CONTRIBUTION TO THESIS

This chapter focuses on the available means principle which is central to value creation through an effectual urban governance process. In the context of urban infrastructure projects, the chapter details the shortcomings of conventional planning projects when faced with infrastructure funding gaps and heightened uncertainty. It also shows how applying an effectual urban governance approach to infrastructure development offers significant potential to create more economic, social and environmental value from projects.

To take an effectual urban governance approach to transit corridor development, practitioners should aim to do the following:

- Undertake an early scoping study of 'what available means exist' that enable the maximisation of economic value creation. This process does not even need to be centred around transport, but can be focused on land, industry and economy.
- Early engagement with partners, discussed further in the next chapter. While a scoping study of local opportunities may provide value, an effectual process remains open and flexible to proposals that may arise from private parties who perceive their own opportunities for value creation.
- Flexible and iterative corridor planning that is collaborative and brings together property developers, industry, academic institutions, superannuation funds, and other self-selecting stakeholders to discuss and ideate how value creation can be maximised through transit provision.
- Allow self-selecting stakeholder commitments to 'lock in' elements of the plan, and along these dimensions create certainty about the future upon which to undertake more detailed transport planning work to establish the detailed route and corridor details.

Allowing the principles and process of effectual urban governance to guide the transit activate corridor planning process consists of (1) Determining effectual design principles that establish a set of project values that establish boundaries but allow flexibility within these boundaries – as per Chapter 5; (2) Identifying available means that provide an opportunity for value creation – this Chapter; and (3) Establishing strategic partnerships that focus on shared value creation and effectual stakeholder commitments – which is discussed in the next Chapter. It is proposed that through a partnerships-based approach based on available means, more value can be created by aligning the drivers of economic value creation with the opportunities for value creation and structuring the transit corridor around this (rather than structuring the transit corridor around travel time savings).

In summary, this chapter makes the following contributions to the thesis and the literature:

1. Translates the entrepreneurial effectuation principle of available means to the urban governance domain and elucidates this using two illustrative examples of regional regeneration, and two illustrative examples of urban regeneration.
2. Distinguishes between a causation-driven approach to corridor planning and an effectual urban governance approach to corridor planning, extending the Entrepreneur Rail Model presented by Newman, Davies-Slate and Jones (2018) to incorporate effectual urban governance insights.

CHAPTER 7

EFFECTUAL URBAN GOVERNANCE:

PARTNERSHIPS AND EFFECTUAL STAKEHOLDER COMMITMENTS

7.1 CONTEXT

Effectual urban governance seeks to align incentives and use effectual stakeholder commitments, or partnerships, to steer ventures for the best collective outcomes. 'Partnership' is a broad term – and partnerships can take many different forms. They can be tokenistic and/or transactional. Effectual urban governance opts for a partnerships-based approach to achieving sustainability transitions in cities; this approach aims to facilitate more effective outcomes in conditions where transformative systems change is required and uncertainty is prevalent. In doing so, effectual urban governance responds to the increasing global call for partnerships between the community, public and private sectors to deliver essential civil infrastructure. This chapter, building on the previous chapter on available means, focuses on the partnerships component of the effectual governance process that drives commitments from effectual stakeholders.

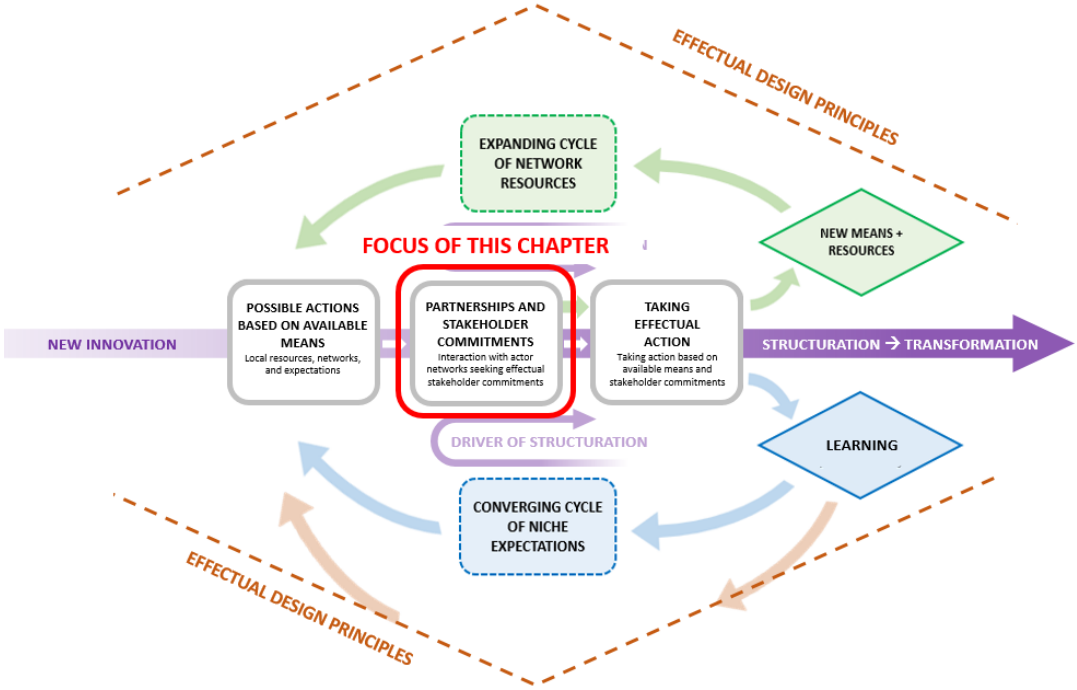


Figure 7-1: Dynamic model of effectual urban governance – with partnerships being the focus of this chapter

7.2 NETWORKS AND PARTNERSHIPS AS ESSENTIAL FOR NEW FUTURES

Among the many contributions that Aristotle made to philosophy, he was the first to propose frameworks of thinking and problem solving. Analytics and rhetoric were of Aristotle's thinking systems. Aristotle considered analytical/logical thinking to be suited for problems where things cannot be other than they are and not so much for creating new futures in unknown or uncharted territory. For this, Aristotle characterised rhetoric as being useful where things can be other than they are. This thinking system is based on dialogue and debate (Aristotle, 4th Century BC).

The western world has mastered Aristotle's thinking system of 'analytics'. This realm of logic gave birth to the scientific method and the reductionist approaches that have placed decisions in the hands of experts who specialise in core competencies. The modernist movement around the world represented a shift towards this way of thinking and decision-making, with this approach lending itself to logical deductions and the solving of problems using evidence and mathematical methods (Golsby-Smith, 2007). It is the logic that overwhelmingly underpins the planning and engineering of civil infrastructure in cities.

Aristotle's analytical method represents what Golsby-Smith (2007) calls 'First Road Thinking'. The method is based on evidence, numbers, and proof, and aims to make predictions about outcomes to pre-empt results and thus gain more control over situations and decisions. This line of thinking carries almost all of our intellectual traffic today. The analytical road gave birth to science, which established new technologies and improved the quality of life for the human population.

In the panning of urban transport infrastructure, traffic engineers undertake detailed analyses and forecasting to extrapolate existing transportation conditions decades into the future. Their thinking is informed by industrial path dependency which is solidified by the 'logic' and 'analytical' machine that uses historical observations to predict benefits and mitigate risk. This approach further embeds existing path dependency. In the case where the system functions as is needed, the analytical system produces reliable results. However, as the first person to codify thinking into a system, Aristotle had reservations about the reliability of the analytical approach to solving all of society's problems (Golsby-Smith, 2007).

Aristotle's second thinking system was 'rhetoric' (Aristotle, 4th Century BC). According to Aristotle, rhetoric was the way that humans designed alternative futures. The rhetoric system is about thinking 'what could be' and spurring what Aristotle called argumentation and debate about these ideas. This method seeks to answer questions that are not based on the existing model, but instead imagine a new model. Rhetorical thinking cannot be done in isolation, it is necessary to engage members of the

community and other stakeholders to undertake this meaningful discussion about what the future could be.

In rhetorical approaches to problem solving, engagement for shaping alternative futures is not engagement for engagement's sake. It is not a 'box-ticking' exercise that is undertaken by a government or business to satisfy their community engagement criteria. It is meaningful discussion that is intended to challenge belief systems, extend understandings and provoke visions of the future to arrive at the best collective outcome. In this effectual process, niche expectations are adjusted as new partners and commitments are made and built upon to scale a niche to achieve its transformative potential. The niche, as its structuration increases, can be thought of as a 'patchwork quilt' – made up of multiple effectual stakeholder commitments and partnerships. In these networks and partnerships visions for the future are brought forward to be discussed in conjunction with others' visions for the future – to establish a collective vision that encourages commitment from all parties and begins to shape a future that looks like these commitments. This multi-stakeholder undertaking is a more involved process, and in some ways more challenging than a single actor project that is managed in isolation; these two reasons may be why a rhetorical thinking system has garnered much less attention from the Western world despite calls for more collaborative approaches.

7.3 EFFECTUAL PARTNERSHIPS FOR URBAN CHALLENGES

Globally there has been an increasing call for 'Public-Private Partnerships' (PPPs) to solve complex urban challenges. International and multilateral organisations all state the importance of effective partnerships to provide satisfactory infrastructure to meet society's basic human needs (United Nations, 2016; Avellan et al., 2021; Wu & Mehta, 2020). As the public sector has a shortage of capital to supply society's essential infrastructure (transport, water, electricity), the need for new governance models for organising, financing, delivering and operating infrastructure is becoming more imperative. The literature on innovation and sustainability transitions acknowledges this and advocates the importance of networks and partnerships to drive systems change (Mourik and Raven, 2005; Geels and Schot, 2008).

7.3.1 The Global Call for Infrastructure Partnerships

The 21st Century call for the private sector to play a larger role in the provision of key urban infrastructure does not reflect a wholly new paradigm however. In the transport sector, for example, many of the original railway lines of the 19th and early 20th Century around the world were privately developed as a way to unlock new opportunities for real estate and land development (Davies-Slate and Newman, 2018). As has been discussed earlier in this thesis, this entrepreneurial approach to unlocking access to new land through railway provision resulted in lucrative real estate opportunities, and such projects became popular across the United Kingdom and the United States. As discussed in Chapter 3,

Britain's railway expansion in the 19th Century and early 20th century was almost entirely led by private entrepreneurs, resulting in an extensive rail network that delivered economic and social benefits. Rail corridors were built as private real estate ventures based on the land value unlocked by transport connectivity. This approach was replicated in many cities around the world as the basis for expanding mobility and settlements for the next 100 years (Newman and Kenworthy, 1999; Newman, Glazebrook & Kenworthy, 2013). At the time, countries that took a more public-led approach lagged behind the British success, such as the French who relied on state-led planning of routes and facilities before engaging the private sector (Winch, 2002).

In many cities, the urban legacy of the entrepreneurial rail era is a medium density, mixed use urban fabric that follows corridors out from the traditional core walkable fabric in the town centre; these corridors are still quite distinct and given the generally abundant access to useful destinations and opportunities, represent higher than average real estate prices and hold a substantial proportion of the city's knowledge economy jobs (Newman, Kosonen & Kenworthy, 2016). The economic and social benefits of transit and walkable urban fabric are now one of the driving forces behind why cities are seeking to build more transit corridors and are prioritising transit-oriented infill development over outer area urban sprawl (Newman et al. 2013). However, although the outcomes of such transit-driven city shaping has returned to become a priority for cities, the cross-sectorial partnership approach has been lost in favour of government-centric public transport planning.

PPPs can be structured in many different ways, from the entrepreneurial, private-led examples of the 19th and 20th Century in Britain, to government-led planning, design and then outsourcing of operations. In the case of toll roads, a new piece of highway infrastructure is financed by private investment and value captured through user tax meaning there is minimal additional value created. Rather than seeking private finance and allocating risk, or selling of public assets to the private sector, effectual urban governance aims to enable Public-Private Partnerships to prioritise the delivery of collaborative value creating projects for the benefit of the city. To achieve this, innovative partnership models are needed globally to marry the private sectors' skills in planning, design, construction and innovation with the public sectors' fundamental role in providing for the economic and social welfare of its citizens. This approach reflects the tenets of effectual urban governance with public, private and community sectors coming together to solve shared challenges in productive partnerships with aligned incentives for value creation.

7.3.2 Effectual Urban Partnerships

Consistent with effectuation theory (Sarasvathy, 2009), and the case studies presented throughout the thesis, the dynamic model of effectual urban governance presented in Chapter 4 opts for initiating partnerships early in the infrastructure planning process. The early commitments of the partnership network aims to reduce uncertainty and shape the future of the niche. In the case of urban infrastructure

initiatives, partners can be private sector investors, community groups, technology providers, municipal and state governments, educational institutions or corporates. These partnerships need to uphold key tenets to be effective.

Drawing on effectuation theory and the synthesis of effectual and strategic niche management, supported by the insights of the Willunga Basin Water Company, key elements of effectual partnerships are:

- **Effectual partnerships embody 'customer as partner':** The end users of an initiative should be involved from the beginning of the process to ensure that the initiative is aligned to the users' needs. This is also a strategic process to drive demand for a socio-technical niche by aligning technological or infrastructural development with social expectations and norms. In urban contexts, this involves creating forums for collective discussion and debate and participatory approaches that allow innovations and proposals to be tailored to users' expectations. As observed in the case of the Willunga Basin Water Company, creating a group of partners and stakeholders at the beginning of the process reduced uncertainty and risk, as those making the initial commitments to the initiative were also the first users of the system. Technological 'insiders' within a niche should be encouraged to consider and reconsider their expectations based on insights drawn from customers' expectations.
- **Effectual partnerships allow for self-selecting stakeholders:** There may be self-selecting stakeholders that approach a niche and are willing to make commitments to drive the process of structuration forward. Establishing effectual design principles at the beginning of the effectual urban governance process ensures that all stakeholders are aligned to working within a defined set of boundary conditions. As the niche evolves, greater levels of structuration occur and there is less scope for a dramatic shift in niche direction, self-selecting stakeholders continually contribute to the expanding resources of the niche.
- **Effectual partnerships facilitate commitments:** Reducing uncertainty requires commitments that can be acted upon. The shift from causation to effectuation logic is about placing trust in the commitments that are made based on available means. These commitments signal reliability in uncertain conditions, and are a basis for niche development rather than predictions and forecasts.
- **Effectual partnerships expand over time to drive transformation:** The expanding cycle of network resources is one of the key dynamic processes that drives structuration through an effectual urban governance approach. Partnership networks provide resources that are capable of driving an initiative forward. As a project builds momentum, the expansion of partnership networks provide the means by which the structuration of practices is increased. Ultimately, an effectual urban governance approach is focused on the development of a socio-technical niche,

rather than a specific technology – and technology may change and evolve as the niche develops.

The following discussion exemplifies how a collaboration with multi-sectoral partners, representing an effectual urban governance approach, effectively shaped urban infrastructure investment in the UK and other countries.

7.3.3 Example of Effectual Urban Partnerships: City Deals, United Kingdom

The City Deals initiative in the United Kingdom provides a framework for partnerships across the private, public and community sectors to deliver city shaping infrastructure projects. City Deals are representative of an effectual urban governance approach to infrastructure planning and provision where all levels of government, the community and private sector collaboratively shape their vision for the future and make effectual stakeholder commitments in-line with this. The novel and innovative process is much more effectual than conventional urban governance processes. Like any niche, City Deals themselves are subject to ongoing learning about what works and what doesn't, enabling improvements to the structure and process to be made iteratively (O'Brien and Pike, 2015) to create value.

The City Deal concept was introduced in the United Kingdom in 2011 by then Deputy Prime Minister, Nick Clegg and then Minister for Cities, Greg Clark. They described the shift in thinking City Deals represented as:

> "A fundamental shift in the relationship between national government and cities – starting with a genuine transfer of power. Our ambition is to create powerful, innovative cities that are able to shape their economic destinies, with civic and private sector leaders freed to look outwards to businesses and communities rather than upwards to central government for solutions."

City Deals was framed around the principles of decentralisation, localism and rebalancing. The focus of the policy was "enabling places to tailor approaches to local circumstances, and providing incentives for local growth" (Tomaney et al., 2011; cited in O'Brien and Pike, 2015).

City Deals are representative of partnerships approaches to effectual urban governance The City Deal movement thereby represents a shift towards a more entrepreneurial approach to development initiatives in cities. Partnerships between local stakeholders are incentivised, where local urban development outcomes are paramount rather than national top-down planning objectives. In the process, local coalitions of stakeholders pitch in and 'ask' the UK government to fund and finance infrastructure and to formulate supportive policy (O'Brien and Pike, 2015). The proposals are developed by local actors

and combine public sector funding and a mix of public and private infrastructure investment with a focus of the partnership being the generation of economic value.

Effectual urban stakeholder commitments do not always need to be in the form of funding or finance. Liverpool city region identified low carbon technology as a key factor in attracting investment and generating jobs. Many low carbon projects were facing delays due to a lack of clarity in the planning process and the slowness of central regulatory authorities in approving developments. Liverpool's City Deal represented value creation for the low carbon technology sector by facilitating the investment of central funds into local projects, and by committing the central government to fast-tracking responses to permit applications for low carbon infrastructure. One of Whitehall's effectual stakeholder commitments was the easing of regulatory burdens on low carbon infrastructure projects. The City of Liverpool's ongoing facilitation role in supporting the effectual structuration of the clean energy sector includes working with the Green Investment Bank to fund new low carbon projects. This is expected to accelerate £100M of investment into offshore wind, creating 3,000 new jobs (Centre for Cities, 2020). Other cities such as Manchester, Leeds and Birmingham have low carbon initiatives in their City Deals, representing effectual design principles and partnerships aligned to sustainable development.

In Manchester, effectual urban partnerships were established between ten existing local government authorities who combined to form the Greater Manchester Combined Authority. This City Deal was the first to go ahead and is often cited as it is the most mature. The primary objective of the Manchester City Deal was the provision of transport infrastructure, housing and urban regeneration, with benefits shared across the partnering jurisdictions. The key tenets of the Manchester City Deal were skills, business support, carbon reduction, housing and transport. Greater Manchester implemented a number of value capture mechanisms enabling the recuperation and reinvestment of costs – these were termed 'earn-back' mechanisms. In essence, Greater Manchester (GM) operates the 'earn-back' scheme on behalf of the Central Government (CG); the CG shares its taxation revenue from economic development in the area with GM. This incentivises GM to strategically facilitate economic growth, often through developing effectual partnerships and innovations with the private sector.

In this example of multi-level government collaboration, effectual stakeholder commitments made by GM relating to the earn-back feature alone included self-funding, made up of government and private finance, operational resources for the earn-back program at GM level, and commitments to undertake consultation with the CG for infrastructure investments. The CG's effectual stakeholder commitments included agreeing to the earn-back model; agreeing to some of the central government's proceeds from economic growth going to GM; agreeing the earn-back model would operate for 30 years; committing to funding envelopes of £30M per annum between 2015/16 and 2020/21; and committing to reviewing infrastructure and funding liability over time with the option to adjust liability in order to prioritise incentives for economic growth. Many other effectual stakeholder commitments were made by both

GM and CG. These included the creation of a City Apprenticeship and Skills Hub (GM); developing a scheme to support 6,000 new apprentices (CG); establishing a Local Carbon Hub (GM); supporting GM in carbon reduction through inclusion in national policies; and also supporting for GM in CG proposals for European Union funding.

The City Deals approach has been adopted in other countries, including Australia and The Netherlands. In Australia however, cities have longer played the primary role in their own economic destinies through State and Local governments, and therefore the introduction of City Deals in this part of the world represented the Federal Government getting more involved in city shaping rather than less. What was similar in both cases was the aim of bringing multiple levels of government together with private sector and community to shape cities. The Australian City Deal program focuses on bringing together the following participants, visualised in Figure 7-2 (Glazebrook & Newman, 2018; Australian Government, 2018):

- An agreement between the three tiers of government, setting out a plan for the City Deal to accomplish innovation, affordable housing and sustainability outcomes;
- Greater community involvement and support for projects; and
- Involvement of the private sector, including innovative financing with supporting funds from Local, State and Federal Government, with the Federal government providing a risk guarantee (this is based on the UK's Infrastructure and Projects Authority which has attracted several billion pounds of private funding into British infrastructure).

Figure 7-2: Partnerships needed for a City Deal (Newman, Davies-Slate and Jones, 2018)

City Deals represent a new form of governance that is able to connect local ambitions with broader resourcing opportunities and risk guarantees than can be provided by central governments. Each of the City Deals are bespoke and respond to available means and local effectual design principles that are established through effectual partnerships. Urban infrastructure provision is central to City Deals, however the scope of City Deals is much broader with economic development as a key driver. City Deal proposals are developed through collaborative processes that involve government, the community, and the private sector; these partnerships are solidified through effectual stakeholder commitments. City Deals, regardless of their political intent or scale, and depending on the country in which they are implemented, represent how the principles of effectual urban governance are starting to be leveraged to deliver urban infrastructure and economic benefits. In an entrepreneurial fashion, these cities are ultimately looking to differentiate themselves and make themselves competitive on the global stage. They are achieving this through multi-sector partnerships that can be much more creative, more closely tied to the market for urban development, and more aspirational in achieving social outcomes and creating social value. The transport sector, as recognised by entrepreneurs in the 19th and early 20th Century, remains one way to unlock new opportunities for new partnerships and new developments.

7.4 PARTNERSHIPS FOR THE EFFECTUATION OF CITIES: TRANSIT ACTIVATED CORRIDORS

Despite the entrepreneurial provision of railway networks in the 19th and 20th Century (Davies-Slate and Newman, 2018), since the mid-1900s, cities around the world have reformed their public transport networks to be under government control. Public transport systems under government control lack the 'entrepreneurial flair' that was evident in the private automobile industry, led by companies incentivised to sell more vehicles. As a consequence, culture and user preferences in Anglosphere cities shifted to automobiles, and transit became increasingly un-competitive and inefficient. Cities are now rediscovering the potential economic value of transit systems in the face of congestion and inefficiency brought about by decades of automobile dependence (Ewing and Bartholomew, 2013; Sharma and Newman, 2017; Newman, Davies-Slate and Jones, 2018). Cities around the world are also now increasingly seeking innovative means of supplying transit infrastructure as a key component of the broader 'essential urban infrastructure' package that is being sought through Public-Private Partnerships. The focus is on working productively with the private sector for finance, delivery, and operation – while maximising 'win wins' and ensuring projects ultimately deliver benefits for the community. While this represents a shift away from government controlled public transport networks, one of the priorities, and key concerns in public transport governance is effectively managing the tension and contrast between the market initiative and central planning (Rhyzkov and Sarzhan, 2020). The poor performance of the privatised bus systems in the United Kingdom outside London is frequently cited as a point against establishing Public-Private Partnerships. The privatisation of this

public transport operation saw ‘unprofitable routes’ removed which created major service gaps for parts of the population (Mackie et al., 1995; Mees, 2005; White, 1997). This example is a cautionary tale as it exemplifies the importance of effective collaborations and communication in planning the way forward. By returning to a collaborative, entrepreneurial approach it is possible to reinvigorate public transit projects and enhance their competitiveness (Vuchic, 2014) through accessing and optimising appropriate means - mechanisms and controls - to ensure optimal multi-stakeholder outcomes. The following section provides an exemplar of this; it compares and contrasts a conventional causation logic approach and an effectual urban governance approach to the provision of public transport corridor infrastructure.

7.4.1 Decision Levels of Public Transport Governance

The majority of transit systems around the world reflect causation logic in their structure and approach to planning and delivery. The conventional process of planning and operating public transport networks is for the strategic planning to be undertaken by mostly governments. These plans then filter down into tactical planning processes that are again mostly undertaken by government agencies. Operations, or operational planning, are eventually either undertaken by the same government agencies involved in the strategic and tactical planning, or tendered out to the private sector.

Figure 7-3 below represents the three decision levels that public transport decision-making occurs: Strategic, Tactical and Operational (Van de Velde, 1999; Hensher and Macario, 2002; Vuchic, 2014):

- **Strategic:** Strategic planning is the formulation of general aims and determining, in broad terms, the means that can be used to attain these aims which are usually long term.
- **Tactical:** Tactical planning is about making decisions on acquiring means that can contribute to achieving the general aims, and on how to use these means most efficiently within the medium term of one to two years.
- **Operational:** Operational planning is ensuring the tactical decisions become a day-to-day reality, and that this happens in an efficient way in the short term.

Figure 7-3 depicts how these three decision levels may be used as a framework to distinguish different opportunities for private and community sectors to collaborate on a transit initiative across the different levels of planning.

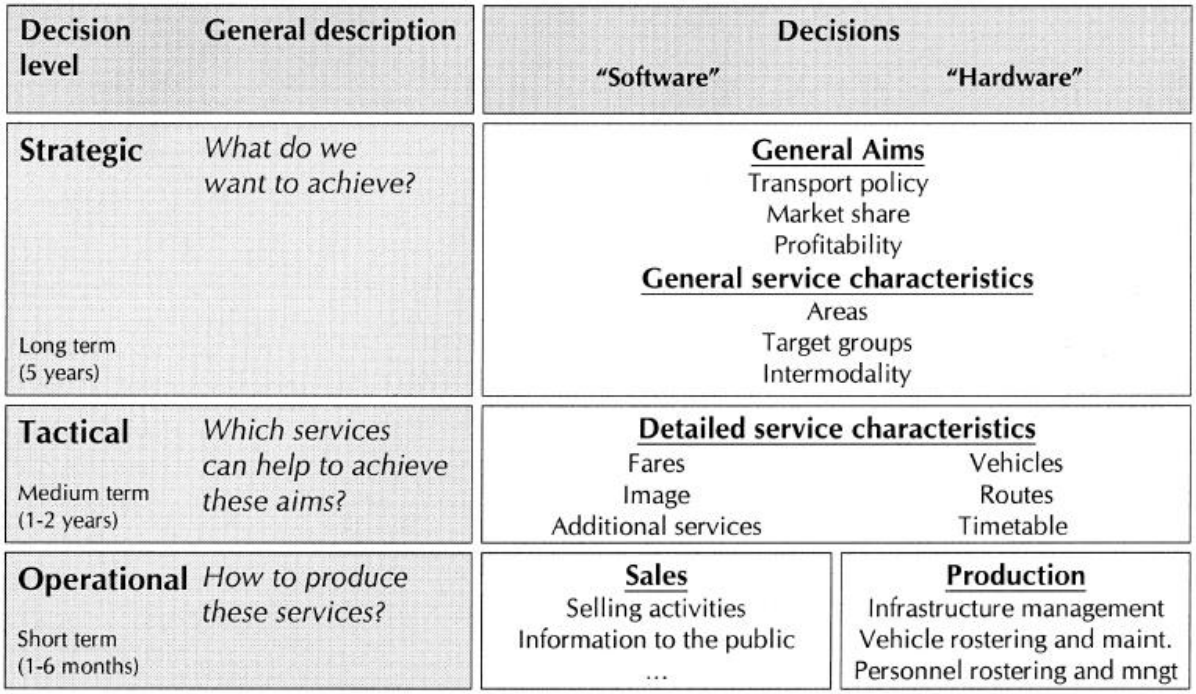


Figure 7-3: Decision layers of public transport planning and general focus of each (Van de Velde, 1999)

As part of this thesis research, in October 2018 I attended the United Nations Centre for Regional Development in Tokyo, Japan for the 'Asia Pacific Training Program for Railways as Low-Carbon and Sustainable Transport Development Solutions in Achieving Safe, Inclusive, Efficient and Resilient Communities under the 2030 Agenda for Sustainable Development' (UNCRD, 2018). I co-facilitated a workshop that was attended by senior transport professionals (n=36) from both the public and private sectors in 14 countries across Asia. The workshop focused on identifying barriers and exploring opportunities for partnerships to deliver Transit Activated Corridors. The findings were then organised using Van de Velde's (1999) framework of strategic, tactical and organisational planning to enhance the discussion in this Chapter. Details on the UNCRD Program, workshop details and responses, and outcomes can be found in the publicly published UNCRD report (UNCRD, 2018). To contextualise the following discussion, a representation of findings from the workshop is provided in Figure 7-4. The responses are color-coded into the six themes that emerged in response to the following question designed to inform this research: "What barriers do you see to creating public-private projects for land development and rail construction along corridors in your cities?".

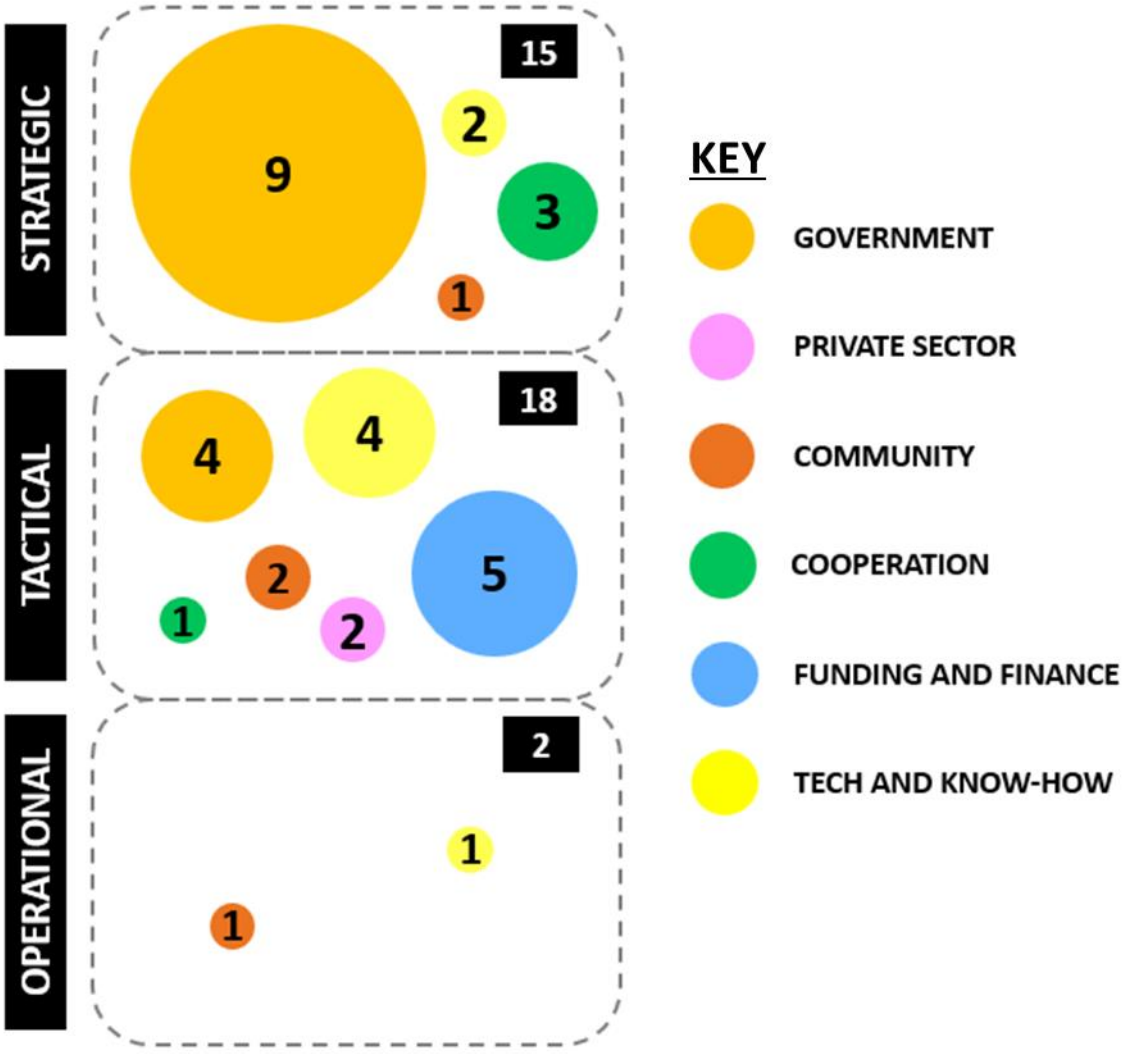


Figure 7-4: Summary of survey responses from United Nations Centre for Regional Development (UNCRD) Partnerships Workshop in Tokyo, Japan using Van de Velde's (1999) framework of strategic, tactical and organisational planning.

It is clear from the workshop responses that creating Public-Private Partnerships for transit infrastructure provision is an undertaking that must overcome challenges at the strategic and tactical levels of planning. I pose, supported by discussion below in this section, that applying the effectual urban governance principle of partnerships early in the planning process (i.e. at the strategic and tactical levels, rather than just operational levels), is key to overcoming potential barriers and unlocking shared value for all collaborators, as well as the public. Table 7-1 below provides an overview of causation and effectuation logic at the three decision levels of public transport planning provided by Van de Velde (1999); it particularly indicates at what level partnerships are created. The distinction between causation and effectual urban governance at each of these levels is then detailed, drawing on the reflections of the participants from the workshop on partnerships for Transit Activated Corridors.

Table 7-1: Comparison of causation and effectuation logic at strategic, tactical and operational level of public transport planning

DECISION LEVEL		CONVENTIONAL GOVERNANCE (CAUSATION LOGIC)		EFFECTUAL URBAN GOVERNANCE (EFFECTUATION LOGIC)
STRATEGIC	*What aims do we want to achieve?*	Analysis of existing situation and prediction of the future form the basis for 'what the solution should look like' to respond to risks and challenges. **Focus is on prediction and strategic positioning.**		***ESTABLISH PARTNERHIPS HERE*** Partnerships are created and opportunities are identified based on available means (rather than pre-determined ends). **Focus is on value creation based on available means and partnerships.**
TACTICAL	*Which services can help to achieve these aims?*	Sourcing and making decisions between means that can contribute to achieving strategic ambitions. **Focus is on efficiency and investment cases built on prediction of the future.**		Building a 'patchwork quilt' of effectual stakeholder commitments, based on opportunities established at a strategic level. **Focus is on value creation and commitments from self-selecting stakeholders.**
OPERATIONAL	*How to produce these services?*	***ESTABLISH PARTNERSHIPS HERE*** Management of resulting system. Often outsourced to contractors on a transactional basis and minimal feedback loops between operations at this level and Strategic and Tactical level. **Focus is on efficiently 'carrying out the orders'.**		Management of resulting system. More opportunity for integration and feedback loops as partners are already established at higher levels. Iterative process between operations, strategy and tactics to continually improve service offering. **Focus is on ongoing improvement within an integrated system.**

7.4.2 Strategic Decision Level

Strategic planning is involved in the formulation of general aims and in the determination in broad terms of the means that can be used to attain those aims. This includes: decisions regarding profit and market share aims, the main area of supply and a general definition of what services will be supplied (without being overly prescriptive), defining the main target groups and determining the strategic market positioning of the public transport services in relation to market substitutes and complimentary services.

Van de Velde (1999) recognises the entrepreneurial parallels involved at the strategic decision level of public transport network development. Van de Velde (1999) defines the strategic decision level as it relates to public transport as:

> "Being at the core of 'entrepreneurship' and the actor responsible for these crucial decisions as the 'entrepreneur' as he takes the initiative for the creation and supply of services, thereby takes some form of risk, and as he delineates at least the main characteristics of the services that will be provided."

In contrast to Van de Velde and to the approach championed in emerging governance examples like City Deals, most cities conventionally undertake this planning process using a causation approach. As depicted in Figure 7.4, many of the barriers identified at a strategic level relate to 'government' and an over-reliance on causation logic which impedes the potential for developing partnerships and value creation.

Strategic public transport decisions using causation logic

Strategic public transport decisions using causation logic involve the transport department establishing the social and policy goals of the transport system. This establishes the aims of the city's public transport system and is influenced by the government's policy agenda which should be designed to serve the public good. This takes the form of strategic ambitions and a vision, with general targets, over time. For example, these targets may state an ambition to increase the percentage of the population that use public transport for journeys to work from 15% to 25% over the coming decade. In most cases, these strategic ambitions are usually supported, and informed, in part, by a consultation period with the community and industry. These strategic ambitions may also be influenced by contextual factors. Participants at the workshop indicated these may include, "the political priorities of politicians, being very short term", a "lack of political will" for transformative proposals more generally, and a case of "the government does not want the private sector to get involved" and further, that "transport and land use are not thought of as linked together." These responses reflect the observation from one participant that the "government often has the upper hand in negotiations." The responses also strongly show how important it is for

governments to better understand the potential of integrated transport corridor development and be actively open to capitalise on this opportunity.

Strategic public transport decisions using effectuation logic

As established in Chapter 5, it is important that effectual design principles are established to guide development of strategies and subsequent tactics and operations, to ensure that societal objectives are still achieved. These may be similar to those found under the causation framework with the key difference being an effectual urban governance approach prioritises establishing partnerships early in the decision-making process than the conventional causation approach. The partnerships may be with transit companies, and also with urban development and land use interests, as in Hong Kong and Tokyo (see Chapter 6). For example, commercial property developers and managers may realise the potential that transit provision provides to development areas as it enables new density and car-free lifestyles. There may also be potential for inclusions in zoning regulations to incentivise preferred development (like affordable housing) in return for density bonuses.

Based on the principles of effectuation, in conditions of heightened uncertainty, and to reduce uncertainty, initiatives can be steered by the commitments of self-selecting stakeholders. For example, general service target areas are established at a strategic level. These can be influenced by development patterns, community concerns and ambitions, and perceived opportunities by self-selecting stakeholders in the same way that cities in the United Kingdom determine priority focus areas for their City Deals based on available means and partner preferences. Adhering to effectual design principles that govern overarching sustainability objectives and design boundaries, such collaborative strategic planning opens up more possibility for effectual stakeholder commitments and enables much more urban value creation at the subsequent tactical level.

7.4.3 Tactical Decision Level

Tactical planning focuses on translating the transit aims developed at a strategic level into detailed public transport service characteristics. This is the level at which the design of the service takes place. Decision-making at this level is focused on specific projects and commitments rather than high-level aims, as the high-level aims have been established in the previous strategic phase. In a public transport context, this level focuses on defining routes, infrastructure, timetables, vehicles and fares. Other integrated aspects of the public transport system are also developed at this level, such as the image/marketing of the service and the provision of additional supporting services.

Tactical public transport decisions using causation logic

Tactical planning following a causal approach is commonly referred to as ‘Predict and Provide’, as discussed earlier in this thesis (Chapter 4). This work is often undertaken using detailed modelling and

forecasting techniques to establish a 'predicted future' to which infrastructure provision can respond. A common limitation of this approach, evident in cities over the world, is the unintended induced traffic demand that results from highway expansions (American Association of State Highway Officials, 1957; Downs, 1962; Growther, 1963; Overgaard, 1966; Thomson, 1977; Newman and Kenworthy, 1989; Mogridge, 1990; SACTRA, 1994; Goodwin, 1996; Hills, 1996; Litman and Colman, 2001; Næss, Mogridge, and Sandberg, 2001; Noland and Lem, 2002; Nicolaisen and Næss, 2011). Predict and provide modelling extrapolates existing conditions to predict more congestion, with infrastructure investment attempting to mitigate this impact by building more highways, which then become more congested due to induced demand. As the cost benefit analyses do not account for this induced demand, causation-driven infrastructure appraisals can be subject to serious bias (Næss, Nicolaisen and Strand, 2012).

Tactical decision-making following causation logic is led by governments and is often siloed into 'transport planning' with little consultation or awareness about the potential of a more collaborative approach. UNCRD workshop participating countries noted that not only are "transport and land use not thought of as linked together" at a strategic level, the structures and processes do not exist at the tactical level to capitalise on the transit activated corridor opportunity. The causal, siloed approach also contributes to partnerships for planning transit corridors in many cities being perceived as "harder than with roads, because with roads you can use tolls whereas with railways it is different". Thinking of railways in isolation also contributed to workshop participants observing "[it would be a] very long time for payback and profit for standard railway, therefore it is hard to engage private sector" and foreseeing difficulties in "defining the percentage of government financial contribution" when private sector opportunities are not clearly articulated. These issues reflect that causal approaches to transit corridor development are primarily driven by government planners with strategic quantitative models, with public funding secured based on cost-benefit analysis that is often heavily based on travel time savings. The opportunity to integrate land development and develop 'partnerships' is usually considered, if at all, at the very end of the project when there is minimal opportunity remaining for value creation.

Tactical public transport decisions using effectuation logic

Tactical decisions taken following an effectual urban governance approach are much more partnership-driven than a causation approach. At a tactical level, partnership networks can establish routing options and development based on perceived opportunities by the private sector. This requires transit agencies to be flexible in the form and function of urban infrastructure proposals, or the specific route of the service, especially because effectual planning processes draw upon effectual stakeholder commitments. This means effectual stakeholder commitments and available means need to drive the process. For example, the Brightline passenger railway service between Miami and Orlando was revived from an

old freight railway by a real estate company with intentions of developing land within station precincts – which underpinned the finance. Local and County government provided the necessary zoning changes and assistance with land assembly and public realm improvement to ensure the project delivered community benefits.

Partnerships in effectual urban governance also involve the community. A 430-acre urban regeneration project in Kalasatama, Helsinki, is one example. This project was fully financed by the private sector with one-third of unit ownerships retained by the city government for government-subsidised housing. This shared value creation aligns with effectual design principles and sustainable development. The developers followed an effectual urban governance approach to community building, where pre-commitments from home buyers were collected (as with most development projects), however the key difference was that those who 'buy in' were included from the very beginning to co-design the development and help determine what should be included. Such collaboration is key to effectual urban governance – particularly at the tactical decision level. Governments can facilitate this by bringing in the private sector and the community and allowing those that demonstrate buy-in through effectual stakeholder commitments, whether this be financial or other means, to constructively discuss and debate the tactical details – culminating in a patchwork quilt of effectual urban commitments.

7.4.4 Operational Decision Level

Operational decisions are about ensuring the 'plans are carried out' – i.e. that the system that has been designed at a tactical level is delivered and contributes to the strategic ambitions. At an operational level, there is little malleability left in the system. The agreements that are established at this point mostly reflect what was determined at a strategic level.

Public transport operational decisions comprise management issues: of the sales staff and the drivers, the management and maintenance of the vehicles, and the management of the infrastructure to ensure that the services specified at the tactical planning level are achieved. These operational aspects should not be isolated from strategy and tactics. Although not the focus of Van de Velde's framework, interactive feedback between the levels of operations, strategy and tactics enable the ongoing improvement and optimisation of the system. As Vuchic (2014) notes:

> "Seen from a dynamic perspective, there has of course to be a feedback between the decision levels involved, notable based on the feedback provided by (potential) clients. Moreover, there will ideally be a link between the hardware and software side at the tactical level to ensure an adequate evolution of the services, in accordance with market needs and the stated general aims."

Operational public transport decisions using causation logic

When causation logic governs the decision-making associated with the planning of a public transport network, the majority of new value creation opportunities have already been accounted for at higher decision levels by the time operational agreements are made. This means for private and community stakeholders of the public transport network, there is little opportunity for new value creation at the operational level. Governments will often tender out bus operations, however the result of 'privatising' operations at this level is that contractual arrangements and partnerships are transactional. This is a result of causation processes undertaken at the strategic and tactical levels without the involvement of the party being introduced to the system at an operational level.

The customer feedback and iterative feedback loops that are integral to system improvement, can, to some extent, be achieved through a causation logic. They are not embedded in the initial system however which is a problem when large capital outlays are required to establish new infrastructure systems, and which once implemented, have multi-decade legacies. At an operational level, causation-based systems provide measurable metrics that aim to incentivise performance. For example, private companies may be penalised if the bus runs late. Their payment may be correlated with patronage levels, or customer feedback. The feedback received by operators is used to continually try and improve their performance across these metrics – however they do not have the ability to change any of the tactical or strategic 'boundaries' that they are governed by – such as alternative route opportunities, or the timetables themselves. This limits its evolution and potential, to optimally serve stakeholders' and customers' needs.

Operational public transport decisions using effectual logic

Introducing partnerships at an operational level only is not reflective of effectual urban governance. By this point in the life of the project, questions such as "What's working?" and "What's not?" cannot be asked and acted upon. This emphasises the importance of effectual processes being undertaken at the earlier levels. By facilitating effectual decision-making at a tactical level there is a greater opportunity for feedback between operations and particularly the tactical level. Potential private operators, manufacturers, developers, and the community can be engaged early to provide input into what could be; this potential future can then be explored and enacted by commitments made by those involved in the necessary these systems. Throughout this process, feedback can inform and improve the operational outcomes of the project.

The International Association for Public Transport (UITP) strongly emphasises the need to improve attention to passenger needs, as well as improve the efficiency of operations (Vuchic, 2014). This is facilitated by following all the stages of the planning framework; it is not achieved through initiating transactional partnerships at the operational level. Cities that have maintained this entrepreneurial type

of transit provision, namely Hong Kong or Tokyo, have some of the highest quality transit networks in the world. In these cities, those that operate the systems are also involved in tactical and strategic planning about 'what could be' and they themselves provide the link between customer service provision and higher-level systems planning.

7.4.5 Creating Value through Partnerships and Commitments

Effectual urban governance has the potential to maximise the value creation of transit activated corridors by promoting engagement with stakeholders at all levels of decision-making. Partnership-based governance approaches rather than siloed professional practices have increased exponentially around the world in recent years (Clark and Clark, 2014; Newman, 2016). City Deals are one example. City Deals exemplify how local government, business and community can creatively and collaboratively identify what opportunities exist for their city, and develop 'patchwork quilt' initiatives that bring together effectual stakeholder commitments from a range of participating parties, in monetary terms and other resources. These new approaches are crucial for unlocking private funding to address the significant capital gap for quality transit infrastructure (Newman et al., 2017). Effectual urban governance provides a framework for implementing such an approach to respond to the need for multi-sectoral infrastructure governance for planning, finance and delivery.

Examples of partnership-driven, effectual urban governance models are increasing. The Indian Government's Metro Rail Policy sets a clear requirement that it must include private stakeholders and consider the potential for private funding contributions and transit-oriented development to obtain central government. Agencies implementing these projects are encouraged to think innovatively about how they may generate non-fare box revenue, in a similar way to the Manchester 'earn-back' scheme. The Urban Mass Transit Company is a 50:50 government and private agency and has the flexibility to raise finance and assess metro proposals (Government of India, 2017).

In the United States, the Portland MAX light rail is an example of how effectual stakeholder commitments generated at a strategic level can create value. In 1997, Bechtel a private company approach the Portland region to propose an extension of the MAX rail service from Downton Portland to the airport. The effectual stakeholder commitment from Bechtel at the strategic planning stage was a commitment to pay for a quarter of the project's cost, and contract to build the light rail extension. In return, Bechtel would receive development rights to a 120-acre land parcel near the entrance to the airport. The effectual partnership meant that the project was funded between TriMet, Bechtel Enterprises, City of Portland and Port of Portland, without the need for state general funds or property taxes (TriMet, 2012).

The nature of self-selecting stakeholders and effectual stakeholder commitments mean that rather than designing initiatives based on pre-conceived outcomes or modelling outputs, and 'selling' an

opportunity to the private partner (as would occur at the tactical or operational planning level), the self-selecting entity takes ownerships of their effectual stakeholder commitment. In the case of the Portland MAX extension, the September 11 attack occurred in New York one day after the light rail extension opened. With significant implications for the economy, Bechtel's proposed jobs and hospitality centre was made more challenging. Bechtel decided to sell the development rights to another developer who has since built a retail centre in this location. Such is the nature of the market and entrepreneurship, and highlights an entrepreneurial response in the face of contingency. Even with these changes and challenges, the infrastructure was delivered and the development occurred to completion. This was enabled by the effectual stakeholder commitments made to complete each respective stage of the project, and an approach to contingency (responding to unpredictable events) that reflects causation logic.

These examples show that to achieve entrepreneurial value creation, governments must be open to more permeable strategic decisions to enable this value to be created. Most traditional value capture approaches typically form partnerships at a tactical or operational level. At the tactical level, governments do the transit planning and spatial economic analysis, and calculate an expected return based on public investment. At the operational level, governments try to attract tenants after the project is completed. Although being described as an alternative funding mechanism, value capture approaches are still public sector capital mechanisms (McIntosh et al., 2014; McIntosh et al., 2015). The risk with value capture approaches is that they are still 'prediction-based', in that they forecast a future where development may occur and define a business case based on this. By not engaging private parties early, there is no guarantee the proposed development will occur – and in some instances it is even dis-incentivised as taxation and land prices in key benefit areas become higher post-transit provision.

At a tactical level, the objective of government is to engage the private sector to help pay for the infrastructure. It then seeks to 'maximise' the value it can extract from the land. This may involve selling development rights within transit precincts. London Crossrail is such an example. In this project, £4.1B of the £14.8B was contributed by the private sector. The government took the lead on planning and facilitating major contributions from businesses/private investors including Heathrow Airport (£70M) and developer Canary Wharf Holdings (£150M) who also committed to design and build the Canary Wharf Station. This process mirrors an effectual governance approach and demonstrates how partnerships can facilitate raising private contributions and commitments to providing infrastructure and public good.

Figure 7-5 demonstrates the relationship and potential benefits of forming partnerships at all planning levels. This framework combines Van de Velde's (1999) framework with Newman's (2018) value capture framework that describes different levels of value creation that result from different approaches to transport infrastructure planning and public private partnerships. It illustrates the increased

opportunities to create shared value when meaningful stakeholder engagement and meaningful discussions on available means and commitment occur at all levels of decision-making.

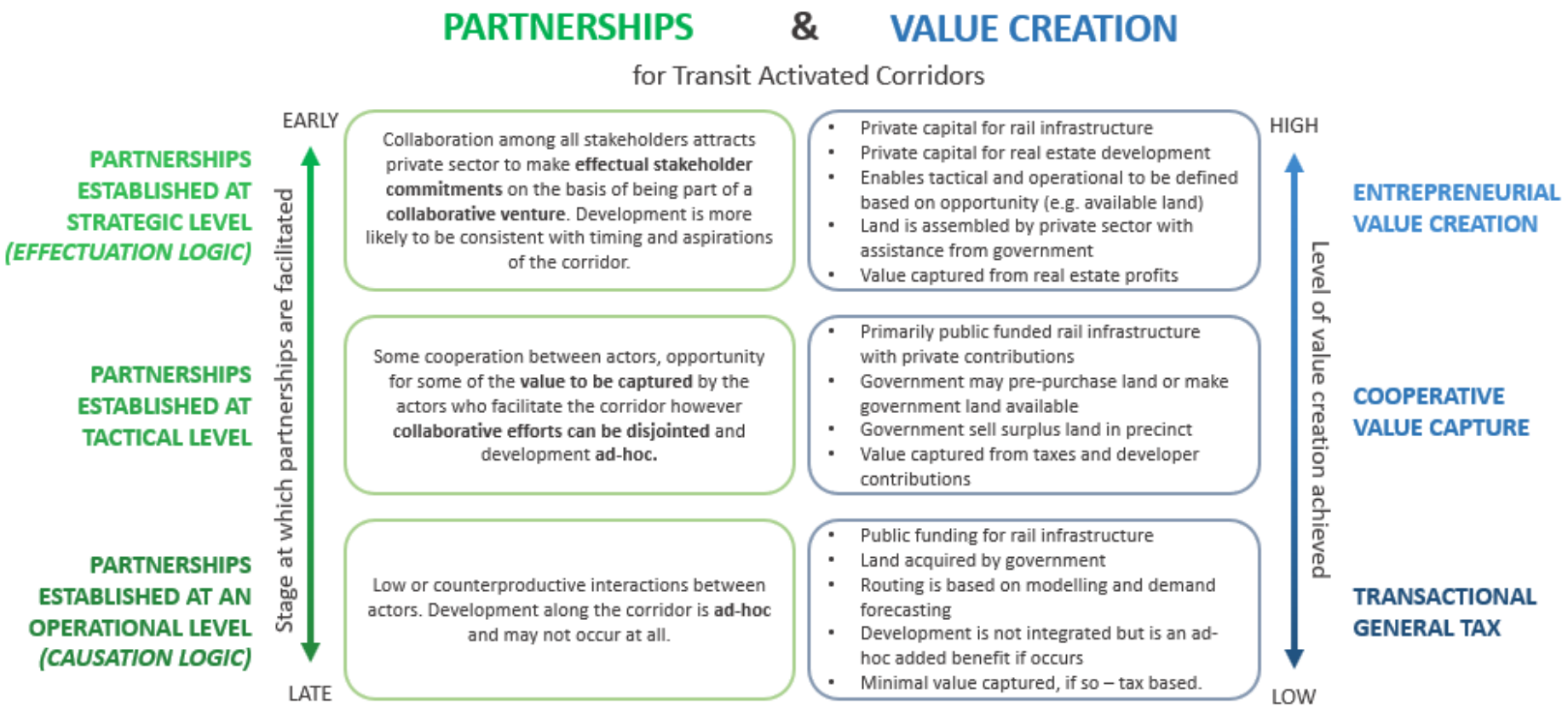


Figure 7-5: Relationship between partnerships and value creation at respective organisational levels for transit activated corridors (Adapted from Evan Jones (Newman et al., 2018); with Van de Velde (1999))

7.5 CONCLUSION AND CONTRIBUTION TO THESIS

While many traditional transit agencies undertake strategic, tactical and operational activities within the same organisation, there is a need to open up the planning process. Facilitating more permeable collaborations and inviting community and private sector partners to share in the value creation opportunities from the very beginning of the process helps to establish effectual stakeholder commitments. In the context of global infrastructure funding shortages and heightened uncertainty, this new approach can expedite the necessary reorganisation and changes in attitude that transit agencies, as is already occurring in some countries (Vuchic, 2014)..

Like the examples discussed in this chapter from the United Kingdom, India, and the United States, an effectual urban governance approach shifts the focus of transit corridor creation towards a partnerships-driven and entrepreneurial approach. The examples illustrate the viability of the approach; they are also proving effective in meeting cities' infrastructure needs. By enabling partnerships earlier in the planning process, particularly at a strategic level, there are greater opportunities to create shared value from successful Public-Private Partnerships.

To facilitate transit activated corridors through a partnership-driven effectual urban governance approach, practitioners should aim to:

- Allow for collaborative interaction to occur at a strategic level, with input from self-selecting stakeholders who are willing to make pre-commitments that align with effectual design principles that are in-place to ensure that 'public good' is achieved as a result of initiatives.
- Re-think stakeholder consultation and debate and shift it to a process that underpins the development of strategy, tactics and operations. Consultation and debate should be opened up from the beginning of the planning process and allowed to have meaningful input rather than from seeing it as an 'added task' to be initiated after the bulk of the strategic and tactical planning has occurred.
- Be open to unsolicited proposals from the private sector to deliver infrastructure. Again, the government should set reasonable boundaries on what is acceptable based on its policy platform; dismissing private proposals because there is no local precedent for private transit provision, or any other type of infrastructure provision may prematurely shut down potential benefits.

This chapter makes the following contributions to the thesis, and literature more broadly:

1. Translates the partnerships principle of effectuation theory - which has predominantly been applied in the business and entrepreneurship domain – to public infrastructure governance and particularly transit activated corridors (integrated transport and land use planning).

2. Positions the rationale for partnerships in response to Aristotle's 4th Century BC work relating to collective problem solving – Rhetoric – giving deep historical context to the distinction between 'Predict and Provide' infrastructure (in the realm of Aristotle's 'Analytics') and the new type of governance needed to break free of path dependencies.
3. Illustrates effectual urban governance and associated partnerships through the United Kingdom's City Deals. This enhances the theoretical contribution of applying an entrepreneurial-based thinking system in an infrastructure context.
4. Synthesises Van de Velde's (1999) decision levels in public transport with causation and effectuation logic. This includes elucidating distinct features of strategic, tactical and operational planning associated with each of the entrepreneurship-based logics and incorporating workshop outcomes from United Nations Centre for Regional Development (UNCRD) workshop on Transit Activated Corridors to add a practitioner's perspective to the synthesis of Van de Velde's (1999) organisational forms and Newman's value capture framework in public transport with causation and effectual urban governance.
5. Extends Van de Velde's (1999) contribution of levels of organisational forms in public transport to relate to how value is created through partnerships, by synthesising with transit infrastructure funding mechanisms (Newman, Davies-Slate and Jones, 2018), and Causation and Effectuation logic as distinct approaches to the engagement of partners at differing stages or levels of public transport planning.

CHAPTER 8

EFFECTUAL URBAN GOVERNANCE:

TAKING EFFECTUAL ACTION

8.1 CONTEXT

For the last fifty years, the 'Predict and Provide' approach has relied heavily on transport models that use the current state of the system to predict a version of the future that then informs infrastructure decision-making. This version of the future, as established in the previous chapters, is based on present assumptions – key among these being that as population and income grows, so will car use. Under this model, car use is further reinforced as the prevailing transport mode in the majority of Anglosphere cities – rather than funding and developing high quality transit systems. Some of these cities, such as Sydney (Sydney Metro) and Auckland (Auckland Light Rail), are now embarking on ambitious public transport agendas to break the dependence on automobile transport that is stymying economic productivity and quality of life.

This chapter builds on the previous chapters and details effectual action as the next step in enacting effectual urban governance processes. Effectual action is particularly important in contexts of heightened uncertainty. This approach is not based wholly on predictions of the future. Establishing strong partnerships with those who are willing to make effectual stakeholder commitments builds alliances with users who are able to commit to new socio-technical innovations or systems. This may be at full scale, or not, monetary, or not; it utilises and the resources at hand to remain within the boundary of affordable loss. This action allows for feedback to guide the evolution of the system through new stakeholder commitments, converging expectations and expanding the resources available to the socio-technical niche. The focus of this chapter is taking effectual action as the next stage within the dynamic model of effectual urban governance, as shown in the figure below.

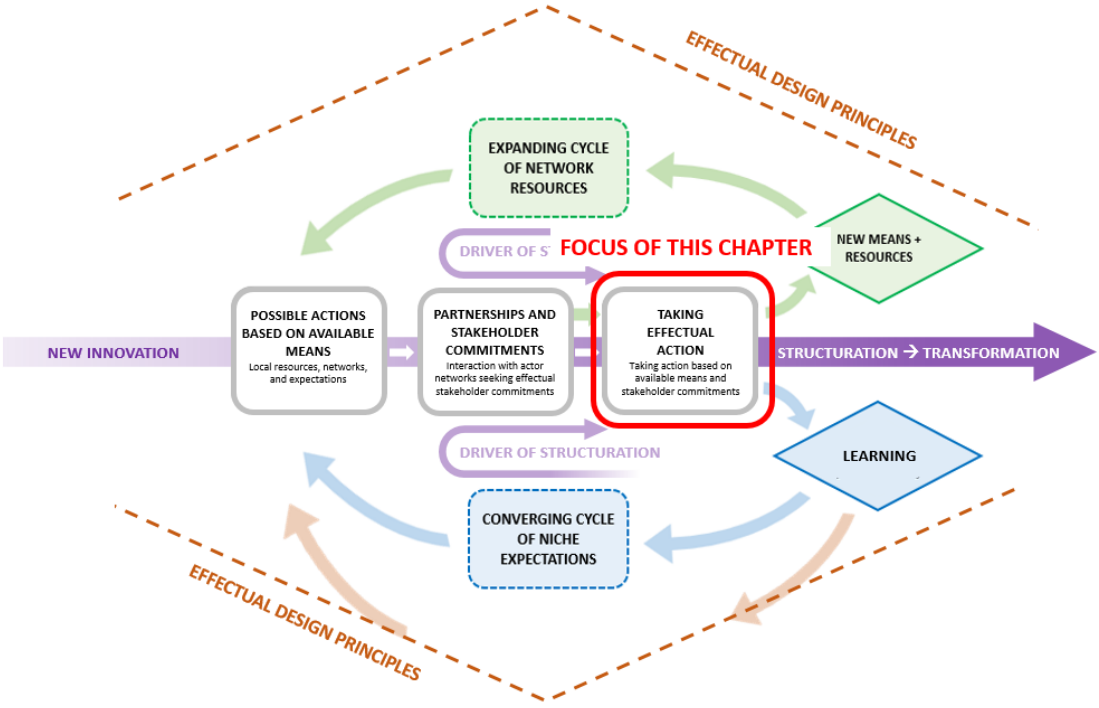


Figure 8-1: Dynamic model of effectual urban governance – highlighting effectual action as the focus of this chapter

8.2 TAKING EFFECTUAL ACTION UNDER UNCERTAINTY

Taking action is a critical element of effectual urban governance. Effectual urban governance draws on effectuation theory to respond to systems change under heightened uncertainty. As such, the focus of effectual urban governance is on taking action to co-create and structure a socio-technical niche based on available means and partnerships commitments, as established in the preceding discussion.

The modernist mentality of top-down planning and governance has waned in contemporary times. The idea of incremental implementation of urban infrastructure initiatives has grown stronger as cities seek to implement initiatives *with* (and for) the communities which they serve. Such an approach is at the core of effectual urban governance. This approach allows users to practically participate and to make initial commitments early that are within their means i.e. affordable loss and risk tolerance. It also attracts new partners and resources to the niche as the system is proven and expands. Therefore, taking effectual action is not confined to the domain of private companies seeking to experiment with and commercialise new mobility applications; governments and community can also take effectual action within their means to facilitate 'learning by doing' in the face of uncertainty.

In an entrepreneurial context, disruptive innovation requires that an innovation is aligned to market demand and addresses user needs. How does an entrepreneur know that what they have developed is the right fit? They learn this from their users, with commitments being the ultimate litmus test. The entrepreneurial process of designing disruptive innovation is often referred to as a process of taking action and learning from customers, before then taking action again to build on what is learned. By taking action entrepreneurs develop deeper understanding of local contexts and dynamics, understand market needs, understand the drivers of stakeholders, and mine for new ideas that are not immediately evident. In highly uncertain environments, over-investing based on prediction is a risky approach.

The following section provides examples of successful and unsuccessful urban projects to demonstrate the value inherent in an effectual action approach. This includes a reduced reliance on predictions of the future, which if incorrect, can lead to significant community backlash and failed projects. Successful examples such as the cycling infrastructure in Boston, public transport reform in Auckland, traffic congestion charge in Stockholm and parking management in Austin, Texas discussed below, demonstrate that taking effectual action in the face of irreducible uncertainty opens the possibility for more radical solutions to addressing urban transport challenges in contemporary society.

8.2.1 Cycling Infrastructure: Comparison of Stevenage, United Kingdom and Boston, United States

Globally, European cities located in Denmark and Netherlands provide best practice and the safest models of urban cycling. Establishing urban cycling infrastructure in Anglosphere cities is arguably more challenging given the embedded socio-technical conditions where urban transport configurations privilege motorised vehicles. In these cities, motorists, elected members and even transport

professionals are likely to underappreciate the potential benefits of taking road space away from vehicles for cycle-friendly alternatives. The examples from Stevenage in the UK and Boston in the US, provided below, demonstrate how effectual urban action can play a key role in facilitating systems change or failure in these contexts.

Cycling is a mode of travel that is highly influenced by the level of perceived user safety. One of the key contributors to how safe users feel is the level of infrastructure that is provided for cyclists. However, infrastructure is only one important factor, as Amsterdam cycling Professor Marco te Brommelstroet and colleagues (2017) state: "the narrow focus on measurable environmental variables, which dominates in the transport geography and planning literature, helps us explain an important part of what makes a fitting cycling environment, but it does not provide us with a complete picture". Brommelstroet and colleagues suggest 'Embodied Making' as a preferred process to increase cycling mode share. 'Embodied Making' aligns with an effectual urban governance approach as it is a process of developing user patterns from the ground up in a context-specific manner, allowing for the co-evolution of infrastructure with user preferences suited to a specific context (Quillien, 2017).

A pre-planned cycling network in Stevenage, United Kingdom

Stevenage is a town of 80,000 people located 29 miles north of London in the United Kingdom. It is one of the first 'New Towns' that was built near London following World War II. The town was designed and built from the ground up, allowing the town planners to integrate an extensive network of separated cycleways from the 1950s onwards. From an infrastructure perspective, these cycleways were state of the art at a time when automobile dependence was prevalent across the United Kingdom. The cycleways were physically separated from traffic and allowed cyclists to bypass intersections using grade separated underpasses as depicted in Figure 8.2.

Figure 8-2: An example of Stevenage's grade-separated cycling infrastructure that avoids interaction with traffic (Source: Carlton Reid, The Guardian)

The key element missing from Stevenage's cycleways is the cyclists. Less than 3.5% of the population in Stevenage currently cycle, compared to the predicted 40% when the masterplan was developed. Views vary on the reasons for the failure of the cycling network, with the preference for residents to drive rather than cycle being the most obvious. Stevenage's cycleways are a clear demonstration of a misalignment between community and cultural values and prediction-based planning. The cycleways network in Stevenage was based on the Dutch model which had been developed over decades in partnership with users. This approach did not occur in Stevenage. The subsequent misalignment between the infrastructure development process and the users themselves resulted in a 'failed revolution' towards cycling in Stevenage (Reid, 2017).

Taking effectual action towards cycling in Boston, United States

The city of Boston located in Massachusetts in the United States made decisive moves in 2020 to expand its cycling infrastructure. The uncertainty and need for a rapid response to the COVID-19 pandemic played a role in this. Pre-COVID-19, less than half of the residents in the Boston area drove to work; this is a higher ratio than expected of an Anglo-American city which are traditionally dominated by private vehicles (Boston Transportation Department, 2017).

Over the summer of 2020, as COVID-19 hit the city, many residents became reluctant to travel on public transport as social perceptions shifted towards a greater need for inter-personal space. This caused a significant shift towards single occupant vehicles on the roads as a result of COVID-19 and the associated public transport reluctance. It was estimated that the single occupancy vehicles would translate to 776,000 added traffic hours per day, or an extra 22-minute commute for each person on the road (Hu et al, 2020).

Taking effectual action with available means and within affordable loss, Boston town planners responded with temporary 'pop-up' bike lanes to provide residents with an alternative to driving cars. This pop-up infrastructure was comprised of traffic cones and barrels. Initially, this was a temporary measure and the lanes were planned to be removed by winter. However, the temporary infrastructure allowed users to build new travel patterns and see the value in this new system. As a result, the bike lanes are now permanent and play a big part in accelerating the city's 'Healthy Streets' initiative that aims to provide residents with greater opportunities to walk and cycle between destinations.

The permanency and expansion of the network has been supported by the community, with further calls for a greater expansion of the cycling network to replicate this success outside of the downtown area. The business community is also enthusiastic as it has provided expanded street space for outdoor dining to produce a holistic and people-centric shift towards more liveable cities. In going 'against the norm' of a car-based, highly trafficked transport network Boston's 'pop-up' bike lanes demonstrate how effectual urban action is within an affordable loss threshold and can allow users to experience a new way of doing things; resulting in the users becoming the driving force behind the expansion of such new futures.

8.2.2 Bus Network Reform: Comparison of Adelaide, Australia and Auckland, New Zealand

Bus network reform can be a challenging process with winners and losers. Winners generally gain frequency along key corridors, making for an overall increase in usefulness and ridership on the public transport system, with population increases likely in areas with access to a nearby frequent service. Some people will have a nearby bus stop removed or moved further away however, increasing their walking distance and reducing the effectiveness of the service despite the 'reform'. Adelaide (Australia) and Auckland (New Zealand) both embarked on bus network reform to achieve better public transport for the population as a whole.

Adelaide, Australia and Auckland, New Zealand are cities of similar cultural contexts, having both removed historic tram lines in the 1950s in favour of car-oriented development. Adelaide opted for an 'all at once' approach to city-wide network changes – which was unsuccessful and met with community backlash. Auckland opted for a staged approach that over a longer period of time has resulted in a transit network transformation and increased ridership.

Attempted bus network reform in Adelaide, South Australia

In 2020, the South Australian Department of Transport and Infrastructure, released details of a 'better, faster and more frequent' bus network for the city of Adelaide. The network changes were a move towards a simpler network with high-frequency priority corridors and second tier coverage services with less frequency beyond the priority corridors.

The proposed network offered a bus network with superior network characteristics. For example, the new network would increase the population close to a high frequency (15-minutes or less) weekday service from 500,000 to 700,000 – more than half of Adelaide's 1.3 million population. For most residents who did not have a 15-minute all day service nearby, there would be a nearby bus service with an interpeak weekday frequency of 30 minutes (compared to 40 minutes in Melbourne and 60-minute frequencies in Brisbane and Perth). The trade-off in simplifying the system was that some bus stops would be removed (approximately 1,000) and in many cases, users would need to walk slightly further to reach a more frequent bus.

The Department released the city-wide plan to the population for consultation. The plan presented an 'all at once', dramatic overhaul of the system. The benefits of the proposed reform were not fully articulated or clear to existing and potential users. In the absence of any form of effectual action, the full extent of the benefits were not explicit so residents who would benefit did not advocate for the changes. On the other hand, the opposing political party, community groups and residents facing a further walk to a bus stop fought hard to resist the proposed changes. This loud minority, with very legitimate concerns if considered independently of the broader population, were enough for the State's

Premier to overrule the proposed changes in preference of business as usual with leaving the new network abandoned within two weeks of being released for public consultation.

In envisaging a new bus system, Adelaide arguably attempted to change too much at once. In proposing to overhaul the city's entire public transport/bus network, it may have been more strategic to take effectual action in one area first, and then allow the feedback and user experience learnings from this to feed into subsequent changes in other zones. Similarly, there was no 'middle ground' for planners to assess and receive feedback from users to inform a more gradual and iterative change. Instead, the new network was developed by technical professionals, released to the public and then discarded within two weeks. If an effectual approach was taken, it is likely that more efficient use of resources could have been achieved by being more targeted in communications for a specific region, with lessons learned earlier in the process prior to broad city-wide planning investment.

Taking effectual action to bus network reform in Auckland, New Zealand

In 2012, the City of Auckland in New Zealand set the target of more than doubling public transport patronage from 52 million to 140 million passengers in 2022 – a world-leading ambition. Achieving such a goal would require transformative changes to increase the frequency of key routes, create more direct routes, a new fare system, and new bus stops (Auckland Transport, 2020). Rather than an 'all at once approach' that was adopted in Adelaide, this transformation occurred through ongoing effectual action over the years since 2012.

Taking an effectual action approach, collaboration with the community has been integral to shaping a better transport network and defined actions, based on commitments and local available means, and has meant allies have been gained along the way. In Auckland, public feedback led to changes in the coverage network and fed into subsequent rollout phases, the core network remained consistent with the initial design (Walker, 2018).

Each phase of the rollout has led to patronage increases and highlighted the patronage benefits of more frequent networks. According to Auckland Transport, bus patronage for the 12 months up to February 2020 was 75.3 million passenger boardings, an increase of 7% from the previous year (City Rail Link, 2020). As of February 2020, the bus network had experienced a 44% growth in ridership from approximately 52 million boardings for the year ending December 2012, a significant rise to complement an increase in rail patronage towards achieving their city's ambitious goal.

Auckland's approach reflects effectual urban governance through effectual action with available means and within affordable loss. For example, in the North-West, the short term plan (1-5 years) is to first take effectual action with a 'pop-up' busway. This is a fast and affordable option that requires the delivery of two interim bus interchanges and using the existing shoulder lanes of the motorway rather than planning and developing a purpose-built priority lane. This first stage uses available means within the bounds of affordable loss (significantly leveraging existing assets without over-committing new infrastructure spend). It also paves the way for a medium-term expansion of the bus rapid transit system,

while future proofing for a longer-term ambition (10-15 years) of potential light rail delivery (Auckland Transport, 2019).

The following two cases provide examples of effectual action for congestion charging and parking management.

8.2.3 Congestion Charging: Taking Effectual Action in Stockholm, Sweden

Congestion charging, or road user charging, is a travel demand management policy that seeks to address excess road demand through a charge to those that contribute to the congestion of public infrastructure (roads). Transport economists have long advocated for this policy as an effective means of reducing congestion while addressing air quality issues and generating investment in public transit. However, introducing any 'tax' or 'charge' to the population is a contentious issue, and so while some cities have succeeded in introducing effective congestion charging schemes, many have been reluctant to try.

In January, 2006, Stockholm, Sweden implemented a congestion charge for vehicles entering the city. Initial public support for the policy was 36%; by May 2011, public support for the congestion charge was over 70% - with people even calling for the charge amount to be increased. Despite a public referendum indicating the initial unpopularity of the policy, support for this initiative was generated through an incremental approach that was within the realm of affordable loss.

Stockholm first introduced congestion charging as a seven-month initiative (Eliasson, 2014). It was made very clear at the beginning of the initiative that this was not a permanent development, but a temporary measure. Throughout the trial, extensive monitoring evaluated the performance of the new regime and showed a decline of 21 percent in traffic, a significant increase in public transport ridership and a reduction in emissions. The streets were quieter, cleaner and safer and the population had the opportunity and time to experience these benefits. Figure 8-3 below shows the reduction in traffic during the 2016 trial period (and subsequent years once the congestion charges were made permanent).

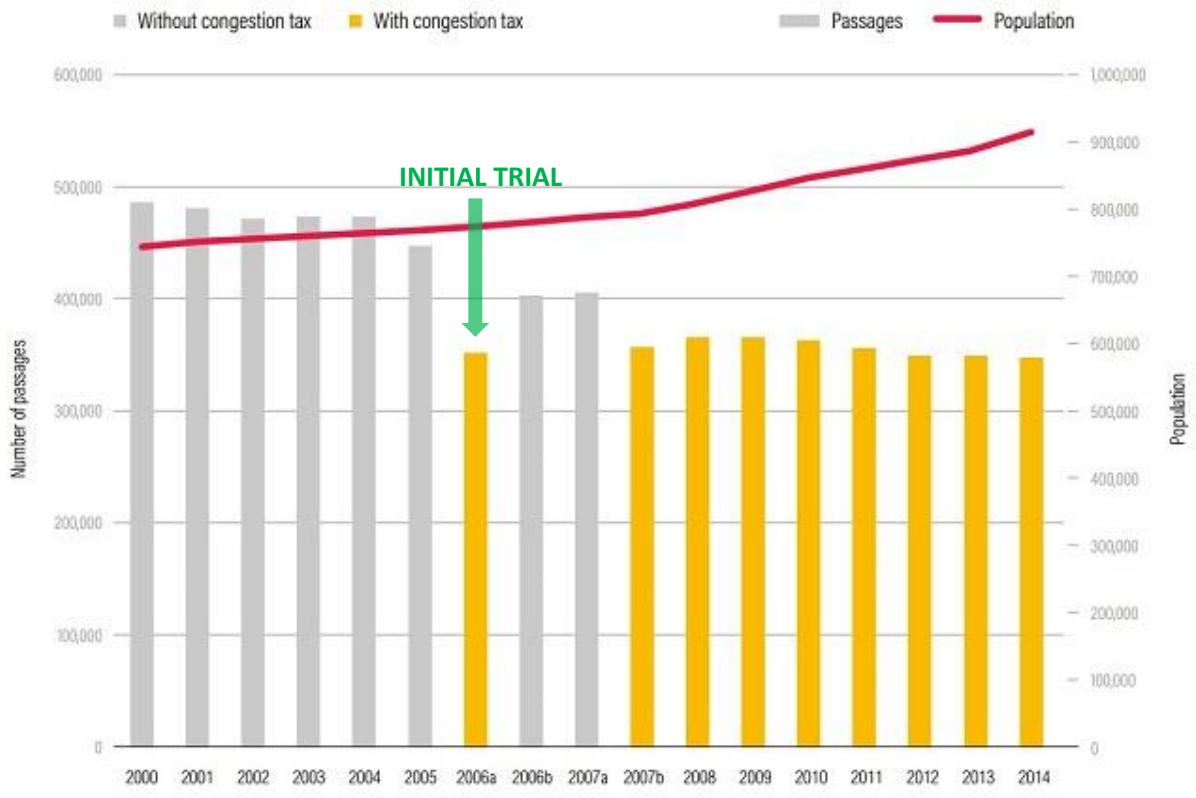


Figure 8-3: Average traffic volumes across the cordon on weekdays between 6:00-17:00, overlayed with population growth (Adapted from Elaisson, 2014)

When the trial period came to an end, an effectual urban governance approach was adopted to ensure that subsequent effectual commitments were aligned to stakeholder (community) expectations. A referendum was undertaken, with the population voting for the congestion charge to be a permanent feature of the city's transport system.

Stockholm's success with congestion charges has led to ongoing effectual action across the country. In 2016, congestion charges were increased for vehicles entering the inner city. Gothenburg, Sweden's second largest city, followed Stockholm's lead and introduced a similar program in 2013. New charges were implemented on the Essingeleden motorway, the busiest road in the country. Congestion charging is now a key component of transport policy in Sweden, particularly Stockholm. In taking an effectual urban governance approach, the public's initial negative perceptions were shifted to supporting the initiative.

8.2.4 Parking Management: Taking Effectual Action in Austin, Texas

Parking is an issue in most cities. Citizens often complain about the cost of parking in their role as motorists, however it is often overlooked that parking has a much more significant cost to the city as a whole (Shoup, 2018). Minimum parking requirements imposed on new developments drive up the cost of construction and reduces the capital value of development by limiting floor space or dwelling yield to satisfy the physical space requirements demanded by parking. The direct cost (and opportunity cost) of constructing parking spaces is factored into sale prices and rents, regardless of car ownership or

parking space utilisation. In commercial settings, these costs flow through to the total cost of providing goods and services. Aiming to address these issues in the city, Austin, Texas created a Parking Benefit District program in 2011, to help "improve the availability of on-street parking while promoting walking, cycling and transit use".

A Parking Benefit District is paid parking that allocates a fair market rate to parking spaces e.g. a market-price that allows 10-15 percent parking spaces to be free throughout the day for those with atypical travel demands, not just those who arrive at the train station first in the morning. The funds raised within a Parking Benefit District are then allocated to the local community in which they are generated.

Austin took an effectual urban governance approach to implementing the Parking Benefit District program. This was key to generating community support and conveying the benefits to users. The first stage involved taking effectual action through a time-bound introductory initiative within the bounds of affordable loss, the second phase allowed for communities to 'opt in' as self-selecting stakeholders, rather than it being forced upon them, and the third phase now involves official districts being opened under the ongoing program, expanding the cycle of socio-technical structuration.

Initially, Austin introduced 96 paid parking spaces to allow community members to experience the system. This pilot facilitated learning for both members of the community and the policy makers. Over four years, the pilot of the PBD was combined with other capital funding to improve walking, cycling and transit services within the neighbourhood. This included widening sidewalks, adding benches, planting trees, providing bicycle racks, and providing a cycleway along two of the main streets in the area. Residents could use these improvements and see the transformational benefits in their neighbourhood.

After the initial phase, the program was rolled out more broadly. This process was driven by self-selecting stakeholders. Residents across the city were given the opportunity to apply for a permanent PBD in their area. A year after the ordinance to allow resident group applications was passed, the first permanent PBD was approved, being the West University PBD, the site of the pilot project. This permanent PBD area was not enforced top-down but instead proposed by area residents after experiencing the success of the pilot project. They were also heavily engaged in the consultation process to finalise the details of the ordinance, meaning they were very satisfied by the time the opportunity to apply arose. In 2016, after four years of operating, the West University PBD began constructing several blocks of new sidewalk along a pedestrian priority street.

The city treated 'customer as partner' by agreeing to hold an annual meeting with district stakeholders to share monthly profit and loss reports. The city were transparent in sharing sidewalk construction costings and proposed that when a residential group applied for a PBD in their area, they should prepare a list of potential projects. A parallel program has since been created in Austin, called Parking Transportation Management Districts (PTMDs), which follows the same concept of revenues being

allocated to local betterment. This initiative allows applications from resident, developer and merchant groups and is an example of effectual urban governance scaling through self-selecting stakeholders and effectual action.

8.2.5 Transit Innovation: Autonomous Rail Rapid Transit in Yibin, China

The invention of the 'trackless tram' – or Autonomous Rail Rapid Transit (ART) – by the Chinese Railway Rolling Stock Company (CRRC) presents a new transit innovation that has the potential to facilitate entrepreneurial transit corridor creation. This new hybrid mode is essentially a tram with rubber wheels. Because the ART can be operated on existing roads (particularly major highways that have been reinforced for heavy commercial vehicles), it lends itself to effectual action as it can be implemented quickly to demonstrate value to users. This is the approach that has been taken in Yibin, China.

Figure 8-4: The Chinese Railway Rolling Stock Company's Autonomous Rail Rapid Transit in Yibin, China (Source: Author)

Yibin's T1 ART route is the first Trackless Tram route to enter revenue service in the world. However, prior to entering revenue service the CRRC in partnership with local authorities ran a trial route throughout 2019. At the time of the site visit that informed this study, Yibin's ART route was 9.7km long. The route was extended to 17.7km and commenced commercial operation on December 5th, 2019. There is approximately 150km of additional track planned for across the city.

At one end of the route is the 'ART Industry Park', adjacent the Belt and Road offices and nearby to the CRRC offices, production facility and depot. ART vehicles charge at this end of the line for 10 minutes each run. At the other end is the Jiudu Road Station, located in a dense urban area of Yibin.

This location is in the heart of a lively urban area, surrounded by shops, residential buildings and office spaces.

The initial stage route has 9 stations, and traverses urban areas varying from outer highways with adjacent industrial complexes, across the Chongjiang Bridge, and into the urban centre which is mixed use and high density. The ART's run at a frequency of every 15 minutes between 7:30am and 8:00pm. They have 6 of 16 vehicles operational currently and in peak hours increase the frequency to every 10 minutes.

The ART overcomes shortcomings of both trams and buses. Trams are costly to implement. Buses have generally underperformed in their ability to facilitate land development around their corridors. However, with the support of high-quality tram-like stations, ride quality comparable to light rail, and the ability to quickly deploy along corridors – the trackless tram has the potential to facilitate a new entrepreneurial approach to transit activated corridors. Under this approach, as is the case in Yibin, a pilot phase can be introduced to familiarise users with the technology. Over time, supporting infrastructure (larger stations, lane priority, road strengthening) can be implemented to increase the structuration of the system over time. A detailed case study of Yibin's trackless tram system can be found in Appendix B.

Traditional light rail systems are delivered under a causal logic. They are expensive and funded by governments, who undertake detailed planning and seek to recapture value through land value capture mechanisms. There is limited opportunity for effectual action. The ART technology has shifted this paradigm, and make lower-cost, nimble implementation of high-quality transit corridor systems possible.

8.3 EFFECTUAL ACTION FOR TRANSFORMATION

Taking effectual action forms a key element of effectual urban governance. By taking effectual action based on affordable loss, those driving the implementation and structuration of a niche can identify adjustments to maximise demand and uptake and to guide subsequent stakeholder commitments to expand the resources available to the niche. The processes of effectual urban governance leads with what is available, establish partnerships and attracts self-selecting stakeholder commitments to co-create and deliver a new project, and ultimately a new future. An effectual urban governance approach is distinct from an entrepreneurial new venture creation process however, as public funds must deliver public benefit, as detailed in Chapter 4 and Chapter 5. Effectual urban governance facilitates systems change under conditions of high uncertainty; it also reduces risks while simultaneously delivering value for stakeholders.

Examples above show the vulnerabilities of the Predict and Provide approach which have been disrupted since the COVID-19 pandemic. There is a discontinuity in the path-dependent evolutionary nature of our cities (Raskin and Swart, 2020) with even Vision and Validate approaches, as discussed

in Chapter 4, relying on prediction to validate proposed initiatives against scenarios of an uncertain future. In times of uncertainty, even visionary endeavours can be unreliable, given there is some element of prediction involved in visioning for the future, validating proposals against predicted scenarios, and then investing based on this. That future is even more uncertain now.

8.3.1 Moving Beyond Prediction-Based Models

This research presents and demonstrates how effectual urban governance can enable transport infrastructure planning to move beyond prediction-based approaches. This is not to suggest that prediction should be completely avoided in every situation moving forward - but in situations of high uncertainty, prediction models are unreliable.

Figure 8-5 below compares prediction and control models, introduced in Chapter 2, with a Vision and Validate approach. The matrix also includes a new approach to transport planning suited to the transformative domain, based on effectual action through effectual urban governance. This effectual urban governance approach is not based on prediction of an uncertain future – but instead on taking effectual action and testing, learning and iterating for transformation towards a co-created future. The 'Test and Transform' approach is proposed in this thesis as a viable alternative to the current dominant Predict and Provide approach. The Test and Transform approach brings forward the interaction with self-selecting stakeholders. It brings forward a focus on creating integrated benefits (in the case of transport this may be land use development or job creation). Based on the commitments from stakeholders, it then initiates effectual action. This process is ongoing and iterative and the increased structuration of new innovations is achieved by expanding network resources and more strongly aligned expectations over time.

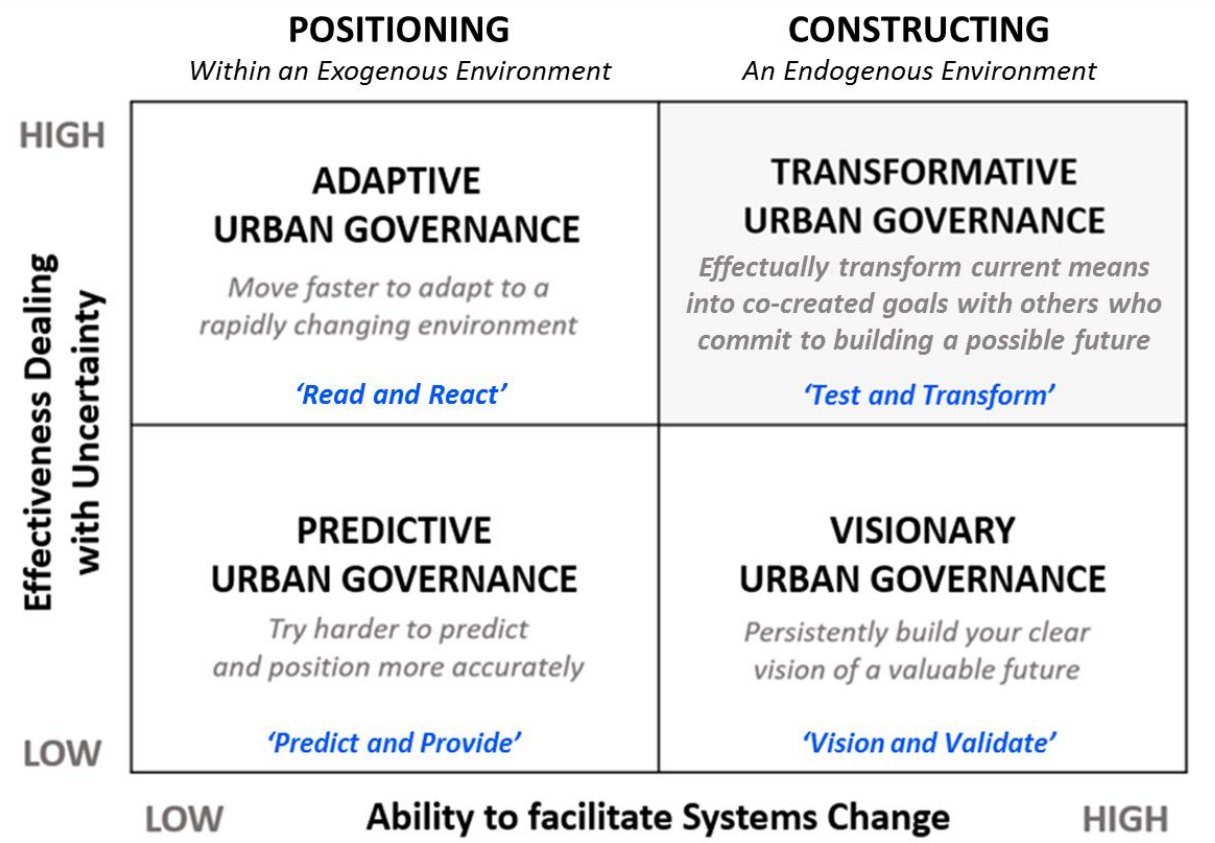


Figure 8-5: Approaches to infrastructure governance displayed on matrix of prediction and control

Test and Transform is achieved through leveraging available means, partnership commitments and effectual action. Figure 8-6 below compares the Predict and Provide and Vision and Validate approaches to transport planning with a Test and Transform approach. The Test and Transform approach is distinct from 'experimentation' as it is based on commitments and without prediction.

The Predict and Provide flowcharts in Figure 8-6 below are adapted from Professor Peter Jones' (2016) pivotal identification that our ongoing predictions of future transport scenarios, based on traffic flows of the past, are leading to more of the same problems, i.e. wider congested roads. Jones' distinction of the Vision and Validate approach in comparison to this is powerful and it is beginning to be used around the world as a means of 'shaping the future' rather than just responding to our predictions of it. This thesis acknowledges the ongoing importance of Vision and Validate and its suitability to its respective context.

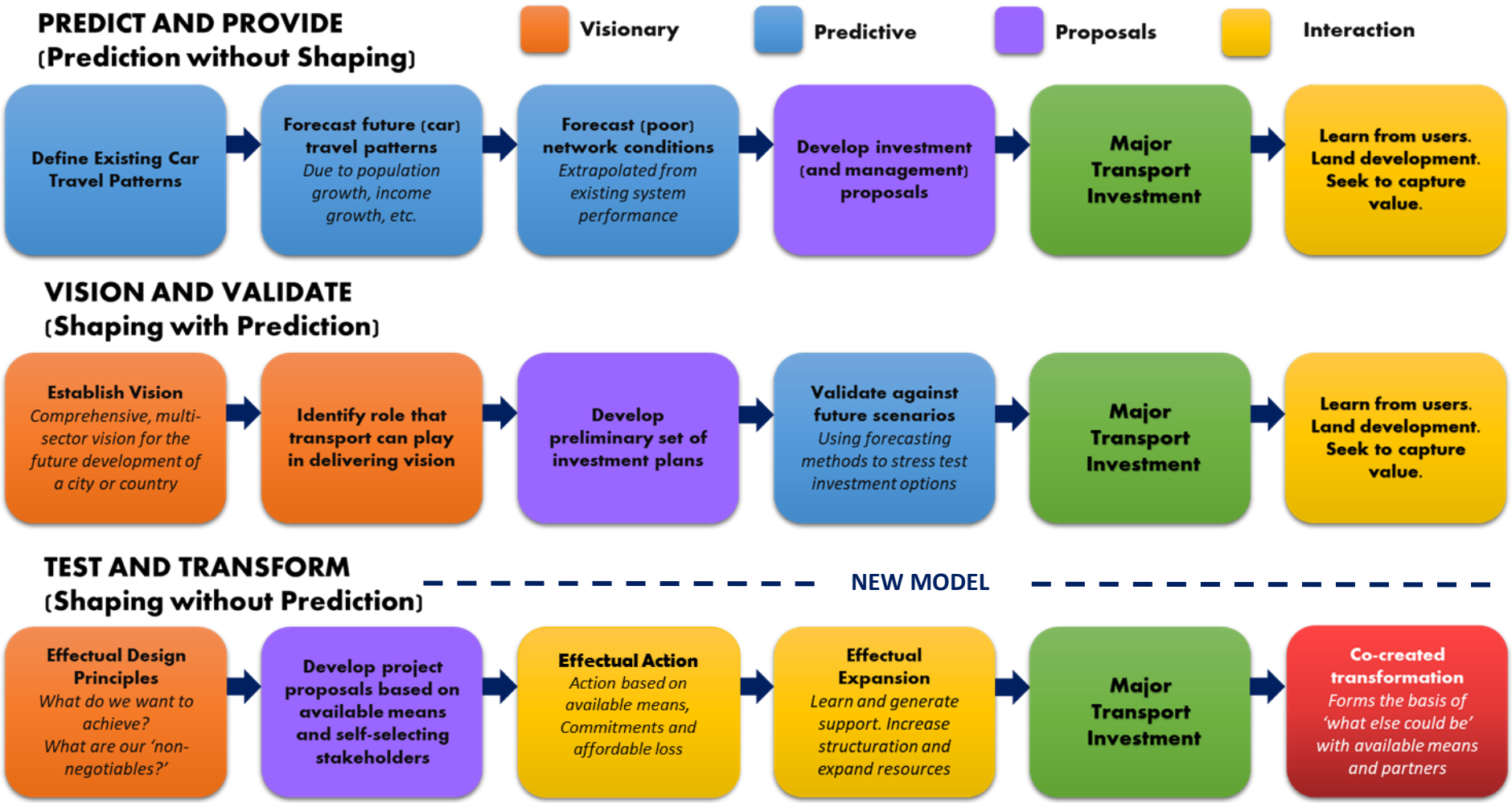


Figure 8-6: Comparison of Predict and Provide, Vision and Validate (Peter Jones at UCL, 2016) and Test and Transform

The key distinctions between the processes shown in Figure 8-6 are:

- ‘Prediction’ is not the basis of the Test and Transform approach. While this is the centrepiece of a Predict and Provide approach, and is incorporated in a Vision and Validate approach, the effectual approach to infrastructure embodied through Test and Transform instead opts for co-creation with partners.
- ‘Proposals’ are developed earlier in the Vision and Validate process, and earlier again the Test and Transform process. The steps that are reduced in the process are those related to prediction and analysis. This still occurs in both cases, however as a key step in the decision-making process it is replaced by other important factors for both V&V and T&T.
- ‘Interaction’ with key stakeholders external to the planning and delivery parties happens much earlier in the Test and Transform process than it does in the other processes. Partners are involved much earlier in the process. It happens before investment is made. For example, Test and Transform projects develop proposals based on user preferences, available land opportunities, rather than waiting for this to occur as a ‘by-product’ of the system post-investment.
- Taking effectuation action means starting smaller and earlier. When it is possible to take action, effectual urban governance suggests strategically managing commitments and expectations to begin within the bounds of affordable loss (it does not need to be the full-scope solution). Not only does the world start to change around the project, but learning is stimulated and gained information reduces uncertainty.
- By the time the ‘Major Transport Investment’ is made, it is being invested in a socio-technical configuration that has already gained momentum. Often the users of this initiative are demanding that it be expanded (rather than opposing it). Often the resources come from the partners that were engaged early in the process. It is a different dynamic to the Predict and Provide or Vision and Validate approaches.

This can be further examined at transit corridor scale in Appendix B, with an in-depth case study of the world’s first commercial service Autonomous Rail Rapid Transit route in Yibin, China, leveraging new technology to take effectual action in creating transit activated corridors at city scale. This case study is based on my time in China visiting and studying this new emerging transit system as part of this research project.

8.4 CONCLUSION AND CONTRIBUTION TO THESIS

This chapter has detailed the process of effectual action and provided examples of the process being implemented, both successes and failures. Taking effectual action is an important element to enable socio-technical systems change towards sustainability in the face of uncertainty, and has been demonstrated with much success in the urban examples provided in this chapter, further supported by Appendix B.

This chapter has also proposed 'Test and Transform' to enhance the transformative urban governance approach, emerging in the domain of 'Transformation' established by Wiltbank et al. (2006). Test and Transform is not proposed as a new governance model to replace all other strategic approaches. Instead, it is intended to complement existing approaches, particularly Vision and Validate which is also suited to facilitating systems change in conditions with less uncertainty. In conditions of heightened uncertainty, there is merit in leading with effectual action to gain support from users and iterate the structuration of transformative innovation.

Taking effectual action to advance transit activated corridors is facilitated by:

- Seeking low-cost 'starting points' for urban initiatives. The initial stages of a project may not reflect the final product, however in conditions of heightened uncertainty, learning about the socio-technical system likely occurs through an interactive process of structuration. This guides the development of the innovation to ensure that user-fit is optimised for disruptive uptake and final delivery. Urban practitioners may ask themselves what entrepreneurs ask themselves, 'What does the Minimum Viable Product (MVP) look like?'
- Working closely with stakeholders during the effectual action phase, particularly users of the system. Learning about the innovation from a 'product-fit' perspective is important, as is user learning that creates demand for a permanent solution. This is evidenced in practical examples and is another benefit of taking this approach.
- Leveraging new technologies to overcome traditional barriers to action. Such technologies may be capable of leveraging available infrastructure without additional expenditure, performing functions at lower costs, and in doing so, enable projects to get started.

Taking a test and transform approach to implement effectual action to advance transit activated corridors is facilitated by following the process outlined in the model of effectual urban governance informed by effectuation logic and detailed in Part 2 of this thesis. Establishing and seeking agreement on effectual design principles, leveraging available means, establishing partnerships to underpin effectual action that then guides the development of the niche.

This chapter makes the following contributions to the thesis, and literature more broadly:

1. Articulates effectual action in an urban context, referencing successful and unsuccessful urban transformation efforts across urban cycling infrastructure provision; bus network reform; parking management; and congestion charging.
2. Is supported by a detailed case study in Appendix B of the world's first Autonomous Rail Rapid Transit/Trackless Tram system to enter revenue service, informed by site visits and research in Hunan, ZhuZhou Province and Yibin, Sichuan Province China.
3. Presents 'Test and Transform' as a transformative urban governance approach particularly applicable for systems change under conditions of heightened uncertainty. Test and Transform, based on novel Urban Governance Framework extended from Wiltbank et al (2006) and Contributions made by Jones (2016), aims to complement Vision and Validate and other urban governance approaches.

CHAPTER 9

CONCLUSIONS AND FURTHER WORK

9.1 CONCLUSIONS

The overarching objective of this research was to answer the following research question:

'How can urban governance facilitate systems change for sustainable development under conditions of heightened uncertainty?'

To respond to this research question, the research was divided into three sub-research questions. The conclusions that respond to each of these sub-research questions are:

Research Sub-Question 1: Are current mainstream models of urban governance suitable for responding to the imperative for systems change under conditions of heightened uncertainty?

This thesis has shown that current mainstream models of urban governance are not suitable for responding to the imperative for systems change under uncertainty. The thesis suggests that there are two dimensions that demonstrate why this is so. They are the dimensions of (1) Effectiveness Dealing with Uncertainty; and (2) Ability to Facilitate Systems Change. It is evident that the majority of mainstream urban governance models that have been prominent throughout the 20th and 21st Century rely on a high level of prediction (i.e. Predict and Provide approaches), or are less reliant on prediction, however, do not have the ability to facilitate systems change (Adaptive approaches). This thesis has developed a framework for conceiving urban governance typologies along these dimensions, illustrated in Figure 9-1. This Figure presents a set of urban governance typologies based on different levels of dealing with uncertainty matched with different levels of ability to break out of path dependency and facilitate systems change. There are four types of governance that emerge. As outlined in the thesis, Visionary Urban Governance approaches are emerging as capable of breaking free of unsustainable path-dependencies (eg. Vision and Validate – Jones, 2016). The thesis suggests that to respond to heightened levels of uncertainty (less reliance on prediction and forecasting) while facilitating systems change, Transformative Urban Governance approaches are required, which are lacking in both literature and practice.

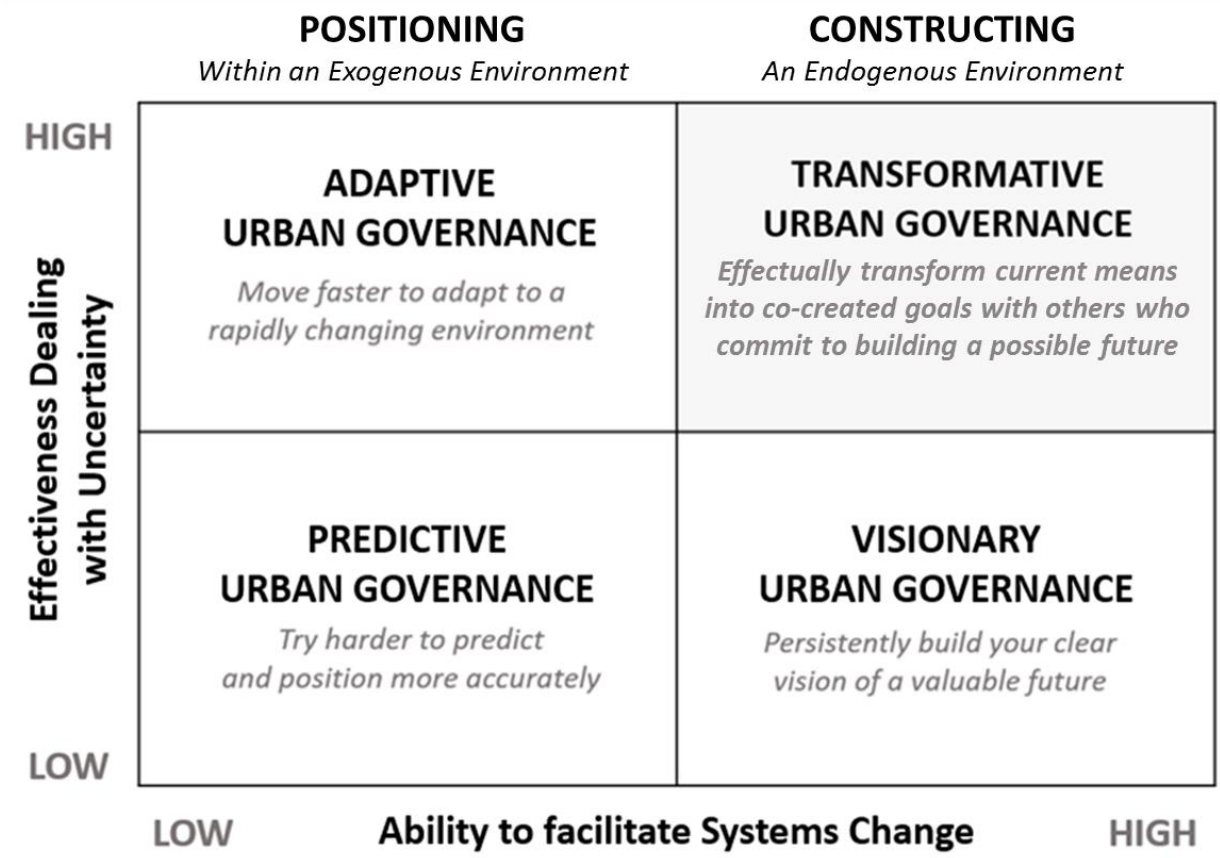


Figure 9-1: Urban Governance Framework of Uncertainty and Systems Change

Research sub-question 2: What role has entrepreneurial agency played in urban systems change throughout history?

The thesis outlined how entrepreneurship has played a central role in historical industrial transformation. In the case of four transformative energy technologies studied (Steam Engine; Railways; Electricity; and Automobile), entrepreneurial agency was key to converting 'inventions' to 'innovations' – in that a technology became a commercial reality causing systems change. In essence, entrepreneurs are actors applying agency to facilitate systems change under conditions of heightened uncertainty. Many of the approaches taken throughout history are not inherently 'entrepreneurial', but have potential to be applied in other domains of governance and civil society. However, overwhelmingly the literature on entrepreneurship is focused on individuals starting businesses for their own financial gain, rather than multi-sector actors seeking to facilitate systems change. The small literature on entrepreneurship's role in systems change is used to show how important it is in the transformations needed for solving current issues, especially if sustainable solutions are to reach a 'mainstream' level of structuration.

Research sub-question 3: Is the entrepreneurial decision-making logic effectuation a useful construct for transformative urban governance approaches applied to civil infrastructure?

Effectuation, the entrepreneurial decision-making logic developed by Saras Sarasvathy through the study of expert entrepreneurs has been demonstrated to have applicability far beyond the entrepreneurship domain. At its core it is composed of a set of principles that distinguish it from Causation appraoches – with Causation being overly prominent in urban governance today. Through the in-depth study of one particular civil infrastructure case study – the formation and structuration of the Willunga Basin Water Company in South Australia – it is evident that the principles and processes of effectuation have been applied for transformative projects, however there has been no linking of this theory to governance contexts prior to this thesis. While still considered an 'entrepreneurial venture' due to the formation of a commercial entity to deliver public infrastructure, the WBWC exemplifies how effectuation logic can be applied at a systems level to deliver civil infrastructure that has underpinned decades of economic prosperity for an entire region. Thus effectuation is a fundamental concept in the thesis approach to answering the research questions.

Research sub-question 4: How can effectuation inform governance for accelerating systems change for sustainable development under conditions of heightened uncertainty?

The development of effectual urban governance in this thesis outlines how the principles and process of effectuation can be applied to deliver transformative governance. The model is applied to urban transport – or 'Transit Activated Corridors' as the concept is termed in the thesis. The dynamic process of effectual urban governance developed in this thesis is shown below in Figure 9-2.

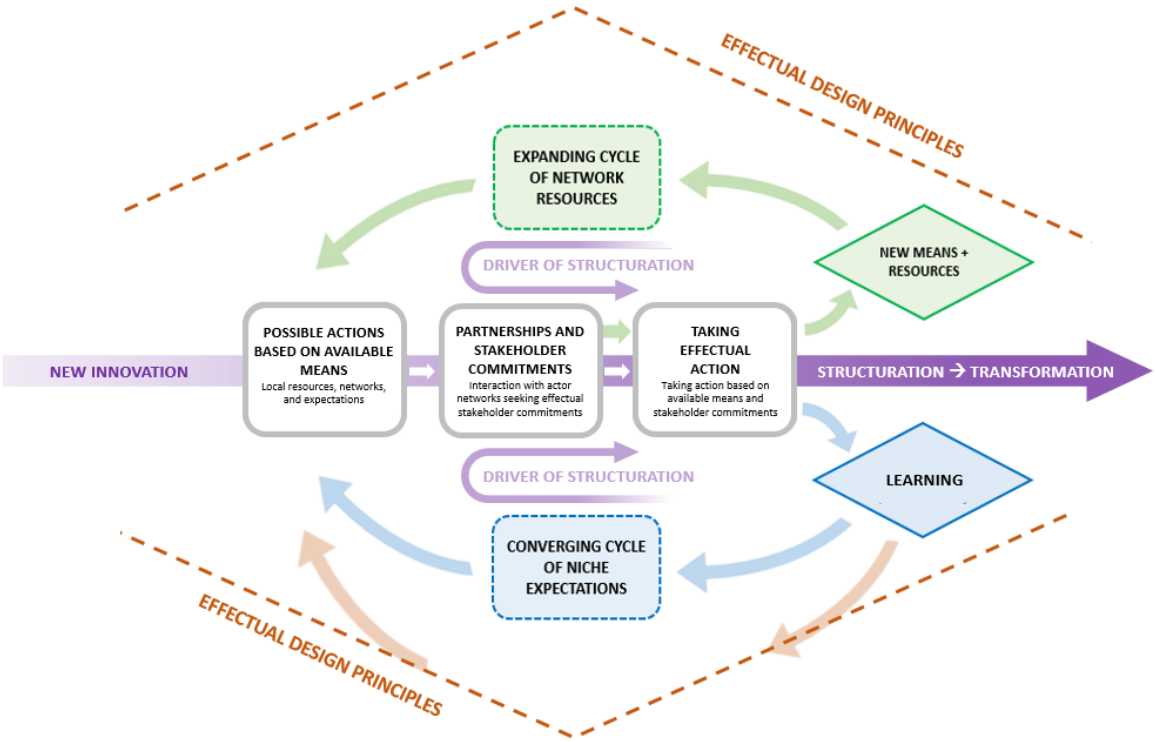


Figure 9-2: Dynamic process of effectual urban governance

Four core elements of effectual urban governance were developed and elucidated in the thesis in order to provide guidance on a shift in planning and governance of urban infrastructure projects:

1. Establish effectual design principles: The articulation of guiding design principles to ensure that initiatives undertaken through effectual urban governance align with the necessary dimensions of systems change – i.e. respond to sustainable development objectives. These principles are intended to be broad and not overly prescriptive to avoid inhibiting collaborative action, but to set boundary limits on co-creation to ensure social good is achieved.

2. Begin with available means for value creation: Taking available means and resources as a basis for action rather than pre-determined outcomes. Not only does this leverage reduce uncertainty and leverage slack resources but also provides the opportunity for greater value creation.

3. Establish early partnerships and seek effectual stakeholder commitments: Create partnerships from the beginning of the effectual process and seek effectual stakeholder commitments that destroy uncertainty by creating certainty around action and demand.

4. Take effectual action: It is important to 'get going' and take action with partners based on available means. The first stage may not be the final product, but taking action in some form facilitates socio-technical establishment and learning which forms the basis for adjusting the niche and iteratively expanding.

Prediction approaches have been termed ‘Predict and Provide; and Visionary approaches have been termed ‘Vision and Validate’. In the same way, effectual urban governance that emerges from the Transformative Governance domain are termed ‘Test and Transform’ and are suited to systems change under uncertainty. The process develops actions based on available means and effectual stakeholder commitments, and iteratively adjusts user-fit to enable disruptive transformation that is driven by demand. The drivers of this process are expanding network resources and converging expectations over time as effectual action is taken. Test and Transform does not seek to replace other methods such as Vision and Validate, but rather provides an alternate complementary approach that is especially useful under conditions of heightened uncertainty.

These approaches as outlined above have been discussed and applied to a range of examples and case studies throughout the thesis to demonstrate the elements of this approach in practice. These include the Pearl District Streetcar in Portland; the Portland MAX light rail; South Lake Union Streetcar, Seattle; Novamont’s biorefinery in Sardinia, Italy; the energy transformation of El Hierro in the Canary Islands; Bus network reform in Auckland, New Zealand; Cycling infrastructure in Boston, USA; Congestion charging in Stockholm, Sweden; Parking benefit district in Austin, Texas; and Autonomous Rail Rapid Transport in Yibin, Sichuan Province, China.

The approach appears to lend itself to a range of potential uses as set out in the following section. These are presented as a personal reflection on the thesis.

9.2 IMPLICATIONS OF THE RESEARCH

It is anticipated that the findings of the research will have implications for the global and local community, and for cities everywhere. I suggest that the following could happen if effectual urban governance was seriously adopted:

1. Traditional thinking about the ‘black box’ of entrepreneurship, and the view that entrepreneurs are high-risk taking individuals within society would become outdated. Entrepreneurs apply agency to drive systems change under conditions of heightened uncertainty and this element of their actions will become more and more the approach taken by government public servants, corporate managers and leaders in civil society. By translating entrepreneurial approaches to a governance context and providing a range of case studies and illustrative examples, this thesis will hopefully help change thinking about what it means to ‘behave entrepreneurially’ and who is capable of such behaviour. Indeed, I hope this thesis compels governments, industry and civil society to consider themselves ‘entrepreneurial’ when it comes to facilitating systems innovation – as it is unquestionable that the very principles that expert entrepreneurs follow for success can be observed, and ultimately applied, in urban projects.

2. Conversations about new approaches to complex problems will not be solely based on causation logic. Conventional strategy and planning process surrounding urban infrastructure (and most governance-related decision-making) is based on embedded institutions that reflect 'causation' logic rather than effectuation. In the entrepreneurial domain, Sarasvathy herself does not claim that effectuation should be used by all actors all of the time – nor do I claim effectuation is the only urban governance approach. What this research does demonstrate, however, is that current societal institutions that consider causation-based approaches (in Aristotle's domain of Analytics) as the 'only way' are not well-founded, and perhaps even are causing society a disservice. This is a complex question that challenges every aspect of how modern humans make decisions, how society and political systems function, and the foundations on which modern systems of education and professional practice are established. If more than anything, by illuminating the effectual way as relevant to not just entrepreneurship but governance, I hope this research helps to move this complex conversation along much further and illuminate the potential of new thinking about how we solve our shared, complex, urban challenges.

3. Public private partnerships in infrastructure will become commonplace. Following from (2) above, in response to global calls in both practice and literature for innovative methods of undertaking public-private partnerships for urban transit infrastructure, this thesis has challenged conventional thinking about the very process by which the majority of infrastructure projects are developed. It is demonstrated through theory and practical examples that the process of government-driven planning, public funding, and attempted value capture has shortcomings in producing optimal results. Again, this thesis does not provide a 'one size fits all' solution for success, however, the thesis shows that in governance contexts a one size fits all solution based entirely on government is not an optimal solution. What is provided here are clear principles to inform governance decision making and planning processes, so that regardless of the political or economic context, urban stakeholders in government, private industry and the community are able to better work together to achieve win-win-wins. In the emerging future under an effectuation governance approach, governments will be more flexible in order to gain the benefits of private sector investment and innovation capacity, the private sector will ensure public good outcomes are achieved through adhering to guiding effectual design principles that establish ecological and social limits for operating, and the community will be more supportive of change as they see benefits of good quality infrastructure with broad benefits.

4. More and more case studies will emerge like Yibin (Appendix B). The research has provided insights into new transformative socio-technical systems with significant potential to accelerate systems change towards sustainability. In particular, the thesis did an in-depth case study on

the world's first commercially operating Autonomous Rail Rapid Transit (ART) system emerging from Yibin, China. Time spent with the Chinese Railway Rolling Stock Company (CRRC) learning about this new technology has informed the case study, which demonstrates the promising transformative potential of this technology in cities around the world. By combining the best features of a bus and a tram, the CRRC have ushered in a new period of transit technology innovation. I expect that transit rolling stock manufacturers around the world will be spurred to dissolve the boundaries of what is considered a 'bus' or a 'tram' and will help transform our cities with these innovative and creative technologies. This type of innovation is transformative and has applicability beyond trackless trams but is expected to occur across the entire transport sector over the coming decades. Often, such efforts can remain focused solely on the technology, however, this research intentionally kept a focus on the overarching and integrated system to communicate the technology's transformative potential. I would expect hundreds of new case studies to emerge showing such potential as effectual urban governance is adopted.

9.3 FUTURE RESEARCH QUESTIONS

As with all research projects, at the conclusion of this thesis I feel that there may be more questions arising than answers. The concepts developed in this research span multiple disciplines and create a foundation for a broad array of subsequent research. The following list outlines some of the areas that warrant further investigation:

What are the challenges and roadblocks of shifting to an effectual urban governance logic for infrastructure decision-making and how may they be overcome?

This thesis forms a theoretical basis for effectual urban governance and demonstrates its applicability across a number of urban infrastructure examples. The approach does represent an approach that differs from the conventional way in which many government agencies currently operate. One limitation of this work is the extent to which the full suite of challenges that may arise in applying the effectual urban governance model in practice has been explored. Therefore, it is recommended that further study be undertaken, in a specific context such as Australia, relating to the challenges and roadblocks that may exist for a government agency who seeks to apply effectual urban governance in a setting with deeply embedded causation-based institutions. This thesis does remain broad with the principles being the major focus in order to allow flexibility within them, but further analysis culminating in specific guidance for practitioners based on the application of effectual urban governance from this thesis would be of value.

How may effectual urban governance contribute to infrastructure development in the Energy, Water, and Waste sectors?

One limitation of this thesis is that while touching on multiple infrastructure sectors (e.g. water, transport), the infrastructure sector explored in the most detail in Part 2 of the thesis as the primary sector of focus was the transport sector. Effectual urban governance, of course, is not confined to one sector or even to infrastructure itself. It is recommended that further research be undertaken to investigate this new governance logic in other infrastructure sectors, in order to move toward a unified and coherent governance model that is applicable in any contexts. Having said this, the intention of this thesis is to present this model as applicable to all urban infrastructure, however deep research in other sectors may illuminate sector-specific learnings that enhance the model overall.

In the case of integrated transit corridor planning, or Transit Activated Corridors, what is the new guidebook following effectual urban governance logic?

This research has focused on demonstrating the logics of causation and effectuation and validating the importance of considering an alternate way of infrastructure development in order to address ecological imperatives. While the research does provide practical recommendations, the thesis is limited in the degree it fully elucidates a practical, step-by-step guidebook for practitioners. For the benefit of practitioners it is recommended that further research is undertaken to expand and further articulate the specific changes to infrastructure planning processes under effectual urban governance. This has the opportunity for a type of 'guidebook' that has clear steps for practitioners to follow but not to the detail often used in causative thinking, but leaving eroom for creative solutions and options that may not be considered yet by the gatekeepers of public outcomes.

How may effectual urban governance be validated or iterated through empirical research studies following this process?

This thesis presents a new way of thinking about urban governance that follows a logic distinctly opposed to the conventional way of planning and delivering infrastructure. Therefore, there are many questions to be answered. One limitation of this work is that all of the case studies were analysed post factum. It is recommended that in order to further validate effectual urban governance, or even (in an effectual way) iterate it or adjust it, that it is used as a theoretical basis for real-time empirical research projects and urban living labs. Combining research and practice allows for the learnings in practice to be shared back into the literature and as an early-stage model, effectual urban governance would benefit from these learnings.

What role do the principles of affordable loss and leveraging contingencies play in effectual urban governance, and can they be further elucidated in an urban context?

This thesis has focused on the principles of effectuation most relevant to urban governance. There are other concepts of effectuation that have not been explored in depth in this research, that also offer value for urban decision-makers. One limitation of this thesis is the limited elucidation of the role of affordable loss and contingency - both warrant further study to articulate their role in infrastructure planning. It was the view of this research that these principles are 'embedded throughout' rather than acting as standalone principles and stages in a dynamic process, however they would benefit from further articulation nonetheless.

How does the effectual urban governance model apply to developing economies?

One limitation of this work is that the thesis draws mostly on case studies from developed countries. However, growth occurring in developing countries, particularly throughout Asia, Africa and South America create the impetus to study how the effectual urban governance approach applies in these contexts. This is especially important due to the exacerbated infrastructure finance gaps in these economies, the pace of growth, and the localised benefits associated with implementing solutions aligned to the Sustainable Development Goals.

REFERENCES

Abbott, J. 2005. Understanding and managing the unknown. The nature of uncertainty in Planning. Journal of Planning Education and Research, 24, pp. 237–251.

Ackoff, R., Addison, H., & Carey, A. 2010. Systems thinking for curious managers. Triarchy Press, Portland

Adger, W.N., Brown, K., Nelson, D.R., Berkes, F., Eakin, H., Folke, C., Galvin, K., Gunderson, L., Goulden, M. & O'Brien, K. 2011. Resilience implications of policy responses to climate change. Wiley Interdisciplinary Reviews: Climate Change, 2 (2011), pp. 757-766.

Ağca, V., Topal, Y., & Kaya, H. 2012. Linking intrapreneurship activities to multidimensional firm performance in Turkish manufacturing firms: An empirical study. International Entrepreneurship and Management Journal. Vol 8(1), pp. 15–33.

Alawadhi, S., Aldama-Nalda, A., Chourabi, H., Gil-Garcia, J. R., Leung, S., Mellouli, S., Nam, T., Pardo, T. A., Scholl H. J & Walker, S. 2012. Building Understanding of Smart City Initiatives. Lecture Notes in Computer Science 7443 (2012), pp.40–53.

Albino, V., Berardi, U. & Dangelico, R. M. 2015. Smart Cities: Definitions, Dimensions, Performance, and Initiatives. Journal of Urban Technology. Vol. 22(1), pp. 3-21.

Albrechts, L. 2010. More of the same is not enough! How could strategic spatial planning be instrumental in dealing with the challenges ahead? Environment and Planning B: Planning & Design, 37, pp. 1115–1127.

Albrechts, L.; Balducci, A. 2013. Practicing Strategic Planning: In Search of Critical Features to Explain the Strategic Character of Plans. disP – The Planning Review, 49, pp. 16–27.

Allen R.C. 2012. Backward into the future: the shift to coal and implications for the next energy transition. Energy Policy, 50, 17-23.

Allen, C., Metternicht, G., Wiedmann, T. & Pedercini, M. 2019. Greater gains for Australia by tackling all SDGs but the last steps will be the most challenging. Nature Sustainability, 2, 1041-1050 (2019).

American Association of State Highway Officials. 1957. A policy on arterial highways in urban areas. American Association of State Highway Officials, Washington.

Amin, A. & Thrift, N. 1995. Globalisation and institutional thickness. In Healey, P. Cameron, S. Davaoudi, S. Graham, C. , & Madani-Pour, A. (Eds.), Managing cities: The New Urban context , Chichester, NY, pp. 91–108.

Amolo, J., and Migiro, O. 2014. Entrepreneurship Complexity: Salient features of entrepreneurship. African Journal of Business Management. Vol. 8(19). Page 832-841. October 2014.

Anderson, E. S. 2009. Schumpeter's evolutionary economics: A theoretical, historical and statistical analysis of the history of capitalism. Anthem Press; 1 edition. ISBN-10: 1843313340.

Andrew, J. H. 1995. The Costs of Eighteenth Century Steam Engines, Transactions of the Newcomen Society, 66 (1994-1995), pp. 77-91, p.83. Cited in Baggott, S. 2009. Matthew Boulton: Enterprising industrialist of the enlightenment.

Andrew, J. H. 2009. Boulton, Watt and Wilkinson: The birth of the improved steam engine. Chapter 6 in Baggot, S. 2009. Matthew Boulton: Enterprising industrialist of the enlightenment.

Antoncic, B. & Prodan, I. 2008. Alliances, corporate technological entrepreneurship and firm performance: Testing a model on manufacturing firms. Technovation, 28(5), 257-265.

Aristotle, 4th Century BC. Rhetoric.

Auckland Transport. 2019. North west rapid transit corridor indicative business case. Board meeting notes 03 December 2019. Accessed on 28/09/2020 at https://at.govt.nz/media/1981679/item-92-closed-dec-nwrtc-indicative-business-case-incl-attachments.pdf

Auckland Transport. 2020. New public transport network. Accessed on 28/09/2020 at https://at.govt.nz/projects-roadworks/new-public-transport-network/

Audit Office of New South Wales. 2020. Audit Report cited in News.com.au. 2020. NSW opposition says world's slowest and most expensive light rail project 'just got worse'. Media article accessed 19/11/2020 at https://www.news.com.au/national/nsw-act/politics/nsw-opposition-says-worlds-slowest-and-most-expensive-light-rail-project-just-got-worse/news-story/0997b1b8c7a85cffe5430de299e706c2

Aunger, R. 2007. Major transitions in 'big' history. Technological Forecasting and Social Change. 74, 8, 1137-1163.

Australian Government. 2018. Delivering City Deals: The fact sheet. Accessed 17/01/2019 at https://infrastructure.gov.au/cities/city-deals/files/City-Deal-Process-factsheet.pdf.

Australian Renewable Energy Agency (ARENA). 2021. Project: AGL Virtual Power Plant. Accessed 27/06/21 at: https://arena.gov.au/projects/agl-virtual-power-plant/

Axon Vibe. 2019. SBB launches test version of the new mobility app SmartWay. Press Release, 17 December 2019. Available at: https://axonvibe.com/press-releases

Baggot, S. 2009. Matthew Boulton: Enterprising industrialist of the enlightenment. Routledge.

Bakker, S. 2014. Actor rationales in sustainability transitions – Interests and expectations regarding vehicle recharging. Environmental Innovation and Societal Transitions, Vol. 13, pp. 60-74.

Balazs, Katalin. 1996. Academic Entrepreneurs and their Role in 'Knowledge' Transfer (PDF). Science Policy Research Unit, University of Sussex. pp. 4–9.

Batty, M. 2005. Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals. Cambridge, MA: MIT Press.

Batty, M. 2013. The New Science of Cities. Cambridge: MIT Press.

Baumgartner, B. 2011. Critical perspectives on sustainable development research and practice. Journal of Cleaner Production, 19 (8) (2011), pp. 783-786.

Baumol, W. J., Blinder, A. S. 2011. Economics: Principles and Policy. 12th Edition. South-Western Cengage Learning.

Beinhockler, E. 2006. The origin of wealth. Harvard Business Press.

Bennett, S. J. 2012. Using past transitions to inform scenarios for the future of renewable raw materials in the UK. Energy Policy, 50, 95-108.

Bertolini, L. 2010. Complex systems, evolutionary planning? In Silva, E.; De Roo, G. (eds.), A Planner's Encounter with Complexity. Ashgate: Aldershot, pp. 81–89.

Bertolini, L. 2020. From "streets for traffic" to "streets for people": can street experiments transform urban mobility? Transport Reviews. Vol 40 (6), pp. 734-753.

Birbeck Norman Hill, G. & Powell, L. F. (eds). 1934. Boswell's Life of Johnson, Vol. 2: The Life (1766-1776). Oxford University Press.

Bocken, N. M. P., Allwood, J. M., Willey, A. R. & King, J. M. H. 2012. Development of a tool for rapidly assessing the implementation difficulty and emissions benefits of innovations. Technovation, 32(1), 19-31.

Boltin, R. & Foxon, T. J. 2015. A socio-technical perspective on low carbon investment challenges – Insights for UK energy policy. Vol 14, pp. 165-181.

Bolton and Thompson .2013. Entrepreneurs: Talent, treatment and opportunity. Routledge. ISBN-10: 0415631882.

Boschma, R. 2015. Towards an evolutionary perspective on regional resilience. Regional Studies, 49(5), PP. 733-751.

Boschma, R., Coenen, L., Frenken, K. & Truffer, B. 2017. Towards a theory of regional diversification: combining insights from evolutionary economic geography and transition studies. Regional Studies, 51 (1) (2017), pp. 31-45.

Boston Today, Boston Transportation Department, 2017.

Bower, J. L. & Christensen, C. M. 1995. Disruptive technologies: catching the wave. Harvard Business Review.

Bowonder, B. & Miyake, T. 1994. Globalization, alliances, diversification and innovation: A case study from Hitachi Ltd. Creativity and Innovation Management, Volume3, No. 1, 1994.

Brand, U. 2014. Transition und transformation: sozialökologische perspektiven M. Brie (Ed.), Futuring. Perspektiven Der Transformation Im Kapitalismus über Ihn Hinaus, Westfälisches Dampfboot, Münster (2014), pp. 242-280.

Brand, U. 2016. 'Transformation' as a new critical orthodoxy: the strategic use of the term 'transformation' does not prevent multiple crises. GAIA, Vol. 25(1), pp. 23-27.

Brand, U. Transition und transformation: sozialökologische perspektiven. M. Brie (Ed.), Futuring. Perspektiven Der Transformation Im Kapitalismus über Ihn Hinaus, Westfälisches Dampfboot, Münster (2014), pp. 242-280. Cited in Holscher, K., Wittmayer, J. M. & Loorbach, D. 2018. Transition versus transformation: What's the difference? Environmental Innovation and Societal Transitions. Volume 27, June 2019, Pages 1-3.

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101.

Braun, V. & Clarke, V. 2013. Successful qualitative research: A practical guide for beginners. Sage publishing.

Brews PJ, Hunt MR. 1999. Learning to plan and planning to learn: resolving the planning school/learning school debate. Strategic Management Journal 20(10): 889-913.

Brundland Commission. 1987. Our common future.

Buchanan, C. 1963. Traffic in Towns. HMSO, London.

Budde, B., Alkemade, F., Weber, K.M. 2012. Expectations as a key to understanding actor strategies in the field of fuel cell and hydrogen vehicles. Technological Forecasting and Social Change, Vol. 79, pp. 1072-1083.

Bulliet, R. W., Crossley, P. K., Headrick, D. R., Hirsch, S. W., Johnson, L. L., Northrup, D. 2018. The Earth and it's Peoples: A global history. 7th Edition. ISBN10: 1-337-40147-1.

Bygrave, W.D. and Hofer, C.W. (1991), "Theorizing about entrepreneurship", Entrepreneurship Theory and Practice, Winter, pp. 13-22.

Byrne, R. P. 2009. Learning Drivers: Rural Electrification Regime Building in Kenya and Tanzania. Doctoral thesis (DPhil), University of Sussex.

C. Folke, S. Carpenter, T. Elmqvist, L. Gunderson, C.S. Holling, B. Walker. Resilience and sustainable development: building adaptive capacity in a world of transformations. Ambio, 31 (2002), pp. 437-440

C. Folke, S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin, J. Rockström. 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society, 15 (4), p. 20.

Cagnin, C., Loveridge, D. 2012. A framework, with embedded FTA, to enable business networks to evolve towards sustainable development. Technology Analysis and Strategic Management, Vol 24, pp. 797-820.

Caniels, M. & Romijn, H. A. 2006. Strategic niche management as an operational tool for sustainable innovation: guidelines for practice. Eindhoven Centre for Innovation Studies, The Netherlands Working Paper 06.07.

Carlino, G., Chatterjee, S., and Hunt, R. 2007. Urban density and the rate of invention. Journal of Urban Economics. Volume 61, Issue 3, May 2007, 389-419.

Carter, M. 2001. An investigation into the agricultural use of reclaimed water in the Willunga Basin, South Australia, 2001.

Cassell, Catherine, & Symon, Gillian (1994). Qualitative research in work contexts. In Catherine Cassell & Gillian Symon (Eds.), Qualitative methods in organizational research, a practical guide (pp.1-13). London: Sage.

Casson, M. 2009. The world's first railway system. Oxford University Press. ISBN: 9780199213979.

Centre for Cities. 2020. Delivering change: low carbon regulation. Online article. Accessed 23/11/2020 at https://www.centreforcities.org/reader/delivering-change-cities-go-low-carbon-supporting-economic-growth/regulation/

Cervero, R. & Murakami, J. 2008. Rail and property development in Hong Kong: Experiences, impacts and extensions. Technical report, Lincoln Institute of Land Policy. URL http://www.lincolninst.edu/pubs/download. asp?doc_id=706&pub_id=1388.

Chang, X., Fu, K., Low, A., Zhang, W. 2015. Non-executive employee stock options and corporate innovation. Journal of Financial Economics. 115 (1): 168-188.

Chase, W. G. & Simon, H. A. 1973. The mind's eye in chess. In: Chase, W. G. (Ed.), Visual Information Processing. Academic Press, New York, pp. 215–281.

Chien, S.I.-J.; Ding, Y.; Wei, C. 2002. Dynamic Bus Arrival Time Prediction with Artificial Neural Networks. Journal of Transp. Eng. 2002, 128, 429–438.

China Development Bank Capital (CDBC). 2015. The Pearl District: An urban redevelopment case study of the pearl district and brewery blocks in Portland, Oregon.

Christensen, C. 1997. The Innovator's Dilemma: When new technologies cause great firms to fail. Harvard Business School Press.

Christensen, K. S. 1985. Coping with uncertainty in planning. Journal of the American Planning Association.

Chu, S., Cui, Y., Liu, N. 2017. The path towards sustainable energy. Nature Materials, 16, 16-22.

Cilliers, P. 1998. Complexity and Postmodernism: Understanding Complex Systems. Routledge.

City Rail Link. 2020. Public transport growth today. Accessed 28/09/2020 at https://www.cityraillink.co.nz/public-transport-growth-today

Clark, G. & Clark, G. 2014. Nations and the wealth of cities: A new phase in public policy. Centre for London.

Climate Action Tracker. 2019. Global greenhouse gas emissions and warming scenarios (based on national policies and pledges as of December 2019). Cited at https://ourworldindata.org/future-emissions

Clinton, N. 2015, 'Denmark takes lead in smart traffic control with procurement innovation', Public Spend Forum.

Coenen, L. & Truffer, B. 2012. Places and spaces of sustainability transitions: geographical contributions to an emerging research and policy field. European Planning Studies, Volume 20, Issue 3, pp. 367-374.

Coenen, L., Benneworth, P. & Truffer, B. 2012. Toward a spatial perspective on sustainability transitions. Research Policy. Volume 41, Issue 6, 2012, pp. 968-979.

Coenen, L., Hansen, T. & Rekers, J. V. 2015. Innovation policy for grand challenges. An economic geography perspective. Geography Compass, Volume 9, Issue 9, 2015, pp. 483-496.

Cohen, B. 2012, The top 10 smart cities on the planet, Fast Company & Inc, New York.

Crawford, R. 2016. What can complexity theory tell us about urban planning? Research note 2016/2.

Creswell, J. W. 2009. Qualitative inquiry and research design; Choosing among five approaches (3rd ed.). Thousand Oaks: Sage.

Creutzig, F., Agoston, P., Christoph Goldschmidt, J., Luderer, G., Nemet, G., Pietzcker, R. C. 2017. The underestimated potential of solar energy to mitigate climate change. Nature Energy 2, Article number: 17140 (2017).

Cross, G. 2002. An all-consuming century: Why commercialism won in modern America. Columbia University Press.

CRRC. 2017. Media Release: First railless train unveiled in CRRC Zhuzhou. Accessed 18/02/2020 at https://www.crrcgc.cc/en/g7389/s13996/t286142.aspx

Currie, G. & Dellbosc, 2013. Exploring trends in forced car ownership in Melbourne. Australasian Transport Research Forum, Brisbane, 2013.

Currie, G. 2018. Lies, Damned Lies, AVs, Shared Mobility and Urban Transport Futures. Journal of Public Transportation. Vol. 21(1), pp. 19-30.

Curry, J. A. & Webster P. J. 2011. Climate science and the uncertainty monster. Bull Am Meteorol Soc 92(12):1667–1682. https://doi.org/10.1175/2011BAMS3139.1

da Cruz, N. F., Rode, P. & McQuarrie, M. 2018. New urban governance: A review of current themes and future priorities. Journal of Urban Affairs, Vol. 41 (1), pp. 1-19.

Daniell, K.A., Costa, M.A.M., Ferrand, N., Kingsborough, A.B., Coad, P. & Ribarova, I.S. 2011. Aiding multi-level decision-making processes for climate change mitigation and adaptation. Regional Environmental Change, Vol. 11, pp. 243-258.

Davies, J. 2014. Coercive cities: Reflections on the dark side of urban power in the 21st century. Journal of Urban Affairs, 36(Suppl. 2), 590–599.

Davies-Slate, S. & Newman, P. 2018. Partnerships for private transit investment: the history and practice of private transit infrastructure with a case study in Perth, Australia. Urban Science. Vol. 2 (84).

De Dreu, C.K., West, M. A. 2001. Minority dissent and team innovation: the importance of participation in decision making.

De Roo, G. & Rauws, W. S. 2012. Positioning planning in the world of order, chaos and complexity: on perspectives, behaviour and interventions in a non-linear environment. In Portugali, J.; Meyer, H.; Stolk, E.; Tan, E. (eds.), Complexity theories of cities have come of age: An overview with implications to urban planning and design. Heidelberg: Springer, pp. 207–220.

De Smedt, P., Borch, K., Fuller, T., 2013. Future scenarios to inspire innovation. Technological Forecasting and Social Change, Vol. 80, pp. 432-443.

Del Rio, R. & Unruh, G. 2007. Overcoming the lock-out of renewable energy technologies in Spain: The cases of wind and solar electricity. Renewable and Sustainable Energy Reviews. Vol. 11(7), pp. 1498-1513.

Dew, N., Read, S., Sarasvathy, S. & Wiltbank, R. 2009. Effectual versus predictive logics in entrepreneurial decision-making. Differences between experts and novices. Journal of Business Venturing, Vol. 24, pp. 287-309.

Dew, N., & Sarasvathy, S. D. 2016. Exaptation and niche construction: behavioral insights for an evolutionary theory. Industrial and Corporate Change, Vo. 25(1): , pp. 167-179.

Digi. 2020. Transdata launches transport ticketing, GPS and Wi-Fi, bringing advanced services to riders. Media release. Accessed 11/11/2020 at https://www.digi.com/customer-stories/transdata-launches-transport-ticketing

Doll, J. & Mayr, U. 1987. Intelligenz und Schachleistung — eine Untersuchung an Schachexperten. [Intelligence and achievement in chess — a study of chess masters]. Psychologische Beitrge, Vol. 29, pp. 270–289.

Downs, A. 1962. The law of peak-hour expressway congestion. Traffic Quarterly, Volume 16, no. 3, pp. 393-409.

Downs, A. 1992. Still Stuck in Traffic: Coping with Peak-Hour Traffic Congestion. Brookings Institution Press

Duit, A. & Galaz, V. 2008. Governance and complexity: Emerging issues for governance theory. Governance, 21, pp. 311–335.

Duit, A. & Galaz, V. 2008. Governance and complexity: Emerging issues for governance theory. Governance, 21, pp. 311–335.

Dujon, V., Dillard, J. & Brennan, E. M. 2013. Social Sustainability: A multilevel approach to social inclusion. Routledge. Cited in China Development Bank Capital (CDBC). 2015. The Pearl District: An urban redevelopment case study of the pearl district and brewery blocks in Portland, Oregon.

Dyer, F. L. & Martin, T. C. 1910. Edison, his life and inventions (Volume 2). Harper & Brothers, 1910.

Dynniq 2020. CrossWalk. Accessed 11/11/2020 at https://dynniq.com/products-and-services/crosswalk/

Eliasson, J. 2014. The Stockholm congestion charges: an overview. Centre for Transport Studies, Stockholm, Working Paper 2014:7.

Elmustapha, H., Hoppe, T., Bressers, H. 2018. Comparing two pathways of strategic niche management in a developing economy; the cases of solar photovoltaic and solar thermal energy market development in Lebanon. Journal of Cleaner Production. Volume 186, 10 June 2018, Pages 155-167.

Eltis (2016) Guidelines for Sustainable for Urban Mobility Plans, European Commission's Directorate General for Mobility and Transport.

Elzen, B., Geels, F. W., Hofman, P. S. & Green, K. 2002. Sociotechnical Scenarios as a Tool for Transition Policy, Paper for 10th International Conference of the Greening of Industry Network, Gothenburg, Sweden.

Emerson, J. & Twersky, F. 1996. New social entrepreneurs: The success, challenge and lessons of non-profit enterprise creation. A Progress Report on the Planning and Startup of Non-Profit Businesses. San Francisco, CA: Roberts Foundation Homeless Economic Development Fund.

Ericsson, K.A. 2006a. The influence of experience and deliberate practice on the development of superior expert performance. In: Ericsson, K.A., Charness, N., Feltovich, P.J., Hoffman, R.R. (Eds.), The Cambridge handbook of expertise and expert performance. Cambridge University Press, Cambridge, U.K., pp. 683–704.

Ericsson, K.A. 2006b. An introduction to the Cambridge handbook of expertise and expert performance. In: Ericsson, K.A., Charness, N., Feltovich, P.J. & Hoffman, R.R. (Eds.), The Cambridge handbook of expertise and expert performance. Cambridge University Press, Cambridge, U.K., pp. 3–20.

Ericsson, K.A. 2006c. Protocol analysis and expert thought: concurrent verbalizations of thinking during experts' performance on representative tasks. In: Ericsson, K.A., Charness, N., Feltovich, P.J. & Hoffman, R.R. (Eds.), The Cambridge handbook of expertise and expert performance. Cambridge University Press, Cambridge, U.K., pp. 223–242.

EuroTech. 2016. Counting passengers via the cloud. Media release. Accessed 11/11/2020 at https://www.eurotech.com/en/story/counting-passengers-via-the-cloud

Ewing, R. & Bartholomew, K. 2013. Pedestrian- and transit-oriented design. Washington, D.C.: Urban Land Institute and American Planning Association, 2013. ISBN 978-0-87420-201-4.

Fagerberg, J. 2018. Mobilizing innovation for sustainability transitions: a comment on transformative innovation policy. Research Policy, Volume 47, Issue 9, 2018, pp. 1568-1576,

Farrell, S., Tsukada, S. & Kurawami, C. 1994. Value capture: The Japanese experience. Florida Department of Transportation. 2006. Florida Intercity Passenger Rail Vision Plan. URL: http://www.apta.com/resources/reportsandpublications/Documents/APTA_HSR_Investment_Paper.pdf.

Farrelly, M., Rijke, J. & Brown, R. 2012. Exploring operational attributes of governance for change. 7th International Conference on Water Sensitive Urban Design, Melbourne, Australia (2012).

Figueres, C., Schullnhuber, H. J., Whiteman, G., Rockstrom, J., Hobley, A., Rahmstorf, S. 2017. Three years to safeguard our climate. Nature, Comment, 546, 593-595.

Florida, R. 2002. The rise of the creative class: and how it's transforming work, leisure, community and everyday life. New York: Perseus Book Group.

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T. & Rockstrom, J. 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society. 15(4), p 20.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., Walker, B., 2002. Resilience and sustainable development: building adaptive capacity in a world of transformations. Ambio 31, pp. 437-440.

Ford Motor Company. 2017. 100 years of the moving assembly line. http://corporate.ford.com/innovation/100-years-moving-assembly-line.html

Ford, H., Crowther, S. 1922. My life and work. Garden City Publishing Company, Inc. Page 73. Chapter IV.

Fouquet, R. 2012a. Trends in income and price elasticities of transport demand (1850–2010). Energy Policy, 50, 62-71.

Fouquet, R. 2012b. The demand for environmental quality in driving transitions to low-polluting energy sources. Energy Policy, 50, 138-149.

Frankfurt School-UNEP Centre/BNEF. 2018. Global Trends in Renewable Energy Investment 2018, http://www.fs-unep-centre.org (Frankfurt am Main)

Frazer, Persifor (1859) Journal of the Franklin Institute. pp. 296–297. Retrieved 17 August 2011.

Frederick, H., O'Connor, A. and Kuratko, D. 2013. Entrepreneurship: theory, process, practice.

Freeman, C. Perez, C. 1988. Structural crises of adjustment: business cycles and investment behaviour, in: G. Dosi, et al. (Eds.), Technical Change and Economic Theory, Frances Pinter, London, 1988.

Freeman, M. J. 1999. Railways and the Victorian imagination. Yale University Press. ISBN: 0300079702.

Friedel, R. D., Israel, P., Finn, B. S. 1986. Edison's electric light: Biography of an invention. Rutgers University Press, 115–117.

Friend, J. K. & Jessop, W. N. 1969. Local government and strategic choice: an operational research approach to the process of public planning. Tavistock Publications, London, 1969.

Fujutsu. 2016. Fujitso beings field trial for AI-based train delay prediction. Media release. Accessed 11/11/2020 at https://www.fujitsu.com/global/about/resources/news/press-releases/2016/0719-02.html

Garavan, T. N., & O'Cinneide, B. 1994. Entrepreneurship Education and Training Programmes: A Review and Evaluation Part 1. Journal of European Industrial Training, 18, 3-12.

Garud, R., Hardy, C. & Maguire, S. 2007. Institutional entrepreneurship as embedded agency: an introduction to the special issue. Organization Studies. Vol. 28 (7), pp. 957-969.

Gaziulusoy, et al. 2016. Identifying and addressing challenges faced by transdisciplinary research teams in climate change research. Journal of Cleaner Production, 123, 55-64.

Geels, F. 2005. Technological Transitions and System Innovations: A Co-Evolutionary and Socio-Technical Analysis. Book.

Geels, F. W. 2002. Technological transitions as evolutionary configuration processes: A multi-level perspective and a case-study. Research Policy, 31 (8/9), 1257-1274.

Geels, F. W. 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Res. Pol., 39 (4) (2010), pp. 495-510. https://doi-org.proxy.library.adelaide.edu.au/10.1016/j.respol.2010.01.022

Geels, F. W. 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms. Environmental Innovation and Societal Transitions. Vol. 1(1), pp. 24-40.

Geels, F. W., McMeekin, A. & Pfluger, B. 2020. Socio-technical scenarios as a methodological tool to explore social and political feasibility in low-carbon transitions: Bridging computer models and the multi-level perspective in UK electricity generation (2010–2050). Technological Forecasting and Social Change. Vol. 151, February 2020, 119258.

Geels, F.W. & Raven, R.P.J.M. 2006. Non-linearity and expectations in niche-development trajectories: ups and downs in Dutch biogas development (1973–2003). Technology Analysis and Strategic Management, Vol. 18, pp.375–392.

Geerlings, H., 2012 Transitions towards sustainable mobility – the role of instruments, individuals and institutions. Ashgate.

Gehl, J. 2010. Cities for people. Island Press.

Geissdoerfer, M., Vladimirova, D., Fossen, K. V., & Evans, S. 2018. Sustainable business model innovation: A review. Journal of cleaner production, 198, 401-416.

Genus, A. & Coles, A. M. 2008. Rethinking the multi-level perspective of technological transitions. Research Policy, Vol. 37, pp. 1436-1445.

Geoscience Australia. 2022. Areas of Australian and territory deserts. Accessed 01/01/2023 at: https://www.ga.gov.au/scientific-topics/national-location-information/landforms/deserts

Giddens, A. 1984. The constitution of society: outline of the theory of structuration. University of California Press, Berkeley and Los Angeles.

Giddens, A. 1991. Modernity and self-identity: self and society in the late modern age.

Giddens, A. 2014. Essential concepts in sociology. Polity Press.

Gkiotsalitis, K. & Maslekar, N. 2016. Dynamic Bus Operations Optimization with REFLEX. NEC Technical Journal, Vol.11 No.1, Special Issue on AI & Social Value Creation.

Gläser, J. & Laudel, G. 1999. Theoriegeleitete Textanalyse? Das Potential einer variablenorientierten qualitativen Inhaltsanalyse. Berlin: Wissensschaftszentrum Berlin für Sozialforschung GmbH.

Glazebrook, G. & Newman, P. 2018. The city of the future. Urban Planning. Vol. 3 (2).

Gleeson, B., Randolph, B. 2002. Social disadvantage and planning in the Sydney context. Urban Policy and Research. Vol. 20(1), pp. 101-107.

Global Entrepreneurship Network. 2017. Global Entrepreneurship Index 2017. The Global Entrepreneurship and Development Institute, Washington, D.C., USA.

Golsby-Smith, T. 2007. The second road of thought: how design offers strategy a new toolkit. Journal of Business Strategy, 28, 4, 22-29.

Goodwin, P. 1996. Empirical evidence on induced traffic. A review and synthesis. Transportation, Volume 23, no. 1, pp. 35-54.

Gordon, J. S. 2001. Recorded in: The Business of America. Walker and Company, New York, 2001.

Government of India. 2017. Metro Rail Policy – 2017, GoI, Delhi.

Green, J. & Newman, P. 2017. Citizen utilities: The emerging power paradigm. Energy Policy, 105, 283-293.

Grin, J., Rotmans, J. & Schot, J. W. 2010. Transitions to Sustainable Development. [Electronic Resource]: New Directions in the Study of Long Term Transformative Change. Routledge, New York (2010), p. 2010.

Growther, G. 1963. Traffic in Towns. A study of the long term problems of traffic in urban areas. Reports of the Steering Group and Working Group Appointed by the Minister of Transport, London.

Grubb, M.J. 1990. Energy efficiency and economic fallacies. Energy Policy, 18, 783–785. doi:10.1016/0301-4215(90)90031-x

Grübler, A. 2004. Transitions in energy use. Encyclopedia of Energy, 6, 163–177.

Grübler, A., Nakicenovic, N., Victor, D. G. 1999. Dynamics of energy technologies and global change. Energy Policy, 27, 247–280.

Gunn, S. & Hillier, J. 2014. When uncertainty is interpreted as risk: An analysis of tensions relating to spatial planning reform in England. Planning Practice and Research, 29, pp. 56–74.

Hardin, G. 1968. The tragedy of the commons. Science. Vol. 162 (3859), pp. 1243-1248.

Hargadon, A. 2013. Chapter: Brokerage and Innovation, in book: Dodgson, M., Gann, D. M., Phillips, N. 2013.

Hargroves, K. 2015. Carbon Structural Adjustment: Designing, Motivating, and Delivering an Economy-Wide Transition to Low Greenhouse Gas Emissions, PhD Thesis, Curtin University Sustainability Policy Institute, Curtin University, Australia.

Hargroves, K., Conley, D., Emmoth, E., Wamerdam, S., Kahindi, N., Cui, F., Spajic, L. 2019. Investigating the potential for artificial intelligence and blockchain technology to enhance the transport sector – Project report. Sustainable Built Environment National Research Centre (2019), Australia.

Hargroves, K., Smith, M. 2005. The natural advantage of nations: Business opportunities, innovation and governance in the 21st Century. Earthscan.

Harmony, X. J. & Vikash, V. V. 2017. Evaluation of real-time transit information systems: An information demand and supply approach. International Journal of Transportation Science and Technology. Vol. 6 (1), pp. 86-98.

Hart, S.L. 1992. An integrative framework for strategy-making processes. Academy of Management Review. 17 (2), pp. 327-351.

Harvey, D. 1989. From managerialism to entrepreneurialism: The transformation in urban governance in late capitalism. Geografiska Annaler, 71B, 3–17.

Hauser, E. et al. 2015. Nutzeneffekte von Bürgerenergie. Greenpeace Energy, Bündnis Bürgerenergie e.V. Institut für ZukunftsEnergieSysteme.

Hawken, P. 2017. Drawdown: The most comprehensive plan ever proposed to reverse global warming. New York, New York: Penguin Books.

Healey, P., Cameron, S., Davoudi, S. 1995. Managing cities: the new urban context. London: John Wiley.

Helps, A. 1805-1870. The life and labours of Thomas Brassey. Cited: http://www.englishlanguageandhistory.com/?id=thomas-brassey-2 on 23/07/2018.

Hensher, D. A. & Macario, R. 2002. Organisation and ownership of public transport services, Transport Reviews, Volume 22, Pages 350–357.

Henton, D., Melville, J. & Walesh, K. 1997. The Age of the Civic Entrepreneur: Restoring Civil Society and Building Economic Community, National Civic Review, 86: 149-156.

Heraud, J. A., Kerr, F. & Burger-Helmchen, T. 2019. Creative management of complex systems. John Wiley & Sons, 2019.

Here Mobility, 2020. Accessed 11/11/2020 at: https://www.here.com/solutions/urban-mobility#:~:text=An%20IoT%2Dbased%20tracking%20system,the%20fingertips%20of%20fleet%20operators.

Hero. 1851. [reprint of 1st century CE original], "Section 50 – The Steam Engine", written at Alexandria, Pneumatica. London: Taylor Walton and Maberly, Translated from the original Greek by Bennet Woodcroft (Professor of Machinery in University College London).

Herrfahrdt-Pähle, E. & Pahl-Wostl, C. 2012. Continuity and change in social-ecological systems: the role of institutional resilience. Ecology and Society, Vol. 17.

Herring, H. & Roy, R. 2007. Technological innovation, energy efficient design and the rebound effect. Technovation, 27(4), 194-203.

Highway Engineering Australia 2015, ‘Big data: The key to unlocking the future of traffic, transport and infrastructure’, HEA , vol. 47, no. 2, pp. 40-41.

Hills, P.J. 1996. What is induced traffic?. Transportation, Volume 23, no. 1, pp. 5-16.

Hills, R. L. 1993. Power from steam: History of the stationary steam engine. New Edition, Cambridge University Publishing, 1993. ISBN 052145834X.

Hills, R. L. 2005. James Watt, vol. 2: The Years of Toil. 1775-1785. (Ashbourne, 2005), p.56. Cited in Baggott “Matthew Boulton: Enterprising Industrialist of the Enlightenment”.

Hitachi. 2018. Company History. Accessed 26/09/2018 at http://www.hitachi.com.sg/ice/about/history/index.html

Hitt, M., Ireland, D., Sirmon, D., and Trahms, C. 2011. Strategic Entrepreneurship: Creating Value for Individuals, Organisations and Society. Academy of Management Executive, May 2011.

Hodgkinson, J.H., Hobday, A.J. & Pinkard, E.A. 2014. Climate adaptation in Australia's resource-extraction industries: ready or not? Regional Environmental Change, Vol. 14, pp. 1663-1678.

Hodgson, G. M. 1993. Institutional Economics: Surveying the "old" and the "new". Meteroeconomica. 44 (1-28).

Hodson, M. & Marvin, S. 2010. Can cities shape socio-technical transitions and how would we know if they were?. Research Policy, 39(4), 477-485.

Hofman, P. S., Elzen, B. E. & Geels, F. W. 2004. Sociotechnical scenarios as a new policy tool to explore system innovations: co-evolution of technology and society in the electricity domain. Innov. Manag. Policy Pract., 6 (2) (2004), pp. 344-360.

Hollands, R. G. 2008. Will the real smart city please stand up? City. Vol. 12 (3), 303-320.

Hölscher, K., Wittmayer, J. M. & Loorbach, D. 2018. Transition versus transformation: what's the difference? Environmental Innovation and Societal Transitions, Vol. 27, pp. 1-3.

Hong, Y.-H. & Lam, A. H. S. 1998. Opportunities and risks of capturing land values under Hong Kong's leasehold system. Technical report, Lincoln Institute of Land Policy. URL: http://www.lincolninst.edu/pubs/download.asp?doc_id=24&pub_id=65.

Hoogma, R. 2000. Exploiting technological niches, Thesis, Twente University, Enschede.

Hoogma, R., Kemp, R., Schot, J., Truffer, B. 2005. Experimenting for sustainable transport: The approach of strategic niche management. Spon Press.

Hoogma, R., Schot, J.W. 2001. How innovative are users? A critique of learning-by-doing and-using, in: Coombs, R., Green, K., Richards, A., Walsh, V. (eds.), Technology and the Market, Edward Elgar, Cheltenham/Massachusetts, p. 216-233.

Hörisch, J. 2014. The Role of Large Companies in Sustainability Transitions. Ph.D. Thesis, Leuphana University, Lüneburg, Germany, 16 May 2014.

Hossain, M. 2012. A Bayesian network based framework for real-time crash prediction on the basic freeway segments of urban expressways. Accident Analysis & Prevention, vol. 45. (http://dx.doi.org/10.1016/j.aap.2011.08.004)

Howleg, M. & Pil, F. K. 2004. The Second Century: Reconnecting customer and value chain through built-to-order: Moving beyond mass and lean production in the auto industry. MIT Press, 2004.

Hu, Y., Barbour, W., Samaranayake, S. & Work, D. 2020. The Rebound — How Covid-19 could lead to worse traffic. Accessed 06/06/2020 at https://medium.com/@barbourww/the-rebound-how-covid-19-could-lead-to-worse-traffic-cb245a5b1da2

Hughes, Thomas P. 2004. American genesis: A century of invention and technological enthusiasm (2nd ed.). Chicago: University of Chicago Press. ISBN 978-0-22635-927-4.

Huhne, C. 2011. 'The economics of climate change', speech by Secretary of State for Energy and Climate Change, 29 June 2011, http://www.decc.gov.uk/en/content/cms/news/ec_cc_ch/ec_cc_ch.aspxS.

IEA. 2011. World Energy Outlook. IEA, Paris.

Institute for Sustainable Futures. 2013. Willunga Basin case study: Building industry capability to make recycled water investment decisions. Prepared by the Institute for Sustainable Futures, University of Technology, Sydney for the Australian Water Recycling Centre of Excellence.

Integrated Media Systems Center. 2016. Transdec: Big Data for Transportation, University of Southern California, Columbia.

Intergovernmental Panel on Climate Change (IPCC). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report.

Intergovernmental Panel on Climate Change IPCC-SREX (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. In: Field, C.B., V. Barros, T.F.Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.) (pp. 1–582). Cambridge, United Kingdom and New York, USA: Cambridge University Press

International Energy Agency. 2016. Cities are at the frontline of the energy transition. News release. Accessed at https://www.iea.org/news/cities-are-at-the-frontline-of-the-energy-transition

International Energy Agency. 2017. Statistics; http://www.iea.org/statistics/statisticssearch

International Renewable Energy Agency (IRENA). 2021. Renewable Power Generation Costs in 2020, International Renewable Energy Agency, Abu Dhabi.

Ioannidis, J. P. A., Cripps, S. & Tanner, M. A. 2020. Forecasting for COVID-19 has failed.

IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jacobs, J. 1961. The death and life of great American cities. Random House, New York.

Jager, H.I., Baskaran, L.M., Schweizer, P.E., Turhollow, A.F., Brandt, C.C., Srinivasan, R. 2015. Forecasting changes in water quality in rivers associated with growing biofuels in the Arkansas-White-Red river drainage, USA. Global Change Biology, Bioenergy. 7, pp. 774-784.

Jenks, L. H. 2011. Railroad as an economic force for American development. The Journal of Economic History, 4(1), 1-20.

Jeong, R.; Rilett, R. 2004. Bus arrival time prediction using artificial neural network model. In Proceedings of the 7th International IEEE Conference on Intelligent Transportation Systems, Washington, DC, USA, 3–6 October 2004; pp. 988–993.

Jones, P. M. 2016. Transport planning: turning the process on its head. From 'predict and provide' to 'vision and validate'. Presented at Radical Transport Conference, London, United Kingdom.

Kang, J., Yu, R., Huang, X., Maharjan, S., Zhang, Y., and Hossain, E. (2017) Enabling Localized Peer-to-Peer Electricity Trading Among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains, IEEE Transactions on Industrial Informatics, Volume: 13, Issue: 6, Dec. 2017.

Kaufmann, D. 2013. The influence of causation and effectuation on targeted policies: the case of Singapore and Israel. Technology Analysis & Strategic Management, 2013. Vol. 25, No. 7, 853–870, http://dx.doi.org/10.1080/09537325.2013.815714

Kearns, A. & Paddison, R. 2000. New challenges for urban governance. Urban Studies, 37 (5-6), 845-850, 2000.

Kelly, P., Kranzberg, M. 1975. Technological innovation: A critical review of current knowledge. Georgia Institute of Technology Publishing.

Kemp, R. P. M., Rip, A., & Schot, J. 2001. Constructing Transition Paths Through the Management of Niches. In R. Garud, & P. Karnoe (Eds.), Path Dependence and Creation (pp. 269-299). Mahwa (N.J.) and London: Lawrence Erlbaum.

Kemp, R., Schot, J., Hoogma, R. 1998. Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. Technol. Anal. Strat. Manag., 10 (2) (1998), pp. 175-195.

Kemp, R., van den Bosch, S. 2006. Transitie-experimenten. Praktijkexperimenten met de potentie om bij te dragen aan transities, Publication KCT. Cited in Mourik & Raven, 2006.

Kenworthy, J. and Newman, P. 2015. The End of Automobile Dependence: How Cities are Moving Beyond Car-Based Planning. Washington DC: Island Press.

Keremane, G. B., McKay, J.

Keremane, G. B., McKay, J. 2008. Water reuse projects: the role of community social infrastructure. Water, Journal of the Australian Water Association.

Kern, F. 2015. Engaging with the politics, agency and structures in the technological innovation systems approach. Environmental Innovation and Societal Transitions, 16, pp. 67-69.

Keskin, D., & Markus, A. 2022. Creating Value to Address Urban Challenges in Nascent Ecosystems: A Study of Effectuation in Smart City Context. IEEE Transactions on Engineering Management.

Khiari, J., Moreira-Matias, L., Cerqueira, V., Cats, O. 2016. Automated setting of bus schedule coverage using unsupervised machine learning. PAKDD 2016: Advances in Knowledge Discovery and Data Mining pp 552-564.

Kimes, B. R. & Clark Jr, H. A. 1996. The Standard Catalog of American Cars 1805-1942. Krause Publications.

Kingdon, J. 2003. Agendas, Alternatives, and Public Policies (2nd ed.). New York, NY: Pearson.

Kirzner, I. 1979. Perception, opportunity and profit. Chicago: University of Chicago Press.

Kirzner, I. 1985. Discovery and the capitalist process. Chicago: University of Chicago Press.

Kivimaa, P. & Kern, F. 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. Research Policy, Vol. 45(1), pp. 205-217.

Klepper, S. 2002. The capabilities of new firms and the evolution of the US automobile industry. Industrial and Corporate Change, 11, 4, 645–666.

Klepper, S. 2006. The evolution of geographic structure in new industries.

Klijn, F., Kreibich, H., de Moel, H. & Penning-Rowsell, E. 2015. Adaptive flood risk management planning based on a comprehensive flood risk conceptualisation. Mitigation and Adaptation Strategies for Global Change, Vol. 20, pp. 845-864.

Kline, S.J. and N. Rosenberg. 1986. “An Overview of Innovation”, in R. Landau and N. Rosenberg (eds) The Positive Sum Strategy: Harnessing Technology for Economic Growth, Washington D.C.: National Academy Press, pp. 275-304.

Knight, F. H. 1921. Risk, uncertainty and profit. The Riverside Press.

Knot, J. M. C., van den Ende, J. C. M., Vergragt, P. J. 2001. Flexibility strategies for sustainable technology development. Technovation, 21(6), 335-343.

Koch, P. (2013). Overestimating the shift from government to governance: Evidence from Swiss metropolitan areas. Governance: An International Journal of Policy, Administration, and Institutions, 6, 397–423.

Koh, H.C. (1996), "Testing hypotheses of entrepreneurial characteristics", Journal of Managerial Psychology, Vol. 11 No. 3, pp. 12-25.

Kolb D.A. 1984. Experiential Learning: Experience as the Source of Learning and Development, Englewood Cliffs: Prentice-Hall.

Kolb, D. A., e.a. 1974. Organizational Psychology. A book of readings. New Jersey, Prentice-Halle.

Kondratiev, N. 1935. The long waves in economic life, Review of Economic Statistics 17 (1935) 1065–1115.

Kuranami, C., Winston, B. P., & Kimura, K. & Rose, C. 2000. Study on urban transport development. Final report, The World Bank.

Lack, D. 1983. Darwin's Finches. Cambridge Science Classics.

Lam, A. H. S. & Tsui, S. W. 1998. Policies and mechanisms on land value capture: Taiwan case study. Technical report, Lincoln Institute of Land Policy. URL: http://www.lincolninst.edu/pubs/download.asp?doc_id=85&pub_id=144.

Lambin, E. & Thorlakson, T. 2018. Sustainability Standards: Interactions between private actors, civil society and governments. Annu. Rev. Environ. Resour. Vol. 43, pp. 369–393.

Landry, C. 2006. The art of city-making. Earthscan Publications.

Lardner, D. 1840. The Steam Engine Explained and Illustrated. Taylor and Walton.

Leadbeater, C. & Goss, S. 1999. Civic entrepreneurship. Demos.

Leadbeater, C. 1997. The rise of the social entrepreneur. London: Demos.

Lennips, J. 2016. Effectuation and causation approaches and their effect on business performance: An analysis of business plans. Thesis for Master of Business Administration.

Leonard, D. 1998. Chapter 7: learning from the market, in: Leonard, D., Wellsprings of Knowledge, Harvard Business School Press, Boston/Masachusetts, p. 177-212.

Levinson, D. M., Marshall, W. & Axhausen, K. 2017. Elements of access: Transport planning for engineers, transport engineering for planners. Network Design Lab.

Lindgren, N. 1979. Seizing the moment. EPRI Journal 4: Special.

Link, A. N., & Siegel, D. S. 2007. Innovation, entrepreneurship and technological change. Oxford university press. ISBN-13: 9780199268825.

Link, A. N., & Siegel, D. S. 2007. Innovation, entrepreneurship and technological change. Oxford university press. ISBN-13: 9780199268825.

Linnenluecke, M. K., Verreynne, M. L., de Villiers Scheepers, M. J. & Venter, C. 2017. A review of collaborative planning approaches for transformative change towards a sustainable future. Journal of Cleaner Production. Volume 142 (4), pp. 3212-3224.

Litman, T. 2017. Generated Traffic and Induced Travel: Implications for Transport Planning. A Report from the Victoria Transport Policy Institute.

Litman, T. and Colman, S.B. 2001. Generated Traffic. Implications for Transport Planning. Institute of Transportation Engineers Journal, Volume 71, no. 4, pp. 38-47.

Littunen, H. 2000. Entrepreneurship and the characteristics of the entrepreneurial personality. International Journal of Entrepreneurial Behaviour & Research, Vol. 6 No. 6, pp. 295-309.

Loorbach, D. 2010. Transition management for sustainable development: a prescriptive, complexity based governance framework. Governance, Vol. 23, pp. 161-183.

Loorbach, D., Frantzeskaki, N. & Avelino, F. 2017. Sustainability transitions research: transforming science and practice for societal change. Annual Review of Environment and Resources, 42, 599-626.

Lu, H.P., Sun, Z.Y., Qu, W.C. 2014, 'Big Data-Driven Based Real-Time Traffic Flow State Identification and Prediction', Discrete Dynamics in Nature and Society, vol 1. (DOI:10.1155/2015/284906)

Lu, L., Xue, L. & Zhou, W. 2018. How did Shenzhen, China build world's largest electric bus fleet? Article for World Resources Institute. Accessed 6/8/2020 at: https://www.wri.org/blog/2018/04/how-did-shenzhen-china-build-world-s-largest-electric-bus-fleet

Lucas, J. 2017. Patterns of urban governance: A sequence analysis of long-term institutional change in six Canadian cities. Journal of Urban Affairs, 39, 68–90.

Lüdeke-Freund, F. 2019. Sustainable entrepreneurship, innovation, and business models: Integrative framework and propositions for future research. Business Strategy and the Environment, Vol 29 (2), pp. 665-681.

Luo, J., Olechowski, A. L., Magee, C. L. 2014. Technology-based design and sustainable economic growth. Technovation, 34(11), 663-677.

Luque-Ayala, A. & Marvin, S. 2015. Developing a critical understanding of smart urbanism? Urban Studies, 52 (12) (2015), pp. 2105-2116.

Lynn, G.S., J.G. Morone, A.S. Paulson. 1996. Marketing and discontinuous innovation: the probe and learn process, in: California Management Review, Vol. 38, No. 3, p. 8-37.

Lyons, G. 2018. Getting smart about urban mobility – Aligning the paradigms of smart and sustainable. Transportation Research Part A: Policy and Practice. Volume 115, September 2018, Pages 4-14.

MacDonald, A. E., Clack, C. T. M., Alexander, A., Dunbar, A., Wilczak, J., Xie, Y. 2016. Future cost-competitive electricity systems and their impact on US CO2 emissions. Nature Climate Change, 6, 526–531.

Mackie, P., Preston, J. & Nash, C. 1995. Bus deregulation: ten years on. Transport Reviews, 15, pages 229–251.

Madanipour, A., Cars, G., Allend, J. 1998. Social exclusion in European cities: processes, experiences and responses, pp. 75–94. London: Jessica Kingsley.

Madureira, N. L. 2008. When the South emulates the North: energy policies and nationalism in the twentieth century. Contemporary European History 17(1), 1-21.

Magill, F. N. 1999. The 17th and 18th Centuries: Dictionary of World Biography, Volume 4. Routledge; 1 edition (April 1, 1999).

Maguire, S., Hardy, C. & Lawrence, T. B. 2004. Institutional Entrepreneurship in Emerging Fields: HIV/AIDS Treatment Advocacy in Canada. The Academy of Management Journal 47(5). October 2004.

Marx, A. 2019. Public-Private Partnerships for Sustainable Development: Exploring Their Design and Its Impact on Effectiveness. Sustainability. Vol 11, pp. 1087. https://doi.org/10.3390/su11041087

Maryland Department of Transportation. 2017. Governor Larry Hogan announces next phase of traffic relief plan for major regional corridors. Media release, Maryland Department of Transportation. Accessed 11/11/2020 at https://roads.maryland.gov/mdotsha/pages/pressreleasedetails.aspx?newsId=3016&PageId=818

Mason, S. 2009. Matthew Boulton: Selling what all the world desires. Yale University Press. ISBN-10: 0300143583.

Mathews, J. A. 2013. The renewable energies technology surge: A new techno-economic paradigm in the making? Futures. Volume 46, February 2013, Pages 10-22. https://doi.org/10.1016/j.futures.2012.12.001

May, T. & Marvin, S. 2017. The future of sustainable cities: governance, policy and knowledge. The International Journal of Justice and Sustainability. Vol 22 (1), pp. 1-7.

McCormick, B., Folsom, Jr., B. W. 2003. A Survey of Business Historians on America's Greatest Entrepreneurs. Business History Review. 77, 4, 703-716.

McCormick, K., Neij, L., Anderberg, S., Coenen, L. 2013. Advancing sustainable urban transformation. Journal of Cleaner Production, 50, 1-11.

McDonald, A., Schrattenholzer, L. 2001. Learning rates for energy technologies. Energy Policy, 29, 4, 255-261.

McDonald, J. 2008. Adaptive intelligent power systems: active distribution networks. Energy Policy, Vol. 36, pp. 4346-4351.

McGuire, P., Granovetter, M., Schwartz, M. 1993. Thomas Edison and the social construction of the early electricity industry in America". Chapter 9 of Book: Swedberg, R. 1993. Explorations in Economic Sociology.

McIntosh, J., Trubka, R. & Newman, P. 2015. Tax increment financing framework for integrated transit and urban renewal projects in car dependent cities. Urban Planning and Research. Vol. 33 (1), pp. 37-60.

McIntosh, J., Trubka, R., Kenworthy, J. & Newman, P. 2014. The role of urban form and transit in city car dependence: Analysis of 26 global cities from 1960 to 2000. Transportation Research: Transport and Environment. Vol 33, pp. 95-110.

McIntosh, J., Trubka, R., Kenworthy, J. & Newman, P. 2014. Transportation Research: Transport and Environment, Volume 33, 2014, pp. 95-110.

McKinsey & Company. 2007. Curbing global energy demand growth: the energy productivity opportunity, McKinsey & Company.

McKinsey & Company. 2013. Infrastructure Productivity: How to save $1 trillion a year. McKinsey Global Institute, McKinsey Infrastructure Practice.

McKinsey Global Institute, 2016. Bridging Global Infrastructure Gaps. https://www.un.org/pga/71/wp-content/uploads/sites/40/2017/06/Bridging-Global-Infrastructure-Gaps-Full-report-June-2016.pdf

McLoughlin, J.B. 1969. Urban & regional planning: a systems approach. Faber and Faber.

McMahon, J. 2017. Big fuel savings from autonomous vehicles. Forbes, 17 April 2017.

McMullen, J. & Shepherd, D. A. 2006. Entrepreneurial action and the role of uncertainty in the theory of the entrepreneur. The Academy of Management Review. Vol 31(1), pp. 132-152.

Meadows, D. 2009. Thinking In Systems : a Primer. London, Sterling, VA:Earthscan.

Meadows, D., Meadows, D., Randers, J. & Behrens, W. 1972. The limits to growth. Potomac Associates (1972).

Mees, P. 2015. Privatisation and rail and tram services in Melbourne: What went wrong? Transport Reviews, Volume 25, No. 4, July 2005, Pages 433-449.

Mehta, L., Srivastava, S. & Adam, H.N. 2019. Climate change and uncertainty from 'above' and 'below': perspectives from India. Reg Environ Change. Vol. 19, pp. 1533–1547.

Meijer, A. & Bolivar, M. P. R. 2015. Governing the smart city: a review of the literature on smart urban governance. International Review of Administrative Sciences. Volume 82, Issue 2, 392-408.

Mendes-Moreira, J., Moreira-Matias, L., Gama, J. & Freire de Sousa, J. 2015. Validating the coverage of bus schedules: a machine learning approach. Inf. Sci. 293, 299–313.

Mengelkamp, E., Gärttner, J., Rock, K., Kessler, S., Orsini, L., Weinhardt, C. 2017a Designing microgrid energy markets: a case study: the brooklyn microgrid. Appl Energy.

Mengelkamp, E., Notheisen, B., Beer, C., Dauer, D., Weinhardt, C. 2017b. A blockchain-based smart grid: towards sustainable local energy markets. Computer Science – Research and Development, 33, 1-2, 207-214.

Meredith, J. 1993. Theory building through conceptual methods. International Journal of Operations & Production Management, Vol. 13 (5), pp. 3–11.

Metz, D. 2017. Future transport technologies for an ageing society: Practice and policy. In Transport, Travel and Later Life; Emerald Publishing Limited: Bingley, UK, 2017; pp. 207–220.

Meyer, A. D., Brooks, G. R. & Goes, J. B. 1990. Environmental Jolts and Industry Revolutions: Organization Responses to Discontinuous Change. Strategic Management Journal. Vol. 11, pp. 93-110.

Meyer, J., Becker, H., Bosch, P. & Axhausen, K. W. 2017. Autonomous Vehicles: The next jump in accessibilities? Research in Transportation Economics. Volume 62, June 2017, Pages 80-91.

Mintzberg, H. 1994. The rise and fall of strategic planning: reconceiving roles for planning, plans, planners. Free Press: New York.

Mogridge, M.J.H. 1990. Travel in towns. Jam yesterday, jam today and jam tomorrow? Macmillan Press, London.

Mori, T. & Nishikimi, K. 2002. Economies of transport density and industrial agglomeration. Regional Science and Urban Economics. Vol 32 (2), pp. 167-200.

Mourik, R. & Raven, R. 2006. A practitioner's view on strategic niche management: towards a future research outline. (ECN-E; Vol. ECN-E-06-039 EN). ECN.

Mullich, J. 2013. Drivers avoid traffic jams with Big Data and Analytics. Bloomberg L.P., New York.

Munson, R. 2005. From Edison to Enron. The Electricity Journal, 18, 9, 51-61.

Murphy, M., Danis, W. M. & Mack, J. 2020. From Principles to Action: Community-based entrepreneurship in the Toquaht Nation. Journal of Business Venturing. Vol 35 (6), pp. 106051.

Murray, M., Greer, J., Houston, D., McKay, S & Murtagh, B. 2009. Bridging top down and bottom up: Modelling community preferences for a dispersed rural settlement pattern. European Planning Studies. Vol 17 (3), pp. 441-462.

Næss, P., Mogridge, M. J. H. & Sandberg, S. L. 2001. Wider roads, more cars. Natural Resources Forum, Vol 25(2), pp. 147-155.

Næss, P., Nicolaisen, M. S. & Strand, A. 2012. Traffic forecasts ignoring induced demand: a shaky fundament for cost-benefit analysis. European Journal of Transport and Infrastructure Research, Vol. 12(3), pp. 291-309.

Næss, P., Nicolaisen, M. S., Strand, A. 2012. Traffic forecasts ignoring induced demand: a shaky fundament for cost-benefit analysis. European Journal of Transport and Infrastructure Research (EJTIR), Volume 12, no. 3, pp. 291-309.

NBC. 2015. 'DigitalGlobe enables satellites to recognize details of objects up to 30cm in size', NBC News, 26 February 2015

NEC. 2014. NEC to implement solutions for SMRT Corporation to enhance bus service excellence. Press release, August 5, 2014. Available at https://www.nec.com/en/press/201408/global_20140805_02.html

Newhofer, F. 2003. Systems thinking in education. Forum 45(2):75-77.

Newman, P. 2016. Sustainable urbanization: Four stages of infrastructure planning and progress. Journal of Sustainable Urbanization, Planning and Progress, 1(1), 3–10. doi:10.18063/JSUPP.2016.01.005.

Newman, P. and Kenworthy, J. 1989. Cities and automobile dependence. Gower Publishing Company, Aldershot.

Newman, P. and Kenworthy, J. 1999. Sustainability and Cities: Overcoming Automobile Dependence. Island Press.

Newman, P., Davies-Slate, S. & Jones, E. 2018. The entrepreneur rail model: Funding urban rail through majority private investment in urban regeneration. Research in Transportation Economics, Volume 67, May 2018, Pages 19-28.

Newman, P., Davies-Slate, S. & Jones, E. Why city deals are a deal-breaker for Australian cities. Response to the Inquiry into the Australian Government's role in the development of cities. Submission 28.

Newman, P., Davies-Slate, S., and Jones, E. 2018. The Entrepreneur Rail Model: Funding urban rail through majority private investment in urban regeneration, Research in Transportation Economics, Volume 67, 2018, Pages 19-28.

Newman, P., Davies-Slate, S., Conley, D., Hargroves, K., Mouritz, M. 2021. From TOD to TAC: The Transport Policy Shift to Transit Activated Corridors along Main Roads with New Technology Transit Systems. Urban Science. Vol 5(3), pp. 52.

Newman, P., Glazebrook, G. and Kenworthy, J. 2013. Peak Car and the Rise of Global Rail. Journal of Transportation Technologies. Vol 3 (4), pp. 272-287.

Newman, P., Hargroves, K., Davies-Slate, S., Conley, D., Vershuer, M., Mouritz. & Yangka, D. 2019. The Trackless Tram: Is It the Transit and City Shaping Catalyst We Have Been Waiting for? Journal of Transportation Technologies 09(01):31-55.

Newman, P., Kenworthy, J. 2015. The End of Automobile Dependence. Island Press.

Newman, P., Kosonen, L. and Kenworthy, J. 2016. Theory of urban fabrics: Planning the walking, transit/public transport and automobile/motor car cities for reduced car dependency. Town Planning Review. Vol 87 (4), pp. 429-458.

Newton, P. & Newman, P. 2013. The Geography of Solar Photovoltaics (PV) and a New Low Carbon Urban Transition Theory. Sustainability, Volume 5, 2537-2556.

Nicolaisen, M. S. and Næss, P. 2011. Vejenes virkelige værdi. Trafik og Veje, No. 10/2011, pp. 44-46.

Nicolaisen, M. S. and Næss, P. 2011. Vejenes virkelige værdi. Trafik og Veje, No. 10/2011, pp. 44-46.

Noland, R. B. and Lem, L. L. 2002. A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. Transportation Research Part D: Transport and Environment, Volume. 7, no 1, pp. 1-26.

Noordegraf, D. V., Heijligers, B., van de Riet, O. A. W. T. & van Wee, G. P. 2009. Technology options for distance-based road user charging schemes.

NTI 2018, 'NTI backs blockchain trial to support Australian agriculture and tighten export security', NTI, 10 December 2018.

Nye, D. E. 2004. Electricity use, history of. Reference Module in Earth Systems and Environmental Sciences, Encyclopaedia of Energy, 2004, 177-190.

O'Brien, P. & Pike, A. 2015. City Deals, decentralisation and the governance of local infrastructure funding and financing in the UK. National Institute Economic Review. August 2015, pp. R14-R26.

O'Grady, M. & O'Hare, G. 2012. How Smart Is Your City? Science 335: 3 (2012) pp. 1581–1582.

OECD. 2015. Official Development Finan ce for Infrastructure support by Multilateral and Bilateral Development Partners. OECD report to G20 Finance Ministers and Central Bank Governors, September 2015, page 9.

Ohland, G. & Poticha, S. 2009. Street Smart: Streetcars and Cities in the Twenty-first Century, 2nd Ed. Preface. Accessed at: http://www.reconnectingamerica.org/assets/Uploads/090305streetcarbook.pdf

Olsson, A., Westlund, H., and Larsson, J. 2015. Entrepeneurial Governance for Local Growth. In Kourtit, K., Nijkamp, P., Stouch, R, R., The Rise of the City: Spatial Dynamics in the Urban Century.

Olsson, P., Folke, C. & Hahn, T. 2004. Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. Ecology and Society, Vol 9.

Olsson, P., Gunderson, L., Carpenter, S., Ryan, P., Lebel, L., Folke, C. & Holling, C. 2006. Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. Ecology and Society, Vol. 11, pp. 18.

Ono, H. 2018. Research and development in the frontier service research laboratory. Special feature article. Accessed 11/11/2020 at https://www.jreast.co.jp/e/development/tech/pdf_38/tec-38-05-08eng.pdf

Opazo, J. 2014. The Politics of System Innovation for Emerging Technologies: Understanding the Uptake of Off-grid. University of Sussex (2014). http://sro.sussex.ac.uk/54509/

Oswald, A. J., Proto, E. & Sgroi, D. 2015. Happiness and productivity. Journal of Labor Economics, 33 (4). pp. 789-822.

Overgaard, K.R. 1966. Traffic Estimation in Urban Transportation Planning. Danish Academy of Technical Sciences, Lyngby.

Overgaard, K.R. 1966. Traffic Estimation in Urban Transportation Planning. Danish Academy of Technical Sciences, Lyngby.

Pahl-Wostl, C., Holtz, G., Kastens, B. & Knieper, C. 2010. Analyzing complex water governance regimes: the Management and Transition Framework. Environmental Science and Policy, Vol. 13, pp. 571-581.

Pangbourne, K., Stead, D., Mladenović, M. & Milakis, D. The case of mobility as a service: A critical reflection on challenges for urban transport and mobility governance. In Governance of the Smart Mobility Transition. Emerald Publishing Limited: Bingley, UK, 2018; pp. 33–48.

Parissien, S. 2013. The life of the automobile: A new history of the motor car. Tomas Dunne Books.

Parkinson, G. Victoria's battery storage won't be ready for this summer. Renew Economy. Accessed at https://reneweconomy.com.au/victorias-battery-storage-wont-ready-summer-64243/ on 26/09/2018.

Patel, S., and Mehta, K. 2016. Systems, Design, and Entrepreneurial Thinking: Comparative Frameworks. Systems Practice and Action Research, Springer. DOI 10.1007/s11213-016-9404-5

Pauli, G. 2009. The Blue Economy. A report to the Club of Rome. Paradigm Publications.

Pauli, G. 2017. The Blue Economy 3.0: The marriage of science, innovation and entrepreneurship creates a new business model that transforms society. Xlibris.

Pearson, P. J. G., Foxon, T. J. 2012. A low carbon industrial revolution? Insights and challenges from past technological and economic transformations. Energy Policy, 50, 117-127.

Perez, C. 2009. Technological revolutions and techno-economic paradigms. Cambridge Journal of Economics, 34, 185-202.

Perry, J. T., Chandler, G. N., Markova, G. 2012. Entrepreneurial effectuation: A review and suggestions for future research. Entrepreneurship Theory & Practice. DOI: 10.1111/j.1540-6520.2010.00435.x

Pierre, J. 2005. Comparative urban governance: Uncovering complex causalities. Urban Affairs Review, 40, 446–461.

Pierre, J. 2011. The politics of urban governance. Basingstoke, England: Palgrave.

Pierre, J. 2014. Can urban regimes travel in time and space? Urban regime theory, urban governance theory, and comparative urban politics. Urban Affairs Review, 50, 864–889.

Pissourios, I. 2014. Top-down and bottom-up urban and regional planning: Towards a framework for the use of planning standards. European Spatial Research and Policy. Vol 21 (1) pp. 1-17.

Po, M., Juliane, K. & Nancarrow. B.E. 2004. Literature Review of Factors Influencing Public Perceptions of Water Reuse. Australian Water Conservation and Reuse Research Program. CSIRO.

Pollitt, M.G. 2012. The role of policy in energy transitions: lessons from the energy liberalisation era. Energy Policy, 50, 128-137.

Portugali, J. 2016. What Makes Cities Complex?. In: Portugali J., Stolk E. (eds) Complexity, Cognition, Urban Planning and Design. Springer Proceedings in Complexity. Springer, Cham.

Potts, J., Foster, J., Straton, A. 2010. An entrepreneurial model of economic and environmental co-evolution. Ecological Economics, 70, 375-383.

Pozen, D. E. 2008. We are all entrepreneurs now. Wake Forest Law Review. 43: 283-340.

Pujari, D. 2006. Eco-innovation and new product development: understanding the influences on market performance. Technovation, 26(1), 76-85.

Pyper, J. 2014. Self-driving cars could cut greenhouse gas pollution. Scientific American, 15 September 2014.

Quillien, J. 2017. When Thievery Isn't an Option or an Overview of Embodied Making. In Presentation for the University of Krems, Purplsoc (Pattern Languages for Social Change). Conference Proceedings Forthcoming Summer 2018. Krems, Austria:University of Krems.

Raskin, P. & Swart, R. 2020. Excluded futures: the continuity bias in scenario assessments. Sustainable Earth, 3, 8, 2020.

Rauch, A., Wiklund, J., Lumpkin, G., and Frese, M. 2009. Entrepeneurial orientation and business performance: An assessment of past research and suggestions for the future. Entrepreneurship Theory and Practice, 33(3), 761-787.

Rauws, W. S., Cook, M. & Van Dijk, T. 2014. How to make development plans suitable for volatile contexts. Planning Practice & Research, 29, pp. 133–151.

Raven, R. & Geels, F. W. 2010. Socio-cognitive evolution in niche development: comparative analysis of biogas development in Denmark and The Netherlands (1973-2004). Technovation, 30 (2) (2010), pp. 87-99.

Raven, R. P. J. 2005. Strategic Niche Management for Biomass Eindhoven. Technische Universiteit Eindhoven (2005). https://doi-org.proxy.library.adelaide.edu.au/10.6100/IR590593

Rawnsley, T. 2014. Walking to global competitiveness: A case study of Melbourne's CBD. Sydney Walk 21 Presentation. https://www.sgsep.com.au/publications/walking-global-competitiveness-case-study-melbournes-cbd

Read, S., Song, M. & Smit, W. 2009. A meta-analytic review of effectuation and venture performance. Journal of Business Venturing. Vol. 24, pp. 573-587.

Reid, C. 2017. Build it and they will come? Why Britain's 1960s cycling revolution flopped. The Guardian, Tuesday 19 Sept, 2017. Accessed https://www.theguardian.com/cities/2017/sep/19/britains-1960s-cycling-revolution-flopped-stevenage.

Rhyzkov, A. & Sarzhan, Y. 2020. Market initiative and central planning: A study of the Moscow bus network. Research in Transportation Economics. August 2020, 100919.

Rifkin, J. 2011. The third industrial revolution: How lateral power is transforming energy, the economy, and the world. Palgrave Macmillan.

Rijke, J., Brown, R., Zevenbergen, C., Ashley, R., Farrelly, M., Morison, P., van Herk, S. 2012. Fit-for-purpose governance: a framework to make adaptive governance operational. Environmental Science and Policy, Vol. 22, pp. 73-84.

Rijke, J., Farrelly, M., Brown, R. & Zevenbergen, C. 2013. Configuring transformative governance to enhance resilient urban water systems. Environmental Science & Policy, Vol 25, pp. 62-72.

Rip, A. & Kemp, R. 1998. Technological change. In: Rayner, S., Malone, E.L. (Eds), Human Choice and Climate Change, Vol. 2. Battelle Press, Columbus, OH, pp. 327–399.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F., Lambin, E., Lenton, T., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., de Wit, C., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R., Fabry, V., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., and Foley, J. 2009. A safe operating space for humanity. Nature, 461, pp. 472-475.

Rogge, K. & Reichardt, K. 2013. Towards a comprehensive policy mix conceptualisation for environmental technological change: a literature synthesis. Working paper, no. S3/2013.

Rogge, K. S. & Reichardt, K. 2016. Policy mixes for sustainability transitions: An extended concept and framework for analysis. Research Policy, Vol. 45(8), pp. 1620-1635.

Romijn, H., Raven, R., de Visser, I. 2010. Biomass energy experiments in rural India: insights from learning-based development approaches and lessons for Strategic Niche Management. Environ. Sci. Pol., 13 (4) (2010), pp. 326-338.

Ruhl, C., Appleby, P., Fenema, J., Naumov, A., Schaffer, M. 2012. Economic development and the demand for energy: a historical perspective on the next 20 years. Energy Policy, 50, 109-116.

Rutter, P., Keirstead, J. 2012. A brief history and the possible future of urban energy systems. Energy Policy, 72-80.

Sabatier, P. 1986. Top-down and bottom-up approaches to implementation research: a critical analysis and suggested synthesis. Journal of Public Policy. Vol 6 (1), pp. 21-48.

SACTRA. 1994. Trunk roads and the generation of traffic. Standing Advisory Committee on Trunk Road Assessment, London.

Salet, W., Bertolini, L. & Giezen, M. 2013. Complexity and Uncertainty: Problem or Asset in Decision Making of Mega Infrastructure Projects? International Journal of Urban and Regional Research, 37, pp. 1984–2000.

Sarason, Y., Dean, T. & Dillard, J. 2006. Entrepreneurship as the nexus of individual and opportunity: a structuration view. Journal of Business Venturing, Vol. 21(3), 286-305.

Sarasvathy S. D. 2001. Causation and effectuation: toward a theoretical shift from economic inevitability to entrepreneurial contingency. Academy of Management Review. Vol. 26(2), pp. 243-263.

Sarasvathy, S. D. 2003. Entrepreneurship as a science of the artificial. Journal of Economic Psychology, Vol. 24(2), pp. 203-220.

Sarasvathy, S. 2009. Effectuation: Elements of entrepreneurial expertise. Edward Elgar Publishing.

Sarasvathy, S. D., & Botha, H. 2022. Bringing People to the Table in New Ventures: An Effectual Approach. Negotiation Journal, Vol. 38(1), pp. 11-34.

Sarasvathy, S. & Dew, N. 2005. New market creation through transformation. Journal of Evolutionary Economics. Vol. 15, 533-565.

Sarasvathy, S. D., & Ramesh, A. 2019. An effectual model of collective action for addressing sustainability challenges. Academy of Management Perspectives, Vol. 33(4), pp. 405-424.

SCC 2016, ‘Lessons from a CTO: Seattle’s path to becoming smarter’, Smart Cities Council

Schot, J. & Geels, F. W. 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technology Analysis & Strategic Management. Vol. 20, No. 5, September 2008, 537–554.

Schot, J. & Steinmueller, W. E. 2018. New directions for innovation studies: missions and transformations. Research Policy, 47 (9) (2018), pp. 1583-1584.

Schumpeter, J. A. 1934. The theory of economic development. Harvard Economic Studies 46.

Schumpeter, J. A. 1934. The theory of economic development. Harvard Economic Studies 46.

Sen, A. 2013. The ends and means of sustainability. Journal of Human Development and Capabilities, 14 (1) (2013), pp. 6-20.

SEPTA, 2015. Positive Train Control. Accessed 11/11/2020 at http://www.septa.org/ptc/

Sergi, B.S., Popkova, E.G., Borzenko, K.V. & Przhedetskaya, N.V. 2019. Public–Private Partnerships as a Mechanism of Financing Sustainable Development. In: Ziolo, M., Sergi, B.S. (eds) Financing Sustainable Development. Palgrave Studies in Impact Finance. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-16522-2_13

Seto, K., Güneralp, B., and Hutyra, L. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proc Natl Acad Sci USA 109(40):16083–16088

Seyfang, G., & Smith, A. 2007. Grassroots innovations for sustainable development: Towards a new research and policy agenda. Environmental Politics, 16(4), 584-603.

SFCTA. 2017. TNC's Today - A Profile of San Francisco Transportation Network Company Activity. Draft Report. San Francisco, CA: San Francisco County Transportation Authority.

Shane, S. & Venkataraman, S. 2000. The promise as entrepreneurship as a field of research. The Academy of Management Review, Vol. 25, No. 1 (Jan., 2000), pp. 217-226.

Sharma, R. & Newman, P. 2017. Does rail increase land value in emerging cities? Value uplift from Bangalore metro. Transport Research Part A: Policy and Practice, Volume 117, November 2018, Pages 70-86.

Short, J. R. and Kim, Y.-H. 1999. Globalization and the City. Harlow: Addison Wesley LongmanLtd.

Shoup, D. 2018. Parking and the City. Routledge.

Shove, E. & Walker, G. 2007. Caution! Transitions ahead: Politics, practice, and sustainable transition management. Environmental Planning Part A, Vol. 39, pp. 763–770.

Siemens Mobility, 2020. Increasing COVID-19 resilience of public transport: Offerings to mitigate risks for passengers and operators. Accessed 08/08/2020 at https://assets.new.siemens.com/siemens/assets/api/uuid:d6ee3221-0c38-451e-ab1d-8ec3aff81aae/increasing-covid-19-resilience-of-public-transport.pdf

Simmons, J. 1961. The railways of Britain – a historical introduction. Routledge and Kegan Paul, London, 1961.

Simon, H.A. & Chase, W.G., 1973. Skill in chess. American Scientist 61 (4), pp. 394–403.

Sine, W. D., David, R. J. 2003. Environmental jolts, institutional change, and the creation of entrepreneurial opportunity in the US electric power industry. Research Policy, 32, 2, 185-207.

Smales, L. A. 2021. Geopolitical risk and volatility spillovers in oil and stock markets. The Quarterly Review of Economics and Finance, Vol. 80, pp.358-366.

Smil, V. 1994. Energy in World History. Westview Press Inc, Boulder.

Smil, V. 2000. Energy in the twentieth century: resources, conversions, costs, uses, and consequences. Annual Review of Energy & Environment, 25, 21–51.

Smil, V. 2010. Energy Transitions: History, Requirements, Prospects. Praeger Publishers. Santa Barbara, CA.

Smil, V. 2017. Energy and civilization, a history. The MIT Press. ISBN: 0262035774.

Smith, A. & Raven, R. 2012. What is protective space? Reconsidering niches in transitions to sustainability. Research Policy. Research Policy 41 (2012) 1025–1036.

Smith, A. J. 1999. Privatized infrastructure: The role of government. Thomas Telford Publishing, London.

Smith, A., & Raven, R. 2012. What is protective space? Reconsidering niches in transitions to sustainability. Research Policy, 41(6), 1025-1036.

Smith, A., Stirling, A. & Berkhout, F. 2005. The governance of sustainable socio-technical transitions. Research Policy, Vol. 34, pp. 1491-1510.

Smith, A., Voß, J. P. & Grin, J. 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. Research policy, 39(4), 435-448.

Smith, M. H., Hargroves, K., Desha, C. 2010. Cents and Sustainability: Securing our common future by decoupling economic growth from environmental pressures. Earthscan/Routledge, London.

Snowden, D., and Boone, M. 2007. A Leader's Framework for Decision Making. Harvard Business Review. 2007 Nov; 85(11):68-76, 149.

Solomonow S., Mosquera, N. 2012. NYC DOT announces expansion of Midtown congestion management system, receives National Transportation Award. The City of New York, June 5.

Spielvogel, J. J. 2011. Western Civilization: Volume C: Since 1789. Wadsworth Publishing. ISBN-10: 1111342164.

Stacey, T. 2005. Thomas Brassey: The greatest railway builder in the world. London: Stacey International. ISBN 1-905299-09-5.

Stake, R. E. 1995. The art of case study research. Sage Publications.

Steffen, W., Richardson, K., Rockstr€om, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A. 2015. Planetary boundaries: guiding human development on a changing planet. Science 347, 1259855.

Stern, N. 2006. The Stern Review on the Economic of Climate Change. Report commissioned by the Government of the United Kingdom. Cambridge University Press, Cambridge.

Stern, N. 2011. The Low-Carbon Industrial Revolution, Powerpoint Presentation, Grantham Research Institute on Climate Change and the Environment, LSE. http://www.lse.ac.uk/website-archive/publicEvents/pdf/20110317%20Nick%20Stern%20ppt.pdf.

Stern, N. 2015. Why are we waiting? The logic, urgency and promise of tackling climate change. Lionel Robbins Lectures.

Sterrenberg L., Andringa J., Loorbach D., Raven R. and Wieczorek A. 2013. Low-carbon transition through system innovation: Theoretical notions and applications. Pioneers into Practice mentoring program 2013.

Stoker, G. 1995. Public-private partnerships and urban governance. Paper presented to the Housing Studies Association Conference, Edinburgh, July. Department of Government, University of Strathclyde, Glasgow.

Stoker, G. 1996. Governance as theory: five propositions. Paper presented to Enjeux des Debats sur la Governance, Universite de Lausanne, November. Department of Government, University of Strathclyde, Glasgow.

Stone, C. 1989. Regime politics: Governing Atlanta 1946–1988. Lawrence: University Press of Kansas.

Stopford, J. M. & Baden-Fuller, C. W. 1994. Creating corporate entrepreneurship. Strategic Management Journal. Vol. 15 (7), pp. 521–536.

Sustainability Victoria. 2011. Business models for enabling sustainable precincts. Research report, prepared for Sustainability Victoria by Moreland Energy Foundation, Net Balance and Green Spark Consulting.

Szczygielski, J. J., Charteris, A., Bwanya, P. R. & Brzeszczyński, J. 2022. The impact and role of COVID-19 uncertainty: A global industry analysis. International Review of Financial Analysis. Vol 80.

T.J.N.M. De Bruijn, V. Norberg-Bohm (Eds.), Industrial Transformation; Voluntary Collaborative and Information based Approaches in Environmental Policies in the US and Europe, MIT Press, Cambridge, MA (2005)

Takamatsu, M., Kawasaki, A., Rogers, P.P., Malakie, J.L., 2014. Development of a land use forecast tool for future water resources assessment: case study for the Mekong River 3S Sub-basins. Sustainability Science, 9, pp. 157-172.

Tan, C. W., Park, S., Liu, H., Xu, Q. & Lau, P. 2008. Prediction of transit vehicle arrival time for signal priority control: algorithm and performance. IEEE Transactions on Intelligent Transportation Systems. Vol 9 (4), pp. 688-696.

Te Brommelstroet, M., Nello-Deakin, S., Quillien, J. & Bhattacharya, I. 2017. Towards a pattern language for cycling environments: merging variables and languages. Applied Mobilities, 17 Aug 2018.

Teisman, G. R. 2008. Complexity and management of improvement programmes: An evolutionary approach. Public Management Review, 10, pp. 341–359.

Thiyagarajah, R. A. 2005. Sustainable wastewater reuse through private sector participation – the Adelaide experience.

Thomas, A.S. & Mueller, S.L. 2000. A case for comparative entrepreneurship: assessing the relevance of culture. Journal of International Business Studies, Vol. 31 No. 2, pp. 287-301.

Thomson, J.M. 1977. Great cities and their traffic. Gollancz, London.

Tomaney, J. & McCarthy, A. 2015. The Manchester Model. Town and Country Planning. May, London, Town and Country Planning Association.

Torgerson, D. 2017. Policy sciences and democracy: a re-examination. Policy Science, 50 (3), pp. 339-350.

Trencher, G., Yarime, M., McCormick, K. & Doll, C. N. H. 2014. Beyond the third mission: Exploring the emerging university function of co-creation for sustainability. Science and Public Policy. 41(2):151-179.

TriMet. 2012.Airport MAX tour fact sheet. Accessible at: https://trimet.org/pdfs/history/railfactsheetairport.pdf

Trinks, A., Scholtens, B., Mulder, M., & Dam, L. 2018. Fossil Fuel Divestment and Portfolio Performance, Ecological Economics, Volume 146, 2018, Pages 740-748.

Truffer, B. & Coenen, L. 2012. Environmental innovation and sustainability transitions in regional studies. Regional Studies, 46(1), pp.1-21.

Tsukada, S. & Kuranami, C. 1990. Value capture with integrated urban rail and land development: The Japanese experience and its applicability to developing countries. In Proceedings of Seminar M held at the PTRC Transport and Planning Summer Annual Meeting: University of Sussex (VolumeP339).

Turnheim, B. & Geels, F. W. 2012. Regime destabilisation as the flipside of energy transitions: lessons from the history of the British coal industry (1913–1997). Energy Policy, 50(2012), pp. 35-49.

UITP. 2017. Alphaba Smart Bus. Accessed 11/11/2020 at https://space.uitp.org/initiatives/alphaba-smart-bus-av-pilot-shenzhen-china

UNFCCC. 2017. Accelerated Action on Energy Needed to Implement Paris. UN Climate Press Release 10/11/2017. Accessed on 26/09/2018 at https://unfccc.int/news/accelerated-action-on-energy-needed-to-implement-paris

United Nations Centre for Regional Development. 2018. Summary document of Regional Environmentally Sustainable Transport Training Course: “Railways as the low-carbon and sustainable transport development solutions in achieving safe, inclusive, efficient and resilient communities under the 2030 Agenda for Sustainable Development”. Accessed 06/06/2020 at https://www.uncrd.or.jp/content/documents/6689Training%20Summary%20EST%20Railways%202018%20(FINAL).pdf

United Nations Framework Convention on Climate Change (UNFCCC). 2021. Synthesis report on the aggregate effect of the nationally determined contributions.

United Nations Human Settlements Programme, 2023. Urban Energy Overview. Accessed 01/01/2023 at: https://unhabitat.org/topic/urban-energy

United Nations, 2022. The 17 Sustainable Development Goals. Accessed at 01/01/2022 at: https://sdgs.un.org/goals

United Nations. 2014. World Urbanization Prospects, United Nations.

United Nations. 2015. World Population Prospects: 2015 Revision, United Nations.

Universal Ecological Fund. 2019. The truth behind the climate pledges. Report. ISBN: 978-9831909-3-6.

Unruh, G. C. 2000. Understanding carbon lock-in. Energy Policy, Vol. 28 (12), pp. 817-830.

US Department of Transport. 2018. What Blockchain could mean for Government and Transportation Operations, United States Department of Transportation, Volpe Centre, DOT-VNTSC-18-03.

Van de Belt, H., and A. Rip. 1984. Technologie-ontwikkeling: het Nelson–Winter/Dosi model.A report to the Government, Office of Science Policy. LISBON, University of Leiden.

van de Meene, S., Brown, R., Farrelly, M. 2011. Towards understanding governance for sustainable urban water management. Global Environmental Change, Vol. 21, pp. 1117-1127.

Van de Velde, D. M. 1999. Organisational form and entrepreneurship in public transport: classifying organisational forms. Transport Policy. Volume 6, Issue 3, July 1999, Pages 147-157.

Van de Ven, A. H. 1992. Suggestions for studying strategy process: a research note. Strategic Management Journal. Vol. 13, pp. 169-191.

Van den Bergh, J. C. J. M. 2013. Economic-financial crisis and sustainability transition: introduction to the special issue. Environmental Innovation and Societal Transitions, 6 (2013), pp. 1-8.

Van Lente, H. 1993. Chapter 6: construction by expectations, in: Lente, H. van, Promising Technology – The dynamics of Expectations in Technological Developments, Twente University, p. 177-204.

Van Woerkum, C., Aarts, N. & Van Herzele, A. 2011. Changed planning for planned and unplanned change. Planning Theory, 10, pp. 144–160.

Veldhuizen, C. 2021. Conceptualising the foundations of sustainability focused innovation policy: From constructivism to holism. Technological Forecasting and Social Change. Vol 162.

Verreynne, M., Meyer, D., Liesch, P. 2016. Beyond the formal-informal dichotomy of small firm strategy-making in stable and dynamic environments. Journal of Small Business Management. 54 (2), pp. 420-444.

von Hippel, Eric and Marcie Tyre (1995) "How "Learning by Doing" is Done: Problem Identification in Novel Process Equipment." Research Policy (January) p. 1-12.

von Weizsacker, E. U., Lovins, A. & Lovins, L. H. 1995. Factor four: doubling wealth, halving resource use. Routledge.

von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. & Stasinopoulos, P. 2009. Factor 5: Transforming the global economy through 80% increase in resource productivity. Earthscan, UK and Droemer, Germany.

Voytenko, et al. 2016. Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda. Journal of Cleaner Production, 123, 45-54.

Vuchic, V. R. 2014. Urban transit: Operations, planning and economics. Wiley Publishing.

Wadud, Z., MacKenzie, D. & Leiby, P. 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. Transport Research Part A: Policy and Practice. 2016, Vol. 86, pp. 1–18.

Walker, J. 2018. Auckland: the new bus network is complete! Human Transit. Accessed 28/09/2020 at https://humantransit.org/2018/09/auckland-the-new-bus-network-is-complete.html

Walloth, C. 2016. Emergent nested systems: A theory of understanding and influencing complex systems as well as case studies in urban systems. Springer.

Walsh, P. R. 2012. Innovation Nirvana or Innovation Wasteland? Identifying commercialization strategies for small and medium renewable energy enterprises. Technovation, 32(1), 32-42.

Washburn, D., Sindhu, U., Balaouras, S., Dines, R.A., Hayes, N.M. & Nelson, L.E. 2010. Helping CIOs Understand "Smart City" Initiatives: Defining the Smart City, Its Drivers, and the Role of the CIO (Cambridge, MA: Forrester Research, 2010).

Watts, S. 2005. The people's tycoon: Henry Ford and the American century.

Weber, M & Rohracher, H. 2012. Legitimizing research, technology and innovation policies for transformative change. Research Policy 41, 1037–1047.

Wee-Liang, Williams, J., and Tan, T-M. 2005. Defining the 'Social' in 'Social Entrepreneurship': Altruism and Entrepreneurship. The International Entrepreneurship and Management Journal. no. 3 (2005): 353-365.

Wells, J. 2013. Complexity and Sustainability. Routledge, New York.

Whetten, D. A. 1989. What constitutes a theoretical contribution? Academy of Management Review, Vol. 14 (4), pp. 490–495.

Whetten, D. A. 2009. Modeling theoretic propositions. In A. S. Huff (Ed.), Designing research for publication (pp. 217– 250). Los Angeles, CA: Sage.

White, L. 1943. Energy and the evolution of culture. American Anthropologist, 45, 3, 335-356.

White, P. R. 1997. What conclusions can be drawn from bus deregulation in Britain? Transport Reviews, 17, pages 1–16.

Whitehead, C. M. E. 2006. Planning policies and affordable housing: England as a successful case study? Housing Studies. Vol. 22 (1), pp. 25-44.

Whiteman, G., Walker, B., & Perego, P. 2013. Planetary boundaries: ecological foundations for corporate sustainability. J. Manag. Stud. 50, pp. 307-336.

Wilks-Heeg, S., Perry, N. & Harding, A. 2003. Metropolitan regions in the face of the European dimension: Regimes, re-scaling or repositioning? In Metropolitan Governance and Spatial Planning: Comparative Case Studies of European City Regions; Salet, W., Thornley, A., Kreukels, A., Eds.; Spon Press: London, UK, 2003; pp. 20–38.

Willmont, J. 2017. UK based oil and gas sector insolvencies hit a new high. Written for Moore Stephens, UK. Accessed 05/09/2018 at: https://www.moorestephens.co.uk/news-views/january-2017/uk-based-oil-and-gas-sector-insolvencies

Wilson, C. 2012. Up-scaling, formative phases, and learning in the historical diffusion of energy technologies. Energy Policy, 50, 81-94.

Wilson, K., Desha, C., Bucolo, S., Miller, E., & Hargroves, K. 2014. Emerging Opportunities for "Design Thinking" to Deliver Sustainable Solutions in the Built Environment. The International Journal of Design Management and Professional Practice, 8(1), pp. 1-10.

Wiltbank, R., Dew, N., Read, S. & Sarasvathy, S. 2006. What to do next? The case for non-predictive strategy. Strategic Management Journal. Vol. 27(10), pp. 981-998.

Winch, G. 2002. Managing construction projects: An information processing approach. Wiley. ISBN: 0632058889.

World Urbanization Prospects - United Nations population estimates and projections of major Urban Agglomerations

Xue, Y., You, J., Liang, X., Liu, H-C. 2016. Adopting strategic niche management to evaluate EV demonstration projects in China. Sustainability 2016, 8, 142.

Yates, J. 1997 Using Giddens structuration theory to inform business history. Business and Economic History. 26 (1).

Yigitcanlar, T., Kamruzzaman, M. D., Foth, M., Sabantini-Marques, J., da Costa, E., Ioppolo, G. 2019. Can cities become smart without being sustainable? A systematic review of the literature, Sustainable Cities and Society, Vol. 45, pp. 348-365, ISSN 2210-6707.

Yin, R. K. 2003. Case study research: Design and methods (3rd ed.). Sage Publications.

APPENDIX A: SUMMARY OF INTERVIEWS

Interview Overview

The interviews conducted were face-to-face semi-structured interviews by the PhD candidate. Each interview was approximately 60 minutes in length and was informed by a participant information sheet and based on a set of questions (provided below). The interviews were conducted between July 2017 (International) and April 2020 (Willunga Basin).

Interview Participants

A total of nine interviews were conducted to inform this study. To inform the development of the effectual urban governance model, interview participants were sourced due to their (a) involvement and understanding of the formation of the Willunga Basin Water Company; and/or (b) involvement in global governance, infrastructure development and/or entrepreneurship.

The researcher agreed to not share the names of the interview participants directly in this thesis, however their characteristics are as follows:

1. Senior Infrastructure Professional (Water Sector) who was at one stage Chair of the Willunga Basin Water Company.
2. Senior Infrastructure Professional (Water Sector) who was intricately involved in the formation of the Willunga Basin Water Company.
3. International Diplomat for the United Nations Framework Convention on Climate Change, who was intricately involved in the ratification of the Paris Agreement.
4. Chief Executive of Climate-focused International Non-Profit Organisation working across Australia, Southeast Asia and the Pacific.
5. International Sustainability Entrepreneur
6. 4 x Senior International Transport Experts, with extensive experience working in both developing and developed economy contexts.

Interview Structure

All participants were provided a briefing pack prior to the interview, providing a summary of the principles of effectuation.

Willunga Basin Water Company:

- Introduction to understand participant involvement in WBWC project.
- Ask participant for personal recount of WBWC formation.
- Ask participant for thoughts on the principles of effectuation shared prior to the interview.
- Ask participant for thoughts on the framework of uncertainty and systems change shared prior to the interview.
- Open-ended discussion.

International:

- Do urban sustainability transitions need to be accelerated? If so, what might lead to an acceleration of such change?
- Could a focus on starting with 'available means' rather than pre-determined ends accelerate sustainability transitions?
- Could action based on affordable loss rather than expected return accelerate sustainability transitions?
- Could leveraging contingencies accelerate sustainability transitions?
- Could a greater focus on control rather than prediction accelerate sustainability transitions?

Interview Outcomes

The interviews conducted as part of this thesis research were used to both inform and validate the development of the effectual urban governance model. In the case of the Willunga Basin

Water Company, there is a large suite of existing literature outlining the case, however none that have analysed it from an effectual perspective. As such, the case study in this thesis was constructed using prior literature combined with additional details sourced through the interviews.

APPENDIX B: AUTONOMOUS RAIL RAPID TRANSIT – YIBIN, CHINA

Context

The city of Yibin is located in the South-east of the Sichuan Province in China. The city is located at the junction of the Min and Yangtze rivers and has a population of 797,639 in its urban centre (UN World Urbanization Prospects, 2019), and approximately 4.5 million in the broader metropolitan area. The population of the city is small by Chinese standards, however the central urban population of approximately 800,000 reflects the populations of many mid-size cities in other countries around the world, such as the United States, Australia and Europe (albeit higher density that Australia and US cities as seen in the images).

Figure A2-1: Autonomous Rail Rapid Transit (ART) in Yibin, Sichuan Province, China 2019

Like many Chinese cities, Yibin has a central railway station that links it to other cities, with Chengdu being the major urban agglomeration in the Sichuan Province that most inter-city trips take place between. Yibin's urban transport is made up of private automobiles, buses, motorised two-wheelers (scooters and motorbikes) and bicycles (with frequent hire bike bays). Relatively, Yibin does not suffer from the levels of congestion witnessed in bigger Chinese cities.

Overview of Yibin's Autonomous Rail Rapid Transit Route

Yibin's T1 ART route is the first Trackless Tram route to enter revenue service in the world. However, prior to entering revenue service the CRRC in partnership with local authorities ran a trial route

throughout 2019. At the time of the site visit that informed this study, Yibin's ART route implemented by the Chinese Railway Rolling Stock Company (CRRC) was 9.7km long. The route was extended to 17.7km and commenced commercial operation on December 5th, 2019. There is approximately 150km of additional track planned for across the city.

Seen in Figure A2-2 below, at one end of the route is the 'ART Industry Park', adjacent the Belt and Road offices and nearby to the CRRC offices, production facility and depot. ART vehicles charge at this end of the line for 10 minutes each run. At the other end is the Jiudu Road Station, located in a dense urban area of Yibin. This location is in the heart of a lively urban area, surrounded by shops, residential buildings and office spaces. The initial 9.7km stage (solid blue line) and second stage (dotted red line) of Yibin's ART route can be seen in Figure A2-2.

The initial stage route has 9 stations, and traverses urban areas varying from outer highways with adjacent industrial complexes, across the Chongjiang Bridge, and into the urban centre which is mixed use and high density. The ART's run at a frequency of every 15 minutes between 7:30am and 8:00pm. They have 6 of 16 vehicles operational currently and in peak hours increase the frequency to every 10 minutes.

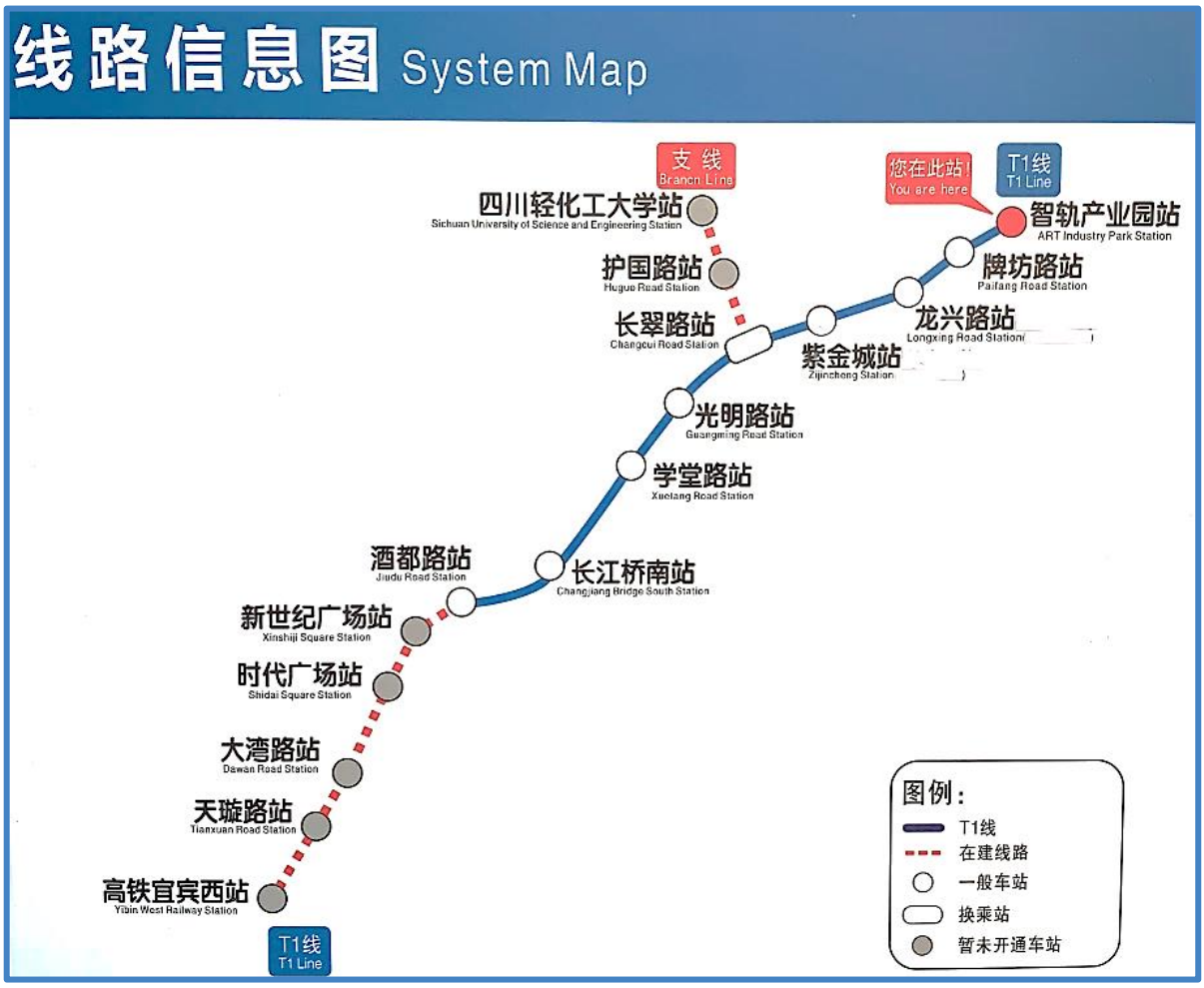


Figure A2-2: ART System Map during November 2019 (prior to full operation of map). In November 2019 dark blue line represented operational line and dotted red line represented soon-to-be-opened line (Captured by researcher in December 2019).

In November 2019 the ART line served a respectable number of riders each day as witnessed by the research team's visit to the city. The initial implementation of the system did not have an associated user charge, as a way to familiarise commuters with the new vehicles, and obtain feedback on their operation. The total 17.7km system connects key precincts such as the University District, and Yibin's Railway Station.

The cost of the 17.7km project was 1.128b Yuan (USD $160M), which comprised of 940M Yuan (USD $133.84M) for the transit system and 188M Yuan (USD $26.8M) for urban infrastructure construction. This equals a total cost of approximately USD $9.04M/km, significantly less than the costs that are being achieved by light rail projects around the world.

Urban settings serviced by the ART

This section describes each of the urban settings that the ART travels through along the initial 9.7km portion of the route. Here the movement and place characteristics of the sections are described, to highlight lessons applicable to other global cities. For each urban setting, the key features (land use and transport observations), ART strategies (planning and operational strategies), and general reflections on the ART's effectiveness as an urban transit system are presented.

The three distinct Urban Settings outlined in this case study are:

1. Arterial roads and highways (High movement; Low place)
2. Space-restricted mixed traffic (High movement; Low place)
3. Dense, mixed use urban core (Medium movement; High place)

Urban Setting 1: Arterial roads and highways

Seen below in Figure A2-3, the 'arterial roads' urban setting features wide, multi-lane highways in the outer areas of the metropolitan area. The ART travels through this type of urban setting between the ART Industry Park Station and Xuetang Road Station. In this context there is ample road space to reallocate a lane from private vehicles in order to provide lane priority for the ART.

Figure A2-3: ART arriving at ART Industry Park Station along wide, multi-lane main road located in the outer urban area (Source: Daniel Conley)

The Arterial roads and highways urban setting has the following movement and place functions.

Movement	**High**	Primarily an urban setting that is characteristic of corridors designed to facilitate the movement of vehicles, particularly between outer and neighbouring metropolitan areas and the centre of Yibin. Wide highways consisting of 4-5 traffic lanes, road space provision reflective of high volume private automobiles and two-wheelers.
Place	**Low**	The destinations that appear along this road corridor are more dispersed than in the core urban area. While there are footpaths for walking between buildings, they are along roads with high traffic speeds. Buildings are a mix of office and industrial, with minimal accompanying shop fronts or other mixed uses.

Key features of this urban setting:

- Ample road space: Main road comprised of 4-5 lanes of road space created primarily for private vehicles, due to outer metropolitan area and focus on moving vehicles long distances. As seen in Figure A2-3, noting that this image was taken during interpeak period (approximately 12pm), there are very minimal vehicles on the road. It is feasible in this urban setting to allocate a priority lane for the ART.
- Pedestrians are not primary users: Pedestrian footpaths are directly adjacent traffic lanes with high speeds, road crossings are spread far apart from one another, and there are little-to-no

shopfronts or accompanying amenities. This urban setting is reflective of higher prioritisation of vehicle movements than pedestrians or cyclists.

- Dispersed destinations: The destinations that make up the land use adjacent main roads are more dispersed and primarily industrial and commercial.

Key features of the ART system observed in this urban setting:

- Lane priority: The ART system is provided lane priority along wide main roads, to remove the interference of traffic. This is particularly important in such a setting because the ART has longer distance to travel from the end of the line into the centre of the city. In the case where these roads are congested at peak hour, lane priority contributes to the ART being a mode of choice due to shorter travel times.
- Large prominent stations: The ART stations are prominent within the community, like a light rail or BRT interchange. In this urban setting this adds a safe space for transit users to wait for the ART, given the busy and high-speed road environment. It also features passenger amenities such as toilets and green space (See Table A2-1).
- Fast charging at terminal: ART Industry Park Station is at the end of the line, and each ART vehicle charges here for approximately 10 minutes prior to completing a full end-to-end trip again.

Reflections on ART system on arterial roads and highways:

- In an outer main road urban setting that is primarily focused on performing a movement function rather than a place one, the ART is able to introduce a highly efficient passenger lane into a predominantly car-based stretch of road.
- The ART works well to link key precincts along this corridor. Given it is not a ‘high street’ urban environment, the ART is more effective in performing a mid-range transport function for commuters between key precincts – providing the opportunity for travellers to avoid peak hour congestion. Stations in this urban settings suit feeder services that can drop passengers from outer metro areas into ART stations, to then be taken into the city centre.
- Amongst the noise and chaos of a typical main road, the ART stations were the nicest places to be. The clean and ambient environment created by indoor plants, toilet amenities, and transport service officials was pleasant and a people-centric highlight amongst the surrounding area.

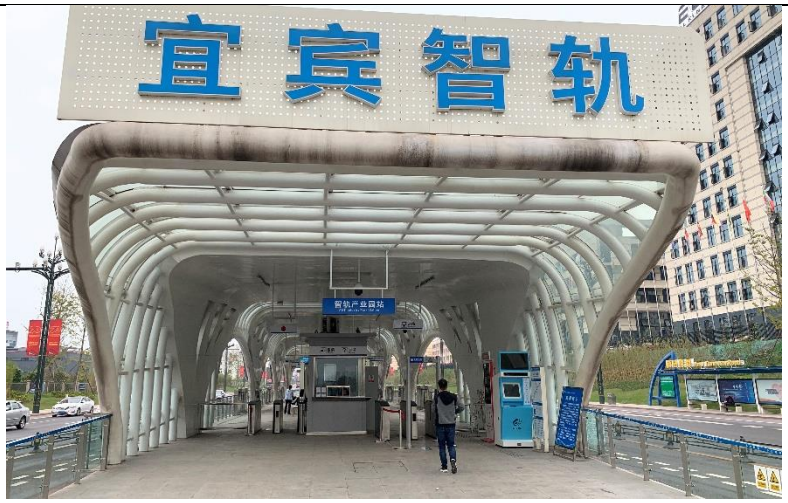
Lessons for effectual action:

- The ART in the arterial roads and highways urban setting takes advantage of the existing infrastructure and space to implement the system. Pavements on these types of roads are often reinforced to cater for heavy vehicles for freight and logistics. By doing so, construction costs are reduced and disruption is avoided.

- Lane priority adds the functionality of the system and improves the customer experience. Taking effectual action to implement this system demonstrates value to customers, which would not be achieved if the ART was run in mixed traffic with other vehicles and not given its own lane priority.
- The ART Industry Park station resembles a metro station in its size and amenity. This is not 'minimising expenditure at all costs', but instead doing stations properly to improve customer experience. It also provides the opportunity for partnerships, such as with land developers who see the potential of the system to attract activity and development to the surrounding catchment due to the prominence of the system within the community.

Table A2-1: Images from Arterial Roads and Highways Urban Setting (Source: Daniel Conley)

Observations	Image
Clear signage communicating lane priority of ART to motorists on main roads.	 ***Signage communicating lane priority for ART***
Four buses are observed utilising the ART lane. Site observations highlighted a delay to the ART vehicle as a result of being behind buses waiting to turn left at this busy intersection. There is the opportunity for traffic signal priority for these buses if it means they can avoid impacting the reliability the ART system.	 ***Buses waiting to turn from ART lane***

Once the ART drops passengers at ART Industry Park Station, it travels another approximately 200m to re-charge it's batteries for 10 minutes. This 10 minute charge allows the vehicle to perform a round-trip before charging at this end again (and avoids the need for overhead wires).	 ***ART vehicle re-charging at ART Industry Park terminal***
Large, prominent station at ART Industry Park Station, signalling permanency of the system. This terminal is larger than most ART stations seen in more place-oriented areas of the route.	 ***Tram/BRT like station at ART Industry Park Station***
Entrance to ART Industry Park Station. Amenity and customer-oriented features include service assistant, gated ticketing, signage and real time information.	 ***Entrance to ART Industry Park Station***

Taken after passengers have boarded the ART, this image shows the cleanliness and amenity of the stations. Customer-centric amenity includes green plants, maps and real time information, and toilet facilities down the far end.	 ***ART Industry Park Station***

Urban Setting 2: Space-constrained mixed traffic across the Chongjiang Bridge

At the confluence of the Min and Jinsha Rivers, Yibin's Changjiang Bridge is the first bridge to cross the world's third longest river, the Yangtze River. The space constraints of the bridge means there is only two lanes of traffic moving in each direction, with relatively high traffic flows due to its role in allowing traffic to cross the river. This urban setting requires the ART route to merge with traffic rather than having its own priority lane.

Figure A2-4: ART vehicle crossing the Changjiang Bridge in mixed traffic lane (Source: Daniel Conley)

This urban setting has the following movement and place functions:

Movement	**High**	By nature, a bridge is a structure of limited width that must transport people, vehicles, goods from one side of a river (in this case) to the other. Therefore, there are limited alternatives for places to cross, logically leading to higher levels of congestion in the case where such a bridge is in an urban area. This urban setting therefore performs primarily a movement function. The bridge is congested for the majority of the day.
Place	**Low**	This urban setting has limited place function. There is clearly no adjacent land use, so this removes any place demands/contributions made to the urban setting in this sense. The researcher walked from one side of the bridge to the other, and was able to gain some pleasant views of the river, however there was limited other amenity or travel attractors. Besides the footpath, there is little to no place function performed by this bridge.

Key features of this urban setting:

- Limited road space: With only two lanes in either direction, space is a premium on this bridge. It is also congested for most of the day. The limited space has resulted in the decision to forego a priority ART lane and instead merge with general traffic over the bridge. This leads to a more complex environment for the ART, and while the delays are managed the main compromise is the potential for abrupt stopping due to unpredictable vehicle behaviour from other road users.
- Highly congested: The traffic is highly congested across the bridge for what is assumed to be the whole day (it was the case for every site visit). The general flow of traffic along this section of road is slow, and in some cases stop-and-start.
- Absence of land use: The absence of land use in this location lowers the place value of this section and therefore most of the consideration is in the context of movement. The absence of land use removes the need to facilitate pedestrians or vehicles crossing the flow of traffic across the bridge.

Key features of the ART system observed in this urban setting:

- Signal priority: While each of the intersections at either immediate end of the bridge are grade separated to reduce the amount of delay experienced at either end of the bridge, the ART still uses pre-emptive signal priority to avoid delays when crossing and exiting the bridge at its first signal intersection (exiting the bridge and approaching Changjiang Road South Station).
- Priority jump spacing at intersection: At either end of the bridge, the ART enters from and exits into its own priority lane. Essentially, the ART vehicle is only mixed with traffic for the span

of the bridge and then is able to regain its own space on the road, which works in conjunction with the signal priority.

Reflections on ART system in space-restricted mixed traffic setting:

- While mixing with traffic impacts travel time reliability of public transport, it is managed very well for this section of the ART route. It is a significant achievement by the CRRC and city transport officials to mitigate the potential delays possible by congested mixed traffic lane. In reality there is minimal delay, and in the context of the broader system this stretch of mixed traffic has no real impact.
- One complication added by the mixed traffic is the unpredictability of other road users, resulting in potential for sudden halts of the ART vehicle to avoid collisions with vehicles pulling out/in of lanes and in front of the transit vehicle.
- Signal priority is an effective tool in streamlining the travel of high capacity transit vehicles, and has potential for across the transit network to support faster, more efficient transit travel times.
- While the place function of the bride is low – the transport conditions are not supportive of this function if it were in place.

Lessons for effectual action:

- Available infrastructure is leveraged in this urban setting, the ART system is implemented on existing road infrastructure. This bridge represents a crucial transport link for the city. Laying light rail tracks down across this bridge would be a significant undertaking, both in complexity of construction but more importantly for disruption given the high importance of the road.
- The transport conditions do not reflect an appropriate street for high streets and public areas. The way the ART operates in this urban setting is reflective of many non-priority bus systems, which have not achieved the same level of integrated city benefits that rail systems have.
- The system also has more capacity to respond to future contingency and opportunity than fixed track systems. While this is true across the entire system, in the sense that routes could be adjusted based on changing stakeholder preferences, it is visible at a street scale in this urban setting. If a motor vehicle was to break down in one of the lanes – the ART would be capable of going around it.

Table A2-2: Additional images from Space-Restricted Mixed Traffic across the Chongjiang Bridge (Source: Daniel Conley)

Observations	Image
Crossing Changjiang Bridge is a point in the ART route of high congestion. The ART must mix with this traffic for the stretch of the bridge (approximately 800m). This is a busy environment for motorists and pedestrians.	 ***ART crossing Changjiang Bridge in mixed traffic lane***
Exiting Changjiang Bridge (same configuration at each end) the ART is re-establishes its lane priority, before approaching the first set of traffic signals. By regaining lane priority before the intersection, it is ensured the vehicle is able to maximise signal priority and not be delayed by other vehicles.	 ***ART exiting bridge into lane priority (like bus jump lane) prior to intersection with signal priority***
ART signal priority upon exiting the bridge, timed to the approach of the ART vehicle. Obtaining lane priority before this point allows ART to jump ahead of congestion.	 ***ART specific signal (left) at intersection timed for ART approach***

Urban setting 3: Dense, mixed-use urban core

Once the ART route crosses the Changjiang Bridge, it enters the denser urban core of Yibin. This area comprises dense apartment buildings and commercial destinations. As seen in the images below, the streets are lined with trees. Cyclists and scooters are common throughout this area, and there are bike share services placed along the ART corridor.

Figure A2-5: ART moving through high density urban core with lane priority (Source: Daniel Conley)

The dense, mixed-use urban core urban setting has the following movement and place functions:

Movement	**Medium**	The corridors that comprise this section of the ART route still have the capacity to move a significant amount of people. The key difference here between the outer main road environments, is that a focus is on moving high amounts of 'people' rather than just 'vehicles'. This shift in focus is important given the space constraints, and there is a noticeable increase in buses, two-wheelers/active travel, and ART.
Place	**High**	This urban setting has a high place function relative to the other urban settings along the ART route. The land use is dense and mixed, comprising of commercial and retail destinations combined with residential and accommodation buildings. There are trees that line the

		streets, and active travellers (both walking and cycling) are prominent. Many of the ground floor shops open onto the street.

Key features of this urban setting:

- Limited road space: Although originally three lanes in either direction, road space in this dense urban core is contended. This is also relative to the size and population of such a city, whereas smaller cities might place the same importance on two lanes of road rather than three. Urban governance decisions to either make this street a three-lane car-based street (as it was before) or two lanes car and one lane transit (as it is now) could both be justified based on different modal transport priorities.
- Dense and mixed use: More so than the other two urban settings, this area is denser and much more mixed-use. It is a place where people can walk through the streets and come across an array of different destinations of interest (such as restaurants, shops, offices). The density of population and destinations demands highly efficient ways to move people through such an urban area.
- Active travel is prominent: This area features significantly more pedestrians, more cyclists and more travellers on two-wheelers (scooters and motorbikes). There are much more places to walk and cycle to in this area. Density creates opportunity for 'trip-chaining', where those on foot can visit 2- or 3 useful destinations along their journey.

Key elements of ART system observed in this urban setting:

- Lane priority: Despite temptation to provide compromised mixed-traffic implementation in this area, the ART has its own lane priority. There is one primary lane for private vehicle travel in either direction, and a second lane that has been converted from on-street car parking to a lane used by two-wheelers and also acts as a slip lane for private vehicles. The lane priority provided to the ART improves travel times, and as seen in Table A2-3, allowing the ART to avoid delays created by congestion in neighbouring lanes. This adds to the appeal of the ART in such areas, as regardless of the number of lanes (1, 2 or 3), it is likely car-based travel in such an area will experience congestion and delay due to the greater density.
- Lane sharing with buses and two-wheelers: In this area, other transit vehicles are able to use the ART lane. Buses frequently streamline behind the ART to avoid private vehicle congestion. In instances where buses face a red light with banked up traffic, they slip into the ART lane and gain signal priority and avoid delay. Similarly, two-wheelers have this opportunity – which would be more difficult with light rail tracks as the wheels risk getting stuck in the ruts.
- Removal of on-street parking: Prior to the introduction of the ART down this stretch of road, there was two lanes of vehicle traffic in each direction and a lane allocated for parking spaces.

This can be seen in Table A2-3. When the ART was introduced, the parking lane was removed and was replaced with a priority two-wheeler lane that also acts as a right slip turn lane for vehicles, seen in Table A2-3. By removing on-street parking, there is much more space on the street and mass transit and two-wheelers are prioritised.

- Prominent stations that integrate into surrounding land use: Prominent stations play an important role in the prominence of the ART within these denser communities. The stations have the opportunity to seamlessly integrate into the surrounding urban area, with easy walking access. Like all ART stations, they are clean, feature real-time information, and have gardens.

Reflections on ART system in dense, mixed use urban cores:

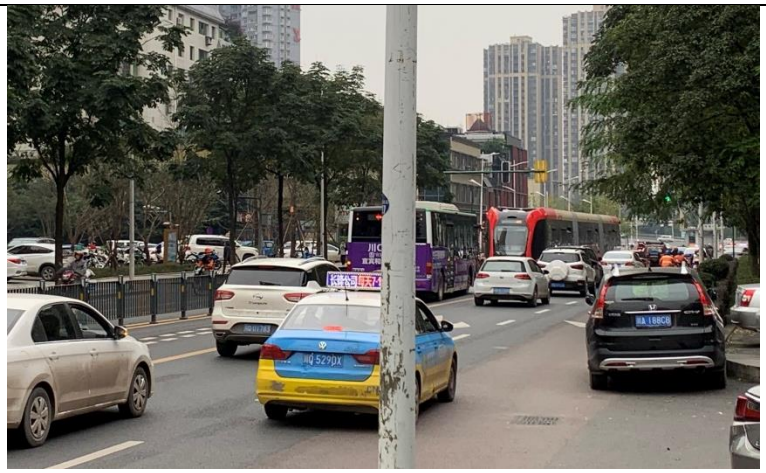
- There is a noticeable difference between this road environment (three lanes: two mixed traffic, one ART) and the bridge (three lanes: two mixed traffic, one car parking). The feeling on the street is much calmer due to reduced traffic and transit priority.
- Similarly, the calmer street complements the overall greater emphasis on place value in this urban setting, which in turn is reciprocated by added amenity and destinations provided by the mixed and dense land use. Here the land use and transport work in synergy.
- The lane sharing with buses and two-wheelers is effective. By providing the backbone for the system, the ART can support a much greater increase in accessibility beyond just its immediate surrounds, as buses potentially performing feeder services can achieve significant travel time reductions.

Lessons for effectual action:

- As with all sections of the route, the ART uses existing infrastructure through the dense, mixed use urban core. This reduces construction costs and disruption and allows the system to get started earlier. See Table A2-3 for a visual of the road pavement taken during research visits in 2019.
- In this urban setting the ART demonstrates its value to high streets and public areas. The system has stations that are well-established and offers a user experience comparable to light rail.
- The system facilitates a high-quality customer experience. The stations are clean, and the vehicles look and feel like a light rail service.

Table A2-3: Additional images from Dense, Mixed-Use Urban Core (Source: Daniel Conley)

Observations	Image
Street view of Xufu Road prior to the implementation of ART system. The street is car-dependent and on-street parking takes up a significant amount of space. This is similar to a typical street cross-section found in car-based, Anglosphere cities. Often road users place high importance on on-street parking.	 ***Xufu Road prior to ART implementation, two lanes of traffic and on-street parking (Source: Baidu Maps)***
The same section of Xufu Road following the implementation of ART system. Middle lane in each direction is allocated to ART. Road space that was once taken up by on-street parking is now free for two-wheelers and active travel. Extensive bike-hire services are found throughout the area, as seen in the image lining the side of the road.	 ***Xufu Road after to ART implementation, one ART lane, one main traffic lane and one lane for slip turns/two-wheelers***
This image displays the typical traffic mix that is found in this urban core setting. Essentially this comprises of private vehicles (cars), and two wheelers. The two wheelers can use the ART lane or the widest lane. Vehicles travelling straight share this middle lanes with buses (who can also change into ART lane at congested points). Vehicles slip turning right also use wide lane.	 **Typical traffic composition in Urban Core settings**

In congested road conditions, the ART is able to avoid delay. This image shows ART and a bus approaching an intersection where cars are congested. As seen in the image below, the bus is able to streamline behind the ART to avoid the congestion.	 **Bus and ART co-existing 1/2**
Image shows bus streamlining behind the ART to avoid congestion. During site visits this approach was seen to save buses significant travel time in avoided delays.	 **Bus and ART co-existing 2/2**
This image displays the types of land uses that can be supported by the ART, which are dense, mixed use and walkable. The ART can underpin the reduction in car dependency in these areas which are better suited to transit and active travel. This helps to mitigate the perceived negative impacts of reduced vehicle lanes and will likely be highly valued by the regular users of the area.	 **Backdrop of dense, mixed use development**

This image shows the road surface following the introduction of the ART system. Clearly, there has not been a resurfacing of the entire road. The ART lines have been painted on the existing road surface, representing an opportunity for 'low cost, high impact' experimentation.	 **Road surface post-ART route introduction**

Lessons from Yibin for a new era of entrepreneurial mass transit

Effectual urban governance is a process for bringing stakeholders together, learning by doing, and driving sustaining transformation in the face of uncertainty. New technology alone cannot achieve this. The Yibin case study itself shows how a new technology can achieve urban transport benefits, but not without appropriate implementation that considers the broader system. Effectual urban governance provides a methodology for doing so. Compared to other transit technologies, the ART system lends themselves to an effectual approach because they overcome the traditional challenges associated with other types of transit technology. As evident by the site visits and case study, if implemented 'like rail' they will achieve similar urban benefits to light rail.

The following 'effectual action checklist' for urban transit is structured around the key principles of effectual urban governance. It aims, through a series of questions, to help potential partners consider and assess the usefulness of an effectual action and governance approach toward possible transit technologies and projects.

Available means rather than pre-determined ends:

1. Can available infrastructure be leveraged to get started?

Focusing on partnerships rather than transactions:

2. Is there city shaping potential of the system – i.e. can it achieve integrated land development benefits?
3. Is the system appropriate for high streets and public areas?
4. Does the system facilitate a high-quality customer experience?

Commitments based on affordable loss rather than expected return:

5. Can some form of the system be introduced without a high construction cost?
6. Can some form of the system be introduced without a high level of disruption?

Leverage contingencies to create greater value:

7. Does the system have the flexibility to respond to future contingency and opportunity?

The benefits of the ART system in response to the above questions are listed below. Note that while some of these are enabled by technological innovation (the new technology being able to overcome traditional challenges), others are a result of the implementation and system that is built around the technology.

1. *Can available infrastructure be leveraged to get started?*

The ART takes advantage of the infrastructure that already exists to run the system, especially for an initial effectual action phase. This means it is possible to run the rubber-tyred vehicles on existing roads – depending on the road type and strength - rather than laying down new road pavements (or needing to lay down rails). This avoids cost and disruption to get the trial going. On a case-by-case basis, it may be necessary to undertake road strengthening works depending on the road design (for example, local roads may need strengthening while major highways have adequate strength), however this can be mitigated by shifting the ART route into the neighbouring lane while this is done. Similarly, if major road strengthening is required, effectual urban action can still be taken to trial the system beforehand.

2. *Is there city-shaping potential of the system – i.e. can it achieve integrated land development benefits?*

The first iteration of effectual action is not all about 'minimising expenditure at all costs'. The stations are done properly, they are large and prominent within the community. This enhances the customer experience and generates interest from land developers. It signals that this system is to be taken seriously. By taking effectual action (rather than purely 'experimenting' with low cost interventions), the benefits of the system can be appropriately conveyed to users.

3. *Is the system appropriate for high streets and public areas?*

The system has a demonstrated capability to support high streets and public areas to facilitate transit-oriented development, due to a combination of the technology and user experience, the prominent stations and the way the system is implemented. For example, the urban core setting demonstrates the potential of the system to facilitate a 'high street' environment with walking, cycling and other transit modes. It supports the movement of buses through its priority lane also. In contrast, the traffic conditions on the bridge (urban setting 2) is not conducive to this type of environment.

4. *Does the system facilitate a high-quality customer experience?*

The customer experience of the system is achieved through the way the system is planned and delivered (stations, lane priority, etc.) and the superior ride quality of the transit vehicle for an on-read vehicle. The lane priority adds to the efficiency of the system. This user experience would not be as significant if the vehicles were unreliable due to traffic congestion – this would be more comparable to a conventional bus system. The stations are high quality with customer amenity. Finally, the CRRC have incorporated a number of technological innovations to improve ride quality of the vehicles (Newman et al., 2019).

5. *Can some form of the system be introduced without a high construction cost?*

Tied to the use of existing infrastructure and minimising upfront construction requirements, the trackless tram system in Yibin has been implemented with a construction cost much lower than traditional light rail systems. Over time, the infrastructure can be expanded (such as pavement strengthening if necessary, however highway roads are likely already strengthened for heavy vehicles), with the ART being capable of pivoting around these works. By this time, more community support has been generated due to the early successes of the system.

6. *Can some form of system be introduced without a high level of disruption?*

To avoid city-wide disruption the ART is implemented in shared traffic across a bridge, given it is a crucial transport link for the city. Laying light rail tracks down across this bridge would be a significant undertaking, both in complexity of construction but more importantly for disruption given the high importance of the road. In these cases, while it is not preferred from a transit perspective, there are other means (such as signal priority and bus jumps) to allow this system to still operate efficiently. Unlike light rail which can take years to install, the ART system requires line marking to function – and can likely be implemented in weeks/months rather than years.

7. *Does the system have the flexibility to respond to future contingency and opportunity?*

The system also has the capacity to respond to future contingency and opportunity. While this is true across the entire system, in the sense that routes could be adjusted based on changing stakeholder preferences, it is visible at a street scale in the bridge urban setting where the ART mixes with traffic. If a motor vehicle was to break down in one of the lanes – the ART would be capable of going around it.

Table A2-4: Modal comparison of BRT, ART, LRT against characteristics to enable effectual action

Transit characteristics to enable effectual action	BRT	ART	LRT
1. Can we leverage available infrastructure to get started?	Yes	Yes	No
2. Is there city shaping potential of the system – i.e. can it achieve integrated land development benefits?	No	Yes	Yes
3. Is the system appropriate for high streets and public areas?	No	Yes	Yes
4. Does the system facilitate a high-quality customer experience?	No	Yes	Yes
5. Can some form of the system be introduced without a high construction cost?	Yes	Yes	No
6. Can some form of the system be introduced without a high level of disruption?	Yes	Yes	No
7. Does the system have the flexibility to respond to future contingency and opportunity?	Yes	Yes	No

This case study demonstrates the potential for leveraging new technology to take effectual action for transit activated corridors. Remaining manufacturer agnostic, the birth of the 'trackless tram' likely represents a new era of transit vehicles that move beyond traditional trams and buses, taking the strengths of both modes and overcoming their respective limitations. The case study demonstrates how an effectual urban governance approach underpinned by effectual action can demonstrate the benefits of the system, build stakeholder support and underpin ongoing transformation of transport systems towards sustainability.