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Evaluating Investment in Public Wi-Fi Infrastructure by Australian Local Governments

A thesis submitted in fulfilment of the requirement for the degree of Doctor of Philosophy

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DECLARATION

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed. I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

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GLOSSARY OF TERMS

ABS	Australian Bureau of Statistics
ACMA	Australian Communication Media Authority
BYOD	Bring Your Own Device
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
EE	Empowerment Evaluation
eWOM	Electronic word-of-mouth
GDP	Gross domestic product
ICT	Information and communications technology
ISM	Industrial, Scientific and Medical (radio spectrum)
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
LGA	Local Government Authority
NBN	National Broadband Network
NPG	New Public Governance
NPM	New Public Management
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary least squares
PPP	Public-private partnership
Ppp	Purchasing power parity
PWF	Public Wi-Fi
RBM	Results-based management approach
RQ	Research question
Telco	Telecommunications company
USO	Universal Service Obligation
WLAN	Wireless local area network

ABSTRACT

Investment by Australian local government authorities (LGA) in public Wi-Fi (PWF) has surged in recent years. PWF represents a new type of infrastructure investment for local authorities and widens the provision of telecommunications beyond the traditional role of the Australian national government. PWF can also be seen as a precursor for other local authority investment in networked digital communication technologies, including sensor networks, that for many commentators represent the evolution of 'smart' cities and the underpinnings of twenty-first century urban infrastructure.

This thesis is the first detailed analysis of LGA investment in public Wi-Fi by Australian LGAs and contributes to emerging scholarship in the broad area of critical infrastructure studies. The research employed a mixed-methods approach, using surveys and interviews, statistical analysis and econometric modelling to generate and analyse data. As the national survey undertaken during this research revealed, by 2018 around two-thirds of local councils had either invested in PWF or planned to invest within the next three years, with most LGAs contracting out service provision to telecommunication companies. However, few local authorities had evaluated their investment in PWF services. While several commentators have identified lack of attention to the systematic evaluation of programs and services as a characteristic of the local government sector, the thesis argues that evaluation of PWF poses significant conceptual and practical challenges relating to the characteristics of open or public wireless networks.

The thesis conceptualises PWF as a form of non-traditional infrastructure, which has generative and post-hoc benefits not captured by conventional evaluation methodologies. To identify an approach to evaluation that recognises the novel characteristics of digital communication networks, while responding to statutory requirements of the local government sector for good governance and responsible resource use, the thesis maps and analyses investment rationales in PWF, and examines whether the policy, institutional and technical settings of PWF provision support these rationales. The thesis also analyses local authority access to PWF metadata, concluding that current policy, procurement and regulatory settings compromise the quality and sustainability of network provision and significantly constrain LGAs from utilising metadata for both urban analytics and innovation.

To respond to the key problem of evaluation, the thesis argues for the adoption of empowerment evaluation (EE) as a rationale and conceptual model that can underpin adaptive local-level planning, investment and operation of PWF infrastructure. The successful implementation of EE in this arena

requires new knowledge and analytical approaches, which are provided in this thesis. From this standpoint, the thesis argues that LGAs should take a more active involvement in and operational control over the provision of PWF, including through investing in the IT capabilities of staff, seeking regulatory change to facilitate the use of network metadata, and encouraging greater use of and experimentation with networks.

Chapter 1: Introduction

It seems like the motivation is a belief that public Wi-Fi is something we "should" be doing, but no strong indication of why.
(Email from an LGA officer in Western Australia to the author, 28 August 2018)

1.1 Preface

Recent years have seen a surge of investment by Australian local government authorities (LGAs) in public Wi-Fi infrastructure (PWF). By 2018, around two-thirds of local councils had either invested in PWF or were planning to invest within the next three years (Grechyn & McShane 2018). PWF represents a new type of infrastructure investment for LGAs which, in addition to providing public access to the Internet, is a precursor to broader digital network infrastructure technologies, including the Internet of Things (IoT), which can represent the evolution of 'smart' cities (Mehmood et al. 2017; Clarke & Brooks 2015; Townsend 2013). However, as indicated by the above comment by a West Australian LGA official, investment rationale and methods of evaluation of PWF investment by LGAs, are not well understood. If LGAs 'should' be investing in PWF, what are the imperatives, what are the benefits, and how can the outcomes be identified and evaluated?

This thesis examines the provision of PWF infrastructure by LGAs with a particular focus on evaluation. As detailed below, evaluation is a key component of a 'policy life cycle' (Menon, Karl & Wignaraja 2009), whereby public authorities plan, implement and assess policies or projects involving the outlay of public revenue to achieve policy and service objectives and meet principles of good governance, such as accountability and transparency. This thesis argues that the evaluation of investment by LGAs in PWF requires new theoretical and empirical approaches that recognise the characteristics of digital information and communication technology (ICT) networks while meeting LGA's statutory mandates for good governance, strategic leadership and responsible resource use (see for example S.3, Local Government Act, 1989, Vic).

The thesis argues that without an adequate level of PWF technical performance indicators, it is unlikely that the rationales articulated by LGAs for PWF provision will be realised. Further, that without operational control or at least informed oversight of PWF provision, LGA cannot leverage PWF infrastructure for purposes such as PWF metadata[1], analytics and other innovative ways to apply PWF for better urban governance.

[1] PWF metadata is information about public Wi-Fi sessions such as IP and MAC addresses of the connected devices,

The evaluation of PWF provision examined in this thesis comprises three levels. First, the thesis overviews the state of PWF provision from a national perspective. Drawing on data obtained from a national survey and interviews, the thesis then focusses on the quality of PWF service and operational control over PWF provision as critical factors determining PWF effectiveness in Internet connectivity and enhancing its feasibility for experimental use by LGAs and their communities. Finally, closer attention is paid to the latter point, the possibilities which emerge through the conjunction of LGA's operational control over PWF and their openness to innovation, such as the usage of PWF metadata in urban analytics.

Overall, the thesis argues that the optimal approach to evaluating PWF infrastructure in the current circumstances can be modelled on the concept of empowerment evaluation (EE) (Fetterman & Wandersman 2005). Empowerment evaluation seeks to actively involve local actors, such as public administrators and communities, in the planning, implementation and evaluation of the project in order to increase the probability of project success.

The application of EE to the present research calls for a greater involvement of LGAs in PWF provision, paired with regular monitoring and evaluation, where LGAs are open to experimenting and determining PWF value taking into account the local circumstances rather than relying on ready-made formula. EE provides the philosophical and conceptual underpinnings of this thesis. PWF is characterised by its local range, accessibility, relative technological simplicity, and flexible use. These characteristics are, the thesis argues, optimised by locally determined and locally relevant policy and governance settings. This is not the current situation, where a reflexive approach to the outsourcing of services, limited capacity and knowledge in the ICT field, and lack of methodological tools for evaluation, constrain policy design and evaluative thinking. In short, local authorities and communities need ‘empowering’ in this area. Section 1.4.3 provides further detail on the application of EE in this thesis.

1.1.1 Why Public Wi-Fi Infrastructure? Positioning the Thesis

As the literature review in chapter 2 shows, both popular understanding and much of the scholarly literature on PWF focuses on PWF as a service or the user experience. This thesis takes a broader perspective in analysing PWF as infrastructure. The main difference between understanding PWF as a

session start and end times and location (the name of the access point of the connected device). See Chapter 7 for details.

service and as infrastructure is that the former has a much narrower context, as the perspective of users who primarily view PWF as a public service or utility that provides Internet access. This thesis argues that in addition to its direct function of providing Internet access for its users, PWF infrastructure, is a complex assemblage which incorporates several layers:

1. An organisational layer which focuses on the roles and functions of LGAs in PWF provision, including motivation (policy rationales) for investing in wireless infrastructure

2. A technical layer which includes the technical characteristics of networks and the users' metadata generated within the network

3. A layer of effects, which reflects the view of PWF as a service; this layer encompasses anticipated positive externalities (such as fostering digital inclusion, space activation or tourism facilitation)

4. An experimental layer, or the layer of innovations, actualises the potential of PWF networks for innovation and experimentation (see Figure 1).

Of course, these layers do not exist in a physical sense. Instead, they constitute a metaphor or symbolic depiction of the complexity of PWF infrastructure.

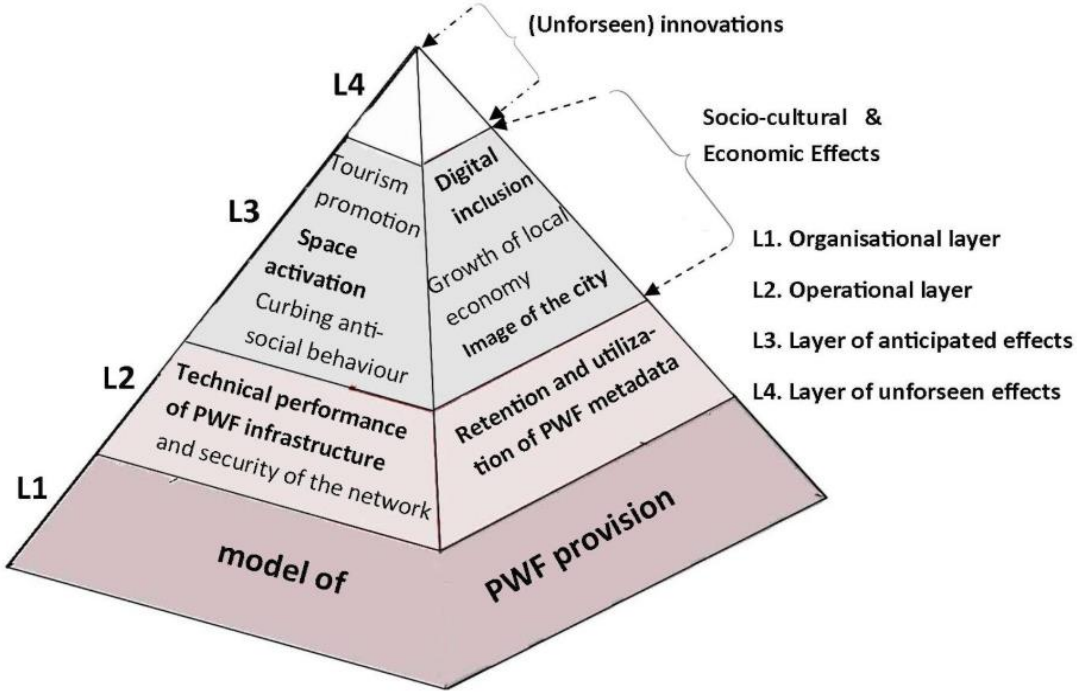

Figure 1. Layers of the PWF infrastructure

Source: author

The significance of the experimental layer lies in the generative character of PWF. This stems from the fact that potential uses of the network are not limited to the straightforward use of PWF as a service, but also in experimenting and creating new usages via interplay within the layers of the PWF infrastructure. The process of generating new uses can be iterative. That is, the previous iterations originate the next steps or even new infrastructures. For example, the use of PWF as a digital wireless communication infrastructure generates PWF network metadata, which is increasingly central to a range of governmental, economic and social activities. However, as detailed in the thesis, PWF is almost entirely contracted out, while local adaptation and experimentation with PWF require a greater level of local government control.

The central concept that frames this analysis is infrastructure. The word 'infrastructure' in association with 'public Wi-Fi' can be interpreted from several perspectives, each of which makes a contribution to the multi-dimensional nature of PWF. Following the etymological origin of the word 'infra' ('underneath' or 'below'), PWF can be understood as a structure underpinning (free) public access to the Internet, capable of delivering information to local communities and facilitating social networking, generating commercial opportunities through, for example, advertising, providing a platform for civic engagement, or supporting smart city and urban analytics initiatives.

In addition to the term 'infrastructure', this thesis uses a range of standard terms: 'network', 'provision' and 'service'. The term 'PWF network' is used to refer to the technical elements or characteristics of PWF, such as access points (APs) that connect devices to the network, or access bandwidth. This term is used primarily for the technical dimensions of PWF. The term 'PWF provision' points to the organisational, managerial and operational aspects of PWF. The term is used when the focus is on the LGA or contractor perspective ('providers' of PWF), and how PWF is procured and delivered, rather than from the user perspective.

For this thesis, public Wi-Fi infrastructure (PWF) is defined as the multi-layered assemblage of technical, financial, institutional and expert knowledge, technical expertise; materials (including network and user technologies and devices, as well as physical infrastructures such as utility poles and buildings); financial and human resources; organisational models; radio spectrum; and space that enables public authorities to provide free-of-charge Internet access to those people (the 'public') who are within network range and have an internet-enabled wireless device (generally a 'smartphone', computer or tablet with a Wi-Fi chip). At LGA level, public Wi-Fi is provided through networks accessed through multiple, connected access points (for example, in a city mall) or through accessing

networks on the premises of local public libraries or similar institutions, usually through BYOD (‘bring your own device’) means.

The focus of this thesis is outdoor networks which, increasingly through the ‘handover’ characteristics of mesh network architecture, provide continuous access to a PWF service as users move through urban space. Mackenzie (2010) describes the technical and social dimensions of such ubiquitous availability in cultural terms, as ‘wirelessness’. However, in some cases, free Wi-Fi access provided within buildings can also be referred to as PWF. For example, the national survey of LGAs, which serves as one of the data sources for this thesis included free Wi-Fi in libraries to PWF on the condition that this service is available beyond library operational hours.

Wi-Fi operates in the unlicensed spectrum, meaning that transmitting a wireless signal via Wi-Fi does not require telecommunication licensing (Lemstra, Hayes & Groenewegen 2010). The devices used for operation in spectrum bands typically allocated across the globe for such transmissions (most commonly 2.4 Gigahertz and 5.0 Gigahertz) are subject to class (device level) certification. The certification is easy and cheap compared to spectrum licensing, and the obligation to obtain certifications is on device manufacturers so individuals or organisations are free-to-use Wi-Fi devices (Bennett 2017).

Although PWF operates in a lightly regulated band of the radio spectrum (Lemstra, Hayes & Groenewegen 2010), if the public Wi-Fi service is provided beyond a single place (such as a shopping mall), it is considered a carriage service and regulated under the telecommunications act (Attorney General, 2016). This condition applies to PWF services provided by LGAs (DSG 2015; DSDBI 2015). The provision of telecommunications is subject to national jurisdiction in Australia and many other countries, and further governed by international agreements around the allocation and use of radio spectrum (the International Telecommunications Union, ITU), and technological standards (the Institute of Electrical and Electronics Engineers, IEEE).

Falling within the regulatory ambit of telecommunications, the providers of PWF service are subject to regulatory requirements such as metadata retention (Telecommunications (Interception and Access) Amendment (Data Retention) Act 2015). Notwithstanding the relatively straightforward technical operation of PWF, the regulatory complexities of telecommunication carriage services is a prime reason why most LGAs outsource PWF provision to commercial telecommunication companies. The implications of this, particularly associated with LGA access to PWF metadata, are explored in chapters 4,7 and 8.

The term ‘PWF service’ refers to what many see as the primary function of PWF infrastructure: providing free Internet access to the public. This term is mainly used where discussion in the thesis focusses on PWF customers or addresses the broad topic area from the perspective of PWF users rather than that of providers.

In places, the thesis uses the term ‘PWF’ without further qualification, to improve readability. In those cases, one should read ‘PWF’ as ‘PWF infrastructure’.

1.2 Thesis Research Questions

The observation by McShane (2006) and others that there has been limited attention to the provision and use of local government infrastructure in Australia still has relevance. This neglect contrasts with the view of commentators such as Barber (2012) on the increasing significance of urban or municipal government—a view that regards cities as loci of innovation and global economic competition, as well as sites of concentrated inequality and unsustainable resource consumption. Looking at this topic from an ICT perspective, research on digital communications media has tended to focus on media users and media content (Buckingham 2007; Webster & Ksiazek 2012). There is little published research on the expanding investment in PWF infrastructure by LGAs in Australia. To fill these gaps in the scholarship, and to address the research objective of evaluating the investment in PWF infrastructure by local governments in Australia, the following set of research questions underpin this thesis:

1. What is the current state of PWF provision by local authorities in Australia? What is the context in which this development is taking place? Which local authorities deploy PWF and why?

2. How do the policy and macroeconomic contexts influence the evaluation of the investment in PWF infrastructure? Why is evaluation important? What are the methodological, policy and practical contexts and challenges involved in evaluating an investment in WF infrastructure?

3. Is the quality of the PWF service important for users?

4. Can PWF metadata be accessed and used for urban management purposes?

5. Does the organisational model through which PWF is provided influence LGA's capacity to sustain and innovate with PWF?

1.3 Key Terms and Concepts

The thesis deals with a complex area of public policy that requires an interdisciplinary approach to advance our understanding; consequently, it brings together several epistemologies and languages, drawn from economics, public administration, socio-technical studies, and computer and network sciences. In addition to the central concepts of infrastructure and evaluation (discussed above), this section defines other key terms and concepts used in the thesis.

1.3.1 PWF as Non-Traditional Infrastructure

The term infrastructure points, first of all, to the systematic character of PWF, including the urban-scale coverage of networks, and the physical equipment such as power supply, backhaul Internet connectivity (carried via optical fibre, copper cable and so on) and wireless access points, as well as the software and application programming interfaces ('apps') that facilitate network and public internet access. Public Wi-Fi infrastructure has semantic connotations with 'IT infrastructure', defined by Kumar (2004, p. 11) as 'a collection of technologies, people, and processes that facilitates large-scale connectivity and effective interoperation of an organisation's IT applications'. Computer scientists and engineers who explore technological possibilities of Wi-Fi networks use the expression 'Wi-Fi infrastructure' to underline its character of a networked communication system (Hao et al., 2011; Kellogg et al. 2014).

The broader concept of 'infrastructure' has been defined, classified and investigated in diverse ways in economics, social sciences, and the humanities. As early as the 1970s, scholars distinguished between 'hard' and 'soft' infrastructure, with the former referring to physical systems, and the latter referring to the knowledge, networks and institutions that underpinned systems such as health management (de Lucenay 1971) and research networks (Blakely, Roberts & Manidis 1987). As Mandeville (1988, p. 96) put it, 'soft' infrastructure 'helps facilitate information flow appropriate to technological development [and] it includes building a working partnership among businesses, universities, and local governments pursuing a common strategy'.

Moving away from a ‘hard’ versus ‘soft’ dichotomy, Frischmann (2012) offers a perspective from which infrastructures are viewed as either traditional or non-traditional, with his research interest focused predominantly on non-traditional infrastructures. Frischmann was not the first to use the terminology ‘traditional infrastructure’. For example, Fox (1988) refers to traditional infrastructure in discussing roads and electricity networks, which he contrasts with satellite hookups (‘high-technology infrastructures’). Hars (2003) classifies paper-based journals as traditional infrastructure and compares them with emerging ‘online infrastructures’ of academic journals.

The significance of the traditional/non-traditional dichotomy in infrastructure is that the latter, as Frischmann (2012) argues, is characterised by the ability to generate unforeseen innovations. Due to the effect of unpredictable innovation, Frischmann (2012) argues that the social surplus from the usage of non-traditional infrastructures is higher in the long run than can be estimated by conventional methods of economic analysis. Frischmann interprets non-traditional infrastructures broadly and includes knowledge, data, the Internet and even language in this category.

PWF has the characteristics of both traditional and non-traditional infrastructure: it includes, for example, data generated by PWF users (metadata), an infrastructure in itself. As a physical layer, it encompasses transmitting equipment (access points, or APs), hardware and software, electricity networks, wired and sometimes wireless (fixed wireless or satellite) infrastructure carrying signals to local distribution and access points (typically referred to as ‘backhaul’). So, being ‘a system that combines various facilities and enables certain activities’ (Tabansky 2011, p.61), PWF can be called local networked wireless infrastructure. PWF affords (free) Internet access, and the Internet in itself is an important non-traditional networked infrastructure (Frischmann 2012). PWF can be deployed by local governments as media infrastructure (Starosielski 2015); for example, by using the PWF launching page for communication, consultation and civic engagement. Finally, PWF infrastructure can be viewed through the lens of opportunities which it provides for urban governance, for example by using short-range wireless coverage for communication of IoT sensor devices (Mehmood et al. 2017) or measuring pedestrian traffic (Kontokosta & Johnson 2017).

PWF can also be described as ‘generative’ infrastructure, which means that its role and value is not limited to its direct usage of providing free Internet access, but also serves as a platform for experimenting and creating other uses. At the same time, this process can be iterative, for example, the previous steps generate the next steps, and so forth. For example, PWF, as digital infrastructure, through its usage, generates PWF network data, while data are also referred to as non-traditional infrastructure (Frischmann 2012). Metadata, processed through analysis and interpretation, originates

knowledge, which is also a kind of non-traditional infrastructure. The knowledge can serve the purposes not directly related to the PWF infrastructure; still, it can also introduce improvements to the PWF design or the methods of data collection, and so forth.

In focusing on infrastructure, in addition to the work of Frischmann (2012) and others, who work principally from an economic perspective, this thesis draws on theoretical and empirical work in the field of critical infrastructure studies. This body of work extends over at least four decades and aims to 'unblackbox' infrastructure, exposing the norms, institutional settings and power relations that shape infrastructure investment. Recent scholarship in this field builds on the foundational work of scholars such as Hughes (1983) on energy networks, and Star and colleagues (Star 1999; Bowker & Star 1999) on information systems, to encompass work in diverse areas of media studies, cultural studies and digital humanities research (Parks & Starosielski 2015; Peters 2015). The work by Egyedi and Mehos (2014) in theorising the emergence of 'inverse infrastructure', or community, 'bottom-up', informal, even disruptive infrastructure—contrasting with state- or market-provided infrastructure—is an important contribution to this field. From a user or consumer perspective, the emergence of the mobile phone as a powerful and increasingly ubiquitous personal infrastructure is an essential element of this story. There is significant literature on the mobile phone that explores its political, technological and cultural properties (for example, Haddon 2017; Light, Burgess & Duguay 2018; Rose 2016). While mobile wireless devices are certainly part of the public Wi-Fi infrastructure, as defined above, the focus of this thesis is not on the devices or their use and not on the user perspective of PWF, but on evaluating PWF infrastructures from the LGA perspective.

1.3.2 Smart city, smart urban governance, urban data analytics

The terms 'smart city', 'smart urban governance' and 'digital urban governance' reflect the process of the rapid digitalisation of cities, and the implications of this. Cocchia's (2014) extensive review of the literature on the topic concludes that the 'smart city' concept embraces several definitions contingent on interpretations of the word 'smart': intelligent city, knowledge city, ubiquitous city, sustainable city, digital or data-driven city, and so on. Cocchia (2014) points out that while many definitions of the smart city exist, none is universally acknowledged. In general, smart city initiatives aim 'to improve urban performance by using data, information and information technologies (IT) to provide more efficient services to citizens, to monitor and optimise existing infrastructure, to increase collaboration among different economic actors and to encourage innovative business models in both the private and public sectors' (Marsal-Llacuna et al. 2015, p. 618). In the same vein, McShane & Wilson (2017) point out that smart cities are characterised by the extensive deployment of digital communication technologies and networks (including wireless and sensor networks) and the use of network data in

urban governance. Respectively, in this thesis, the terms ‘smart urban governance’, ‘urban analytics’ or ‘smart urban analytics’ refer to the uses, current or forecast, of PWF metadata in processes of urban management and governance.

1.3.3. Public Value

The concept of public value was developed by Moore (1995) to encapsulate his key idea that public agencies should be more responsive to both individual and collective aspirations. Associated with the strategic or new public management paradigm, public value reflects the idea that citizens are concerned with efficiency and effectiveness in the delivery of public services, as well as more abstract notions of equity, fairness and accountability. Thus, the concept blends market and governmental rationalities, with Moore drawing an analogy with the private sector, where entrepreneurs are in a continuous search of how to enhance the value delivered to their customers or stakeholders to stay afloat in a competitive market.

However, contrary to the creation of value in the private sector, no individual customer is arbitrating whether a value is or is not produced, but instead, this is determined at a collective level. In other words, public value is not merely a summation of individual customers' benefits or gains (Moore 1995, 2013). Moore defines the pursuit of public value within a "strategic triangle" which encompasses the concept of public value and the possibility of its implementation as measured by its operational and administrative feasibility and the existence of sufficient and continuous political support. Thus, the creation of public value requires the public administrator to be immersed in local circumstances, community peculiarities and problems, thoughtful analysis of available information, experimentation and even risk. Such a proactive role of public managers was subjected to criticism from some scholars, who argued that public managers are not intended or trained to be innovators or take a risk, where they are still accountable if something goes wrong (Rhodes & Wanna 2007). However, these authors also accept that "public officials should seek to innovate and improve services... [and] it is important for managers to increase the value of their services to the public" (Rhodes and Wanna, 2007, p.417).

The case of investing in PWF infrastructure by Australian LGAs can be considered an application of public value theory. Australian LGAs, being close to their communities, can determine service provision according to local needs and the requirements of state and territory legislation (as specified in the Local Government National Report 2013-2014), potentially enhancing the public value of PWF. At the same time, the LGAs' decisions to fund PWF projects are typically time-bound and trial-based,

and PWF provision is dependent on the existing infrastructure, as discussed in chapters 4.4 and 4.5 below.

Reflecting on Rhodes and Wanna's (2007) criticism, it follows that local governments should not be unrestrained in their pursuit of public value, but instead they should act within the clear limits of managerial authority. It is particularly important to recognise the limits of managerial authority where LGA officials respond to the vague injunctions of public value (Moore concedes the difficulty of providing "a clear, objective definition" 2013, p. 8) to act dynamically and imaginatively. At the same time, in public value pursuit, public managers (and LGA officials, closer to the context of the thesis) should not break apart from the root, i.e. from the real needs and circumstances of the communities which they serve. The community voice must be heard through ongoing communication between government and community; in this setting public managers take the role of facilitators. This role, and more generally, the task of public value creation, requires enhancing of LGA staff capacities and qualifications and the "need for all kinds of training" (Grant & Drew, 2017, p.241), see Chapter 7.

Grant & Fisher (2011) question Rhodes & Wanna's (2007) objections to Moore's (1995) public value theory in the Australian context, arguing the opposite point that the theory is especially relevant and applicable to the Australian local government sector. Whilst Rhodes & Wanna (2007) argue that public value principles are not appropriate in the specific context of Westminster system of governance, pointing to the dictates of political parties and the generally subordinate role of bureaucracy that prevents public administrators from taking a proactive position, Grant & Fisher (2011) note that these general restrictions of the Westminster systems do not apply as much to local governments in Australia. The role of political parties and subordination is not significant in the context of local government, since in fact, many elected local officials act on their view of what is best rather than being closely accountable to a political party. Also, local residents, who are local officials' constituents and possibly their neighbours, generally expect "local librarians, office managers, garbage collection personnel and receptionists to search for opportunities to create public value" (Grant & Fisher 2011, p. 17). In general, the concept of public value endorses a more entrepreneurial and locally responsive stance by local officials. In this regard, public value management provides a useful administrative rationale for investment in PWF, consistent with local empowerment. This thesis draws on Grant & Fisher's (2011) argument that the theory of public value is particularly relevant to Australian local government by public value management is pertinent to the concrete case of investing in PWF infrastructure by Australian LGAs.

1.4 Why Evaluation? Identifying the Research Problem

During this research, evaluation emerged as a critical problematic. The local official quoted in the epigraph that opens this chapter suggested there was an increasing expectation that their LGA should offer PWF but was unable to identify a rationale for investing in the service. Data were sought on the 'why' question—the motivation or rationale for investment—through a national survey of LGAs undertaken during this research (discussed in detail in chapter 4). The survey identified a set of investment rationales nominated by LGAs. However, it also highlighted a significant deficit of understanding, and lack of action, in evaluating that investment. While some analysts see lack of attention to evaluation as characteristic of the local government sector (McShane 2006; Thompson 2020), the question of how non-traditional infrastructure such as PWF is evaluated is a central problematic for research and practice in this field.

The evaluation theorist Carol Weiss defines 'evaluation' as 'the systematic assessment of the operation and/or the outcomes of a program or policy, compared to a set of explicit or implicit standards as a means of contributing to the improvement of the program or policy' (Weiss 1998, p.4). Evaluation, though, is a highly elastic term, which has different meanings in different theoretical and applied contexts.

Investment in PWF infrastructure, due to its non-traditional and generative character, cannot be adequately assessed with a conventional approach to evaluation. The conventional approach involves the ultimate determining of the 'value' of the project (via some methods, e.g., cost-benefit analysis), leading to 'conclusions about the state of affairs, value, merit, worth, significance, or quality of a program' (Mathison 2005, p. 139). In contrast, the unconventional path is akin to strategising: not aiming directly at determining value (or at least not quantitatively), it seeks to investigate the conditions under which the potential value of the project (including the not-foreseen value delivered through experimentation and innovation) is the highest. To contextualise the research problem of evaluating investment in PWF infrastructure, it is necessary to briefly introduce the political, fiscal and service contexts in which the Australian local government jurisdiction is located.

1.4.1 Local Government in Australia

The Australian local government sector is the lowest and least powerful level in the three-tier system of governance in Australia. The Australian Constitution does not mention local government. As

statutory authorities, jurisdiction is vested with state and territory governments. Each state provides its own legal and regulatory framework for local governments, which results in significant differences between jurisdictions regarding the functions of councils and the services they deliver, and also indirectly leads to uneven distribution of resources for LGAs, and of skills and decision-making expertise of LGA officials (Grant & Drew 2017).

In August 2019, there were 537 councils in Australia (ALGA 2019a). Historically, from the nineteenth century to the second half of the twentieth century, local governments in Australia were largely focused on providing local physical infrastructure, particularly roads, bridges, drainage and sanitation, and so on. In the twentieth century, the local government jurisdiction underwent a series of reforms pivoted around the expansion of the functions and responsibilities of LGAs. Notably, community services, such as maternal and child health services, local libraries, and other welfare and recreation services, were added. The roles and functions (the 'powers') of LGAs were once strictly defined by state governments; however, as Grant and Drew (2017, p. 184) have noted, '[a defining] feature of the modern era of Australian local government systems is that across all jurisdictions they have been granted enabling powers'. Therefore, by the late twentieth century, the characterisation of local governments' functions as focused on 'roads, rates and rubbish' (Australian Productivity Commission, 2017) became less and less appropriate.

Despite the expansion of their powers, local governments in Australia have not reached a level of responsibility and functions equal to those in local governments in the majority of OECD states. For example, Australian local governments do not have responsibility for schools and hospitals. They do, though, have responsibility for aspects of public health and primary health care, as well as early childhood care and education (a comprehensive list of functions of local governments and services provided can be found in Australian Productivity Commission 2017, p.5). A critical point for our purposes is that local governments do not have jurisdiction over telecommunications or previous experience of involvement in traditional communication infrastructures such as the telephone network or broadcasting. So, investment in PWF is effectively the first widescale local-level engagement with telecommunications. More significantly, technical evolution—particularly the convergence of communications, computing and geo-location capabilities in wireless mobile devices—presents a unique opportunity for LGAs to experiment and test the possibilities which PWF represents for local communities and urban governance.

In addition to their restricted functions, local governments in Australia are experiencing continuing financial stress and austerity, compounded by downward cost- and burden-shifting by higher

governments (Dollery, Crase & Byrnes, 2006; Grant & Drew 2017; House of Representatives Standing Committee on Economics, Finance and Public Administration, 2003). Further, state-level funding or co-funding of local-level infrastructure has the potential to distort local budgets and transfer risk. In cases where PWF services were funded for a trial period by a state government grant (this has occurred in Victoria and Tasmania), the LGA must either self-fund the project or terminate it when the grant comes to an end, shouldering any criticism of residents who typically identify the service with the local authority (personal comment, LGA officer, Tasmania 2016).

Taking into account the innovative character of PWF projects, the financial limitations of many LGAs, the necessity to undertake strategic decisions on (non-)provision of PWF infrastructure and the 'trial' nature of the investment, the importance of evaluation becomes clear. Not only can well-structured evaluation assist in outlining the technical and organisational parameters, which will help optimally deliver PWF infrastructure in the given specific spatial and social contexts, it should also promote and demonstrate accountable use of public funds.

1.4.2 The Research Gap and Research Context

Broadly stated, the term 'evaluation', seeks 'to contribute to enhanced feasibility and also support greater utility, propriety, accuracy, and accountability [of public projects, investments or services]' (Shulha, Caruthers & Hopson 2010, p.87). In this sense, evaluation requires attention to what Lowndes (2006) refers to as 'something old [and] something new'. That is, evaluation of investment in PWF infrastructure invokes conventional questions about the transparency and accountability of (local) government and raises new problematics around how we understand and evaluate the emerging phenomenon of investment in (networked) communication infrastructure by local governments in Australia. There has been little research on this topic internationally, and even fewer studies address the particular Australian context (Humphry 2014; Lambert, McQuire & Papastergiadis 2014; McShane 2019; McShane & Wilson 2017; McShane et al. 2014; Middleton 2014).
The OECD (2013) stresses the benefit of evaluating pilot programs and testing the validity of projects in different contexts. This chimes with the pilot or test status of many PWF projects, which are subject to changing council priorities and the availability of project funding (Interviews with LGA officials from Victoria and WA, 2018).

In the Australian context, the generic and routine character of evaluation has been criticised. First, while evaluation practices are embedded in systems of public administration, their design may provide little insight concerning the project or program under evaluation (ANAO 2013). The Australian

Government Performance Measurement and Reporting Framework (ANAO 2013) suggests that the administrative framework supporting the development and auditing of key performance indicators remains problematic in its focus on measuring output and activity.

The research goal of this thesis, which is to investigate investment in PWF infrastructure in Australia by LGAs, is achieved in several steps. After identifying an appropriate framework or approach for evaluating investment in PWF, which takes into account methodological limitations and the policy context, and reviewing literature relevant to this topic, the thesis turns to map the national picture of PWF provision including analysis of the investment rationales and examines whether the policy, institutional and technical settings of PWF provision support these rationales. Ideally, this will serve to both identify and account for the post-hoc value and social surplus generated by the investment (something new), while monitoring conventional public sector goals of transparency and accountability (something old). To respond to the "old-new" problem of evaluation, the thesis argues for the adoption of empowerment evaluation (EE) as a conceptual framework that can underpin adaptive local-level planning, investment and operation of PWF infrastructure by LGAs.

To reiterate a point made at the outset, we are witnessing a scaling up in PWF investment, as around two-thirds of Australian LGAs are providers of PWF, or plan to provide this soon. It is timely to cast a critical eye on these ventures within the rapidly emerging context of local government involvement in digital networks and platforms as ‘smart city’ and ‘non-traditional’ (generative) infrastructure. Examination of the local government sector’s experience with investment in PWF infrastructure may prove instructive for future policy and operational design in the field of digital communication networks and unveil opportunities or pitfalls in spheres of urban data analytics. There is, for example, international research documenting PWF opportunities for smart city solutions (Kontokosta & Johnson 2017; Mehmood et al. 2017), but little attention to the diversity of the Australian context (McShane & Wilson 2017). Similarly, given the policy focus on PWF as a service, little attention has been paid to the emerging issue of the role of PWF metadata in urban governance (Grechyn 2019).

1.4.3 Empowerment Evaluation as Concept and Strategy

The LGA officer cited in the epigraph pointed out that they would like to know about ‘best practice principles: defined goals, measurable outcomes and opportunities for innovation’ (LGA officer, WA 2018). How can evaluation contribute to the achievement of these principles?

Evaluation is sometimes described as an integral part of a cycle, which is a set of looped processes aimed at continuously improving program or project planning and outcomes while promoting transparency and accountability. The planning-evaluation-monitoring cycle is '[a] guide for doing planning, monitoring and evaluation based on good practices' (Menon, Karl & Wignaraja 2009, p. 32). It includes setting the vision and implementing a results-based management approach (RBM) through continuous usage of the evaluation and monitoring at all stages of project realisation.

This policy cycle model is a theoretical benchmark, and has been criticised for its formal, 'ideal state' character, which hardly reflects the contingent and messy reality of many government processes, and the 'bounded rationality' or knowledge constraints with which officials operate (Colebatch 2006). Regarding the problem of evaluating investments in PWF infrastructure, if a theoretical compendium of sound practice principles is not entirely achievable in practice due to its 'ideal state' character, then what can be proposed instead? Or, more precisely, what might serve as a nuanced 'good practice' approach, which would also be practical to implement for evaluating the investment in PWF infrastructure by local governments?

As detailed in chapter 4, LGAs play a limited role in PWF provision, which is mostly contracted out, have limited access to PWF metadata and little knowledge of how to evaluate infrastructure investment. This thesis argues that a greater involvement of LGA officers in provision and evaluation of PWF will help develop a more comprehensive understanding of the factors which determine the public value of PWF infrastructure in the short and long term. The enhanced capability of LGA personnel (especially IT staff) will contribute to a better understanding of innovation and capacity to adopt innovations in digital communication and smart city initiatives, for which PWF infrastructure can be a stepping stone. In addition, the concept of empowerment evaluation advocates that LGAs and also their communities can develop their own criteria for evaluating PWF infrastructure depending on the local conditions rather than rely on a ready-made formula, or constrained by inflexible contractual limitations. However, the enhanced role of the local government sector in the provision and evaluation of PWF infrastructure requires a research base from which to build and inform that role. This thesis aims to contribute to this research base.

Empowerment evaluation emerged in the late 1990s and is defined by its originators as an approach that "aims to increase the probability of achieving program success by (1) providing program stakeholders with the tools for assessing the planning, implementation, and self-evaluation of their

program, and (2) mainstreaming evaluation as part of the planning and management of the program/organisation" (Fetterman & Wandersman 2005, p.28).

EE responds to a consistent lack of evaluation of PWF investment in Australia (discussed in detail in chapter 4), highlighting the importance of the evaluation factor in project success while pointing out that local agents can internally evaluate local wireless networks without relying on external assessment. The EE approach was introduced in 1993, and in the first decade of operation attracted criticism concerning its conceptual ambiguity and lack of evidence of its effectiveness (Miller & Campbell 2006). Critics claimed that the EE methodology could not be unambiguously distinguished from other types of evaluation and questioned the rigour and validity of results (Cousins 2005; Patton 1997; Scriven 1997). EE's critics also questioned the attainability of empowering outcomes, such as engaging staff members in determining the focus and methods of evaluation or mainstreaming evaluation as a routine practice in an organisation (Miller & Campbell 2006; Patton 2005).

More recently, however, the EE has received renewed attention. For example, Donaldson (2017) argues that EE introduced an approach to project evaluation and self-evaluation by non-professionals. Patton, an early critic of EE, subsequently claimed that EE 'the approach has certainly prevailed, gaining not only legitimacy but utility' (2017, p. 139).

While the EE approach has been applied to a variety of settings, including non-profit, business and education (Fetterman, Rodríguez-Campos & Zukoski 2017), it has not been applied to digital infrastructure, which is one contribution of this thesis. In the context of this thesis, EE is more of a guiding philosophy that promotes the agency of people and organisations, although as a methodology it relies on a set of ten principles (see Table 1) that, according to Fetterman and Wandersman (2005), distinguish EE from other evaluation approaches. While some principles, such as accountability, are explicitly or implicitly inherent in the majority of evaluation methods, others seem particularly relevant to LGA PWF infrastructure investment. Table 1 below provides an explanation of how each of the EE principles relate to the thesis subject.

Table 1. EE principles and their relation to the thesis

EE Principle	Relevant chapters	Application to the thesis
Improvement	Chapters 4, 5, 6, 7, 8	The principle of improvement is fundamentally based on the idea that “empowerment evaluators want programs to succeed” (Fetterman & Wandersman 2005, p.30). To this end, EE values the improvement of organizations, people and projects to help them achieve results. This is not only the first EE principle, but also the leitmotif of this thesis, which looks at LGA's investment in PWF from the perspective of possibility for improvement, capacity-building and experimentation. This is in contrast to traditional evaluation, which values neutrality and objectivity and wants to examine projects in their "natural state".
Organisational Learning	Chapters 4, 8, 9	Organization learning is the capacity to use empowerment evaluation to inform the planning, implementation, and improvement of the PWF project. This principle correlates with the findings and conclusions of this thesis. For example, organisational learning echoes the conclusion of this thesis that LGAs should invest more in the competence of IT staff, and among other things, acquire the necessary skills to collect and analyze PWF metadata.
Community Ownership	Chapters 7, 8, 9	In EE, the community ownership principle means that project stakeholders have the responsibility of making critical decisions about the project and the evaluation. In the context of this thesis, this means that LGA officers, perhaps with the help of the local community and building on the available research base (including this thesis), conduct their own PWF evaluation and put the evaluation findings to use. This is in contrast to typical

		traditional evaluation approaches, where the external evaluator and the funder but not the stakeholders hold the decision-making power regarding the purpose, design, and use of evaluation results.
Inclusion	Chapters 4, 8, 9	The principle of inclusion means, on the one hand, that the interests of all parties should be taken into account. For example, the goal of digital inclusion is not fully achieved as long as there is a group of people who want to have access to the Internet and do not have this access. Therefore, the interests of this digitally disadvantaged group must be taken into account and addressed, no matter how small the group is.
Democratic participation	Chapters 4, 5, 6, 7, 8	The principle of democratic participation is based on the belief that when stakeholders are involved in evaluation and decision making, projects are more likely to fit the needs of the target audiences and to succeed. Democratic participation is a principle that is considered critical for securing stakeholder engagement in EE (Fetterman & Wandersman 2005).
Social Justice	Chapters 4, 5, 6, 7, 8, 9	The principle of social justice assists 'people to use evaluation to improve their programs so that social conditions and communities are positively impacted' (Fetterman & Wandersman 2005, p. 34). This reflects the goal of bridging the digital divide and providing the possibility to access the Internet for everyone that is enabled by an evaluation process that ensures sufficient PWF technical capability to achieve this goal.
Community knowledge	Chapters 7, 8, 9	The value of EE attributed to community knowledge is an important counterbalance to the external evaluation and available research base. External knowledge, evaluation and research serve as a springboard on which stakeholders can build their own evaluation using their unique local knowledge (know-how). The empowered position of local governments in evaluating and delivering PWF puts them in a strong position and contributes to their knowledge base. One of the elements of knowledge detailed in this thesis is the collection and analysis of PWF network data.
Evidence-based	Chapters 4, 5, 6, 7, 8, 9	Evidence-based strategies are those which are

strategies		supported by evidence and research. As Fetterman and Wandersman Fetterman (2005, p.8) put it: "Evidence-based strategies need to be adapted to the local context, but they can save the community precious time and resources". In accordance with this principle, this thesis aims to contribute to an evidence base for local authorities to build their own evaluation, planning and management of PWF infrastructure.
Capacity Building	Chapters 4, 6, 7, 8, 9	As Fetterman and Wandersman (2005, p. 5) point out, "commitment to local control and capacity building are aligned with empowerment evaluation values". The capacity building relates to investing in IT competence of LGA staff and acquiring operational control, or at least, the informed oversight of PWF, which facilitates future LGA experimentation with digital infrastructures. Also, the principle of capacity building in the context of applying EE principles to PWF infrastructure reminds us of the possibility to collect PWF network data, even though it might initially be easier for LGAs not to do so by transferring all control and functions to the PWF contractors.
Accountability	Chapters 4, 8, 9	The issue of minimal accountability and transparency, together with IT competence and evaluation, have emerged as challenges in PWF provision by LGAs in Australia. An EE approach should promote greater accountability and transparency of PWF projects. At the same time, it is a reciprocal process: greater accountability and transparency, and as a consequence, the availability of information will facilitate evaluation, serving as both a knowledge bank and a benchmarking base.

1.5 Thesis Structure

The next chapter of the thesis discusses the epistemological and methodological underpinnings of the thesis, including research design, methods and data. The chapter begins with a discussion of the nature of value in general and in relation to PWF infrastructure in particular; it also considers epistemological constraints for evaluating PWF infrastructure. It then provides a brief overview of the different periods of public administration and their relationship to approaches to valuation, with an argument that the EE

philosophy is consistent with the emerging New Public Governance doctrine. An overview of data collection methods, research tools and research limitations concludes the chapter.

The third chapter provides a comprehensive review of Australian and overseas literature relating to PWF, organised by the symbolic 'layers' of PWF infrastructure as shown in Figure 1 above. It covers rationales for PWF provision, organisational models, policy context, and the role of technical parameters in PWF infrastructure, and identifies the research gaps addressed in this thesis.

The fourth chapter addresses the research questions, 'What is the current state of PWF provision by local authorities in Australia? What is the context in which this development is taking place? Which local authorities deploy PWF and why?'. Drawing on national survey data, it investigates PWF provision by LGAs in Australia, discusses rationales for provision, locations, and technical limitations, and highlights the problems of transparency, accountability and the systematic neglect of evaluation. If an increasing number of LGAs are investing in PWF, few appear to have a grasp of its potential uses and outcomes, whether the outlay represents value for money or generates social value. As is further discussed in the thesis, the outlined drawbacks can be complexly addressed by adhering to EE principles in PWF management and evaluation, particularly via targeting the permanent improvement in project management and evaluation (the first principle of EE) and mainstreaming organizational learning and capacity building into LGA practices.

The fifth chapter addresses the question 'How do policy and macroeconomic contexts influence the evaluation of the investment in PWF infrastructure?'. While Australia lags OECD counterparts in PWF availability and coverage, it remains unclear whether underinvestment in public wireless infrastructure is balanced by more affordable commercial broadband in Australia. The fifth chapter investigates this question by comparing the financial affordability of comparable broadband in Australia and other countries by introducing the concept of the 'perceived broadband price'. This pricing takes into account the level of incomes in sample countries and purchasing power parity adjusted to the price of benchmark consumer goods. While Australia is found to lag in both PWF availability and affordability of commercial broadband, this finding highlights the importance of PWF initiatives to foster digital inclusion as a last resort for Internet connection. Indeed, the national survey revealed that facilitating digital inclusion is one of the main reasons for LGA investment in PWF by LGAs (tourism is the other major rationale, as discussed in chapter 4). Further, over four million Australians who cannot afford broadband, rely solely on a mobile connection (Wilson et al. 2019), and hence, PWF is an indispensable means of accessing the Internet for digitally underprivileged Australians (Humphry 2014; 2019; Rennie 2018). This echoes EE principles of social justice and social inclusion, which in

the digital sphere can be strengthened by LGAs by investing in PWF. At the same time, in order for local authorities to actively implement these principles, EE recommends to enhance community ownership and capacity building.

Chapter 6 addresses the research question, 'Is the quality of the PWF service important for users?'. Along with addressing the digital divide, encouraging tourism and boosting economic activity were the other major rationales for PWF provision identified in the national survey data. However, achieving these aims is contingent on the quality of the PWF service. The lack of access to PWF metadata for analysis (an issue discussed in detail in chapter 7) significantly hampers independent research in this area. To overcome this problem, chapter 6 focuses on a demographic central to tourism and economic activity: hotel customers. It investigates the effect of hotel Wi-Fi speed on tourist satisfaction based on customer feedback. This investigation serves as a proxy model to investigate the effect of PWF technical characteristics on tourist satisfaction. It assumes that tourists are likely to perceive the quality of hotel Wi-Fi and local destination PWF in a similar manner. As much as the findings and practical recommendations in this chapter, being extended to the PWF case, may seem intuitive, they are also often overlooked or ignored on practice. The quality of the PWF infrastructure is critical to how this infrastructure will be viewed by users and ultimately to the success of a PWF project. Consequently, continuous capacity building and a willingness to improve the PWF infrastructure is required, which is in line with similarly named EE principles (i.e., capacity building and improvement).

Chapter 7 addresses the research question 'Can PWF metadata be accessed for urban management purposes'? This thesis showed that few LGAs had considered access to or use of network metadata; instead, they approached PWF mainly as a service. Telco providers, however, were more alert to the value of metadata, and in at least one instance sought to monetise it by selling data analysis to a city government (LGA official, South Australia, 2019). However, local governments that were alert to this issue were concerned that regulatory conditions may prevent metadata use. In this setting, there has been little investigation of the potential of PWF metadata, but there is also little evidence of a skill capacity within the LGA sector to undertake such a task. Fuller investigation of this issue, however, encountered a transparency barrier. No LGA was willing to provide a copy of the contract used to engage telcos to provide PWF, citing commercial-in-confidence reasons, and only one LGA (Launceston, Tasmania) was willing to authorise access to network metadata that it had access to. The subject of PWF metadata, then, illustrates a convergence of 'old' and 'new' problems of urban governance. The chapter argues that without greater access to and operational control over PWF metadata, LGAs cannot leverage PWF infrastructure to effectively utilise data for urban management or experiment with its innovative potential. It concludes that the risk of breaching individual privacy

by access to PWF metadata is minimal. In the context of current regulatory settings and business models relevant to PWF provision, the chapter argues for the establishment of a metadata commons. The recommendations outlined in the chapter are consistent with the EE principles of community ownership, community knowledge and capacity building.

Chapter 8 addresses the research questions 'Does the organisational model through which PWF is provided influence LGA capacity to sustain and innovate using PWF?'. The chapter considers models of PWF provision regarding control issues over PWF technical parameters, long-run sustainability of the PWF project, and the potential of experimentation with PWF metadata. The chapter argues that strengthening the role of LGAs in PWF provision (rather than contracting out as a default choice) will improve the feasibility of the project as well as enhancing possibilities for experimentation. In parallel with considering the arguments for greater local government control over the PWF infrastructure, the chapter also analyzes the arguments and counter-arguments for private provision of PWF infrastructure. This chapter argues that gaining more control over PWF infrastructure is consistent with networked and participatory governance as well as EE principles and recommendations and increases local governments' ability to innovate and create a social surplus for their communities.

The conclusion synthesises the discussion and the findings within the previous chapters, identifies the contribution this research has made to theoretical and applied domains of the topic, and discusses further areas of research opened up by the thesis.

The thesis includes journal publications and conference proceedings, and in one case, a paper which is currently under review by a journal. These are detailed at the beginning of relevant chapters. The formatting, style of referencing, the numbering of Figures and Tables are unified to make all these parameters consistent throughout the thesis.

Chapter 2: Methodology

2.1 Researching PWF

The limited research on the provision of PWF in Australia means the field has not been empirically mapped, and there has been little work on how we conceptualise PWF as a new venture by local governments, and how the growing investment in PWF can be evaluated. This thesis conceptualises PWF as an infrastructure, in contrast with the mainstream view of PWF as a service. In framing PWF this way, the field of critical infrastructure studies provides a theoretical approach that seeks to identify the normative underpinnings, political ideologies and power dynamics that shape the provision and uses of public infrastructure. According to Frischmann (2012), infrastructure can be viewed as an input into a variety of productive social and economic activities, and infrastructure users who engage in such activities often generate spillovers that benefit society as a whole. For example, managing the Internet infrastructure as an open public resource facilitates active citizen involvement in the production and sharing of goods as well as fostering innovation (Frischmann 2012).

The particular challenge of this research was to understand the value of PWF as a new type of infrastructure, and how that value might be optimised by LGAs. While recognizing the potential of PWF as a facilitator of innovation and as a vehicle to achieve economic and social goals (such as bridging the digital divide), this thesis does not aim to quantify these positive outcomes. The calculation of such economic and social effects is associated with methodological and epistemological difficulties, as will be shown in more detail below. In a nutshell, this means that viewing by default the concept of PWF infrastructure as beneficial for society, the thesis aims to investigate under what conditions the value of the PWF infrastructure will be maximized. EE, which serves for this purpose, does not provide a ready-made set of benchmarks or measures, but relies on locally-situated and participatory processes to identify program aims and outcomes, responding to the ten principles. It is a bottom-up rather than a top-down process, reliant on community input rather than expert intervention. However, implementing an EE approach in evaluating PWF investment requires the generation of new theoretical and empirical knowledge, which this thesis aims to do.

To achieve this aim, the first task was to identify an evaluative method that best recognised the particular characteristics of PWF, and the governance and user settings in which PWF is located. The rationale for choosing empowerment evaluation is explained in the section that follows. The effective use of empowerment evaluation to assess PWF investment by local governments and local communities requires a new empirical knowledge base and the development of several quantitative and

qualitative methods or techniques, such as the survey method, interview method, econometric analysis, and others. Details of these methods, as well as an overview of the methodological problems and limitations of this thesis, will continue this chapter.

2.2 Methodological Considerations and Research Limitations

2.2.1 Finding Value: Epistemology, Political Ideologies and Approaches to Evaluating Public Projects

As a principle, when considering the value of the object under evaluation, it is possible to focus on either merit or worth. Worth is usually expressed in numerical monetary terms, as a cost, a price, an estimation of the effort put into the object or project, or a de-facto or expected return on investment. The merit can be described as an intrinsic value of the object expressed in its ability to be useful or convey certain physical, aesthetical or intellectual utilities, regardless of how low or high the object is valued in monetary terms. As Lincoln & Guba (1980) put it, merit is context-free, while worth can be determined only concerning certain circumstances.

A closer investigation of the merit and worth conceptions would lead us more deeply into the study of economic theory, valuation theory or axiology than space allows. The following must suffice. The value is a socially-constructed category since the value of the object is determined by people's need in that object, level of their satisfaction when interacting or using it, emotions or factors which may not be apparent. In market economics, the price model implies that the value is determined by the demand for the object and its scarcity. So, the price (which embodies market value) is determined by the point where supply and demand curves intersect, which is a general model for so-called perfectly competitive markets (Mankiw 2014). But suppose the object is evaluated out of the market. In that case, the value-determining model can not be as much straightforward and transparent, even if the certain degree of abstraction and simplification is applied (Potts 2014).

Furthermore, the principles and extent of government provision of services and infrastructure to the population are closely linked to current and prevailing political discourse. Differences in electoral programs, promises and actual actions of different political parties illustrate this point. Such differences, if exacerbated by the deliberate failure to come to a consensus and lack of transparency, can lead to the significant loss of the taxpayers' money. The East West Link highway project, which

was the central issue in 2014 Victorian government elections and was cancelled at the cost of $1.1 billion by the subsequent government, is a good illustration of this (de Martinis & Moyan 2017).

As much as the valuation of the public project has an intrinsic political component to it, it also stems from certain assumptions, evaluation techniques, or at least from a system of beliefs prevailing in a society or a group. But while some politicians may bluntly appeal to the feelings, needs or values of their target audiences, the public servants who administer the realization of the project, should adhere to the principles of accountability and evaluation, including post-implementation review and analysis, as conditioned by the best-practice principles of public administration (Head 2014). Changing theories, ideologies and practices of public administration in recent decades have entailed changing outlooks on evaluation.A brief description of these periods is given below, which will provide an insight to understanding the historical context of the emergence of EE philosophy.

The inception of large-scale infrastructure projects after World War II was accompanied by an attention to program evaluation as a new technique of government, notably in the US (Fainstein, 2000). Significant funds were allocated by US federal administrations to evaluating public investment in infrastructure, research and educational projects, which led to developing quantitative techniques with the sharpened focus on measuring the effectiveness through estimating projects' outcomes (Urban, 2010). New quantitative methods developed within sociology and economics and applied to evaluating public projects included survey, cost-benefit and cost-utility analysis, and econometric modelling, including regression and multi-regression analysis (Nermend and Łatuszyńska, 2019).

In the 1970s the USA and many other developed countries experienced economic recession and fiscal deficits, marking the end of a period of sustained economic growth after World War II (Zarnowitz and Moore, 1977). Proponents of smaller government and the roll back of welfare provision became increasingly influential. The economical usage of resources came to dominate policy-making and evaluation agenda. Views on the inefficiency of government found outlets in deregulation, privatization and cost-cutting, with private-sector emulation reflected in a rhetoric shift from public administration to public management, and a preference for service delivery by the private sector or corporatized public agencies (Bozeman 2007, Ter Bogt 2008).

Following the precepts of what became known as new public management (NPM), evaluators focused primarily on the cost of projects rather than measuring their results. This marked the shift from complex 'hard sciences' methods to the audit-like examination of the project outcomes. Consequently,

evaluation practitioners adopted cost-benefit analysis and other methods such as KPI (key performance indicators) analysis, with the main focus on cost reduction (Bozeman 2007).

In the 2000's the NPM paradigm has coexisted and competed with New Public Governance (NPG), which continues to evolve (Osborne 2010; Bryson et al. 2014). NPG has contested NPM's market-normative stance focus with a theory of public value. A community turn in public policy has introduced concepts of networked governance (Bryson et al. 2014) and participatory evaluation led by the stakeholders, which marked the emergence of EE (Fetterman & Wandersman 2005). Grant & Drew (2017) refer to NPG as "public value governance", to emphasise the importance of public administrators creating value by engaging more deeply with the interests of the community.

NPG provides a favourable environment for applying empowerment evaluation. EE holds that accountability and transparency is best served through participatory processes (Fetterman & Wandersman 2005). As discussed in the Introduction, empowerment evaluation aims to increase the likelihood of project success by involving the stakeholders in project evaluation while increasing their ability to plan and implement that project (Fetterman & Wandersman 2005). This principle resonates with NPG's drive for public value through more active stakeholders' engagement and providing them with a leading role in evaluation.

Critics have pointed to what they perceive as several limitations of EE. For example, EE has been criticized for being vague and lacking in methodological rigor (Miller & Campbell 2006). Viewed from another perspective, these can be seen as advantages in the specific conditions of evaluating the PWF infrastructure, which, as argued in the introduction, is a non-traditional infrastructure with the potential for innovation and experimentation. To compensate for the general 'vagueness' of the EE approach, this thesis provides methodologies and data that can inform LGA officials in planning and carrying out evaluation of the PWF.

Another limitation stems from the fact that while EE advocates participatory evaluation, broader community involvement can be problematic for the simple reason that community members may not have the motivation or skills for such activity. However, simple feedback from community members (for example, on matters such as Wi-Fi quality and experienced average bandwidth ('speed') or subjective preference for PWF locations) can be useful to increase the value of the PWF, while such feedback can also be viewed as a variant of participatory evaluation.

To summarize, the argument for EE is that the evaluator is not external to the local government, and LGA officials will need to lead in empowerment evaluation of PWF. At the same time, a certain amount of knowledge and technical work is also required to support this process, which is what this thesis serves. The following sections will contextualize the thesis within research limitations, including problems of data availability and validity of results, and then the chapter will move on to describe the design, methods and instruments of the study.

2.2.2 Better no Numbers Than 'Silly Numbers'

A penchant for producing numbers where quantitative evaluation is methodologically inappropriate may result in unreliable results. For example, the universe is too small, the nature of the intervention varies, or the setting of the intervention is novel. In these cases the recommendation is 'better no numbers than silly numbers' (White 2006, p. 16). In the case of PWF, which is non-traditional infrastructure provided outside the market, economic or social estimates may only bring more perplexity than supposed practical insights.

Quantifying the PWF effects, if carried out despite all the methodological limitations, can lead to a misleading impression that the complex nature of certain phenomena can be dissected and easily understood. To illustrate this, let us consider some estimate, say a two per cent increase in sales in the areas covered with PWF infrastructure (an actual result produced by Sobolevsky et al. 2017). Apart from the questionable methodological validity of such a result, what are the practical lessons or implications? For example, is it possible for a two percent increase in sales to serve as a self-sufficient justification for public investment in PWF? To answer this requires additional criteria, for example, comparing the cost of investment in PWF with the local sales effects. However, this comparison would be contestable because PWF is not provided within a market where competitive self-interest and efficiency are of paramount importance. Its purpose is to compensate for market failure of PWF provision (Potts 2014).

On the contrary, a mistake in calculations or unreliable data may distort evaluation, and quantification may omit critical factors, because those factors are not measurable. As Huizinga (1980, p.2) points out in the context of play "they [scientists] attack play direct with the quantitative methods of experimental science without first paying attention to its profoundly aesthetic quality. As a rule they leave the primary quality of play as such, virtually untouched". Indeed, such an approach, by itself, would preclude evaluation of the subtle positive externalities of using PWF such as the possibility to have fun, which unpredictably stems from communication, content creation, or even play.

At root, there is no single purpose for PWF provision, but rather an assembly of goals which interplay and enhance each other. Not all goals or rationales for PWF provision can be turned into quantitative indicators or estimates. The most popular rationales, according to the survey of Australian LGAs described in chapter 4, include encouraging tourism, promoting digital inclusion and facilitating business activity (a comprehensive review of rationales for PWF provision in general and as they are identified by Australian LGAs can be found in chapters 3 and 4). For example, it is difficult, if not impossible, to turn social categories and values into the market-based values or estimations (Bozeman 2007). To illustrate this point: would the number of twenty, ten, or even one individual who uses PWF exclusively to access the Internet be sufficient justification for investing in PWF infrastructure in a small Australian town? While there will always be resource limitations implying the necessity of optimisation, the ideal character of the digital inclusion goal must be taken into account. Indeed, social goals are not easily squeezed into the Procrustean bed of economic feasibility. According to a recent report on Australia's digital divide, 'the goal of digital inclusion is to enable everyone to access and use digital technologies' (Thomas 2020, p. 7). This definition infers universal access to the Internet; formally, 'inclusion' is not fully achieved unless everyone has either first or last (i.e., public) resort[2] for Internet access. So, from this point of view, digital inclusion as a rationale for PWF provision is not as much about numbers as it is primarily about establishing the very possibility of accessing the Internet for everyone who needs it.

2.2.3 Problems of Data Availability and Validity of Results

The previous section considered general methodological limitations of evaluating the economic and social effects of PWF. Moving from general considerations to a more concrete question: is it technically possible to estimate the putative benefits of PWF deployment, such as fostering economic activity or tourism? There are no published studies that quantify the social or economic effects of PWF, other than a self-published study by Sobolevsky et al. (2017). In this article, although the authors solved the problem of the availability of granular data in a rather unusual way, which are discussed briefly below and in more detail in Chapter 6.

From a data availability perspective, the impediment for quantifying the local effects of PWF provision is that statistical information which describes different types of economic activity is not available on

[2] Here, the first resort is understood as the situation when PWF is used as the principal and/or usual way of connecting the Internet (e.g., by people who don't have wired or mobile Internet plan). In contrast, the term 'last resort' describes the situation when people use PWF as a supplementary means of accessing the Internet (e.g., to save mobile traffic or when they run out of mobile traffic allowance).

granular levels such as a city block or several city blocks. Further, PWF coverage in Australia usually only extends to a limited area, like an urban precinct such as a park, square or several city blocks or a linear configuration such as a city street. Researchers who want to use low-aggregated economic data have to obtain data from non-traditional or commercial sources. Sobolevsky et al. (2017) investigated the impact of PWF on the level of local economic activity in New York using low-aggregated financial data concerning the volume of Mastercard transactions at city-block scale.

For estimating PWF effects, theoretically (where the necessary data is available), regression analysis is 'the most widely used statistical procedure to assist in judging economic cause and effect' (Greenspan 2013, pp. 11-12). This is also the method used by Sobolevsky et al. (2017). However, a common problem in econometric analysis, which is the confusion of correlations or simple coincidence of facts with causation (Greenspan 2013), will interfere with the analysis of PWF effects and distort interpretation unless all the variables that are affecting the data are correctly accounted for. For example, if in certain areas with PWF it is found that the rate of economic growth is higher than the average for the city or district, this may be due to the socio-economic characteristics of those urban areas where PWF are usually located (e.g., city centres). At the same time, in other areas (e.g., city outskirts) where PWF are usually not deployed, the level of economic growth is also lower. In other words, the impact of the PWF may be insignificant or negligible, while other factors such as the location of the PWF infrastructure may play a major role. At a time when the cost of mobile phone data is considerably more affordable than in the early years of PWF, the attractiveness of PWF as either the first or last resort for Internet access for many people in Australia is low. To illustrate this point, in Adelaide, which arguably hosts the best Australian PWF network, people often turn off their Wi-Fi connection and instead use their phone data in CBD and North Adelaide (Richards 2020). In such a situation, when people in many cases disregard PWF, intuitive thinking suggests that the impact of the PWF on economic indicators will also be insignificant. At the same time, PWF is still essential for some digitally disadvantaged people or tourists,and is also strategically important in terms of being a unique case of local public telecommunications with a potential for innovation and experimentation.

Hence, in the case of PWF provision, estimating economic effects does not make much sense due to methodological limitations and questionable validity of results. The social effects such as digital inclusion, although they can be accessed with some approximation in the particular case of a local community via survey method (Real et al. 2014), are not instrumental for market-based decision-making (Bozeman 2007). In these circumstances, what evaluation of investment in PWF can and should be made (or, in other words, what are appropriate objectives of evaluation, and how can these be achieved)? The next section addresses this question.

2.2.4 The Technical Performance of PWF

The LGA official cited at the start of this chapter sought details on ‘evaluations against expectations, and end-user satisfaction’ (LGA officer, WA 2018). LGAs cannot control the number of users who connect to the public wireless network or the types of socio-economic benefits facilitated by PWF. However, they can influence the numbers willing to connect to the PWF and become regular users by ensuring adequate PWF technical capability. Logically, proper technical performance is fundamental for PWF usability. In marginal cases where the network characteristics are insufficient for quickly loading a simple HTML page, the PWF network ultimately becomes virtually useless. For example, another official commented during an interview that ‘the evaluation was basically feedback from the community saying this is crap, doesn’t work, never works’ (Local Government Official, WA, 2017).

In the same interview, that LGA officer explained that after negotiating improvements with the PWF service provider, the feedback from the local community changed to be overwhelmingly positive. This change in public opinion can be explained by a significant increase of average bandwidth (‘speed’) and the removal of traffic caps after re-negotiation of the contract agreement. The readiness of the contractor in this instance (in the view of the LGA officer) to improve the technical parameters of PWF network while reducing the service cost may look surprising; yet it can be explained by market factors such asymmetry of information, low transparency and significant variations in price for PWF deployment and maintenance (details in chapter 4). This example illustrates the importance of PWF technical parameters in users’ satisfaction and LGA awareness of and responsiveness to this issue. This may range from a better understanding of the nuances of PWF provision and informed negotiation with PWF contractors by LGAs, through to in-house provision with full control over the digital infrastructure.

2.2.5 Moving Within and Through the Research Limitations

To summarise, evaluating investment in PWF has methodological limitations, particularly in directly assessing the economic impact of PWF or quantifying the social impact. However, this thesis argues that PWF should be viewed as a generative infrastructure, where the opportunities it provides to local governments and communities cannot always be foreseen. To take advantage of these opportunities and at the same time ensure appropriate standards of quality and usability, local governments need to maintain ongoing operational control or at least informed oversight of PWF infrastructure. The underlying research problem, then, is to determine a method of evaluation that responds to the

characteristics of PWF and its deployment in local communities and urban settings. In order to do this, the following research design was executed.

2.3 Research Design

2.3.1 Mixed Methodological Approach

This thesis uses a mixture of quantitative and qualitative methodologies to investigate the research questions. The research methodology relies on critical realism ontology, which 'views reality as complex and recognises the role of both agency and structural factors in influencing human behaviour' (Given 2008, p. 167). Mingers (2006) points out that critical realism legitimises employment of both qualitative and quantitative methods, such as content analysis or quantitative modelling and statistical analysis, combining 'hard' and 'soft' methods. Quantitative and qualitative methods may relate to different aspects of the research object and may be complementary to each other in mixed-methods research. Consequently, the combination of the different perspectives provided by quantitative and qualitative methods may produce a more comprehensive picture of the research object (Lund 2012).

Critical realism emerged as a response to the fundamental difficulty of maintaining a realist position in the domain of social and interdisciplinary sciences (Mingers 2006). In economic science, critical realism sometimes aims to provide explanations in terms of 'hidden generative structures' (Boylan & O'Gorman, p.513), where economic effects cannot be measured via methods of conventional economics. More concretely, although such generative structures 'have the power or capacity to act in certain ways by virtue of their enduring, intrinsic natures or essences', they also may 'be present in reality without being manifest to our observational capacities'; therefore, they may be described as 'hidden' (Boylan & O'Gorman, p.513). In this context, the social and economic effects of PWF infrastructures are often described as 'hidden generative structures'; that is, they cannot be directly captured or measured in their complexity within the methods of conventional economics. This 'hiddenness' should not lead, however, to the mystification of the PWF infrastructures; quite the contrary, by merging quantitative and qualitative methods of inquiry, the thesis attempts to investigate PWF infrastructure, where the realms of technology, information, governance and the social interact.

2.3.2 Overview of Data Collection Methods Within the Different Chapters

This section provides an overview of the data collection method used in this thesis. The data used in this dissertation was obtained using a number of qualitative and quantitative methods, as detailed below. Quantitative methods were used only in those methodological settings that do not compromise the validity and robustness of the study results, taking into account the methodological limitations of quantitative methods described in this chapter.

2.3.2.1 National surveys

The essential primary source of data for the thesis was two national surveys undertaken among the Australian LGAs. Surveys, as well as interviews described in the next section, were undertaken because there was no baseline data on the provision of PWF and few insights from LGA officials about why they invested in PWF, i.e. there was a significant empirical gap. The surveys were designed using Qualtrics software (as required by RMIT University's ethics framework) and administered on-line. The structure and design of the surveys are presented in Appendices A, B and C. The first survey was circulated on November 1 by direct email invitation with a reminder sent on December 13. The second survey (on the evaluation of PWF projects) was distributed among the same LGAs in early 2018. Qualtrics' analysis and data visualization tools are used in this thesis.

Chapter four relied on survey and interview methods to provide the first national-level mapping of PWF provision and generate insights on the LGA rationales. The survey was organised as follows. First, a list of all local governments in Australia was compiled, using the ALGA website, as well as other open sources such as Wikipedia. The author then visited the website of each of these local governments. Virtually all of the local governments listed on either ALGA website or Wikipedia (465 local governments in total) had their official websites, even if the population within their jurisdictions was only a few people. By searching through each website, the author found the contact email address. If several email addresses were available on the site, then the author chose the one that seemed most relevant in the framework of the research (for example, the contact of the head of the IT department). In some cases, websites did not have an email address explicit, but only a contact form. In such cases, the author looked at the webpage source code (HTML or the embedded Javascript) to see if there was an email address linked to the contact form.

The names of the local governments had been listed in an Excel File together with contact information (email, or a link to the website with a contact form in those rare cases when the email address was not

possible to retrieve). Also, each entry for each local government was complemented by the additional information, such as the name of the state, area size in square kilometres and population size. This allowed enriching the survey results with supplementary data such as population density in a given LGA jurisdiction.

The first survey invited the participation of LGAs, regardless of whether they were providers of PWF at the time or not, and was sent in October 2017 to a contact database of 465 LGAs in metropolitan, rural and regional areas. This resulted in 111 usable responses, a response rate of 24%. The second survey, which was undertaken two months after the first one, took a closer look at questions related to the evaluation of PWF investment by local governments. Only the actual PWF providers were invited to participate; however, the survey was disseminated among the whole database in the expectation that circumstances of some LGAs may have changed since the first survey. The second survey consisted of 9 questions and resulted in 62 responses.

2.3.2.2 Interviews

The thesis also uses data from 24 interviews with LGA and telco officials conducted between 2016 and 2018. The author completed nine of these interviews, and the rest were conducted by Assoc Prof Ian McShane and Dr Chris Wilson. Of the interviews conducted by the author, seven were conducted by telephone, and two were face-to-face (in Cowes, Victoria and Adelaide, South Australia). All interviews, including phone and in-person ones, were recorded with the consent of the interviewee and then transcribed.

2.3.2.3 Secondary data sources

In addition to the primary data, the thesis also used data from open sources, such as hotel ratings, average Wi-Fi speeds in Australian hotels, and available research publications, among others. A list of secondary data sources along with their application in the thesis is presented below.

- Open data describing average broadband prices, GDP per capita indexes, Big Mac indexes[3] and population densities for different countries, were sourced from the OECD database, The Economist, ITU, Numbeo.com and the World Bank. The purpose of this data was to estimate

[3] The Big Mac index reflects the difference in purchasing power parity (PPP) between nations, using the price of a McDonald's Big Mac as the benchmark. It has been calculated and published by *The Economist* magazine since 1986.

how expensive Internet connection is in Australia, compared with other nations, and thereby, build a case for its provision as a public good (see chapter 5 for details)

- Rankings of Australian hotels and the average speed of Wi-Fi connection were collected from open sources such as www.hotelWi-Fitest.com and www.tripadvisor.com.au websites; data related to the use of Canberra's PWF network, were sourced from the data commons 'data.gov.au'; and data describing the technical characteristics of PWF networks in Melbourne (Vic) and Adelaide (SA), were collected by the author via the 'WIFIman' application programming interface installed on a mobile phone. The purpose of this data was to investigate the influence of PWF technical parameters on its usability or user satisfaction (see chapter 6 for the details).

- Network metadata were obtained from the PWF in Launceston (Tasmania) and provided to the author by the Launceston LGA. This is a unique source of data as local governments or telecommunications companies do not usually share PWF metadata due to confidentiality considerations (see chapter 7). Launceston PWF metadata allowed the simulation of real-world data analysis scenarios that local governments could undertake with their PWF data.

2.3.3 Research Instruments Design

This section provides a summary of the methodologies that have been applied in the thesis. Figure 2 represents a diagram of the research design.

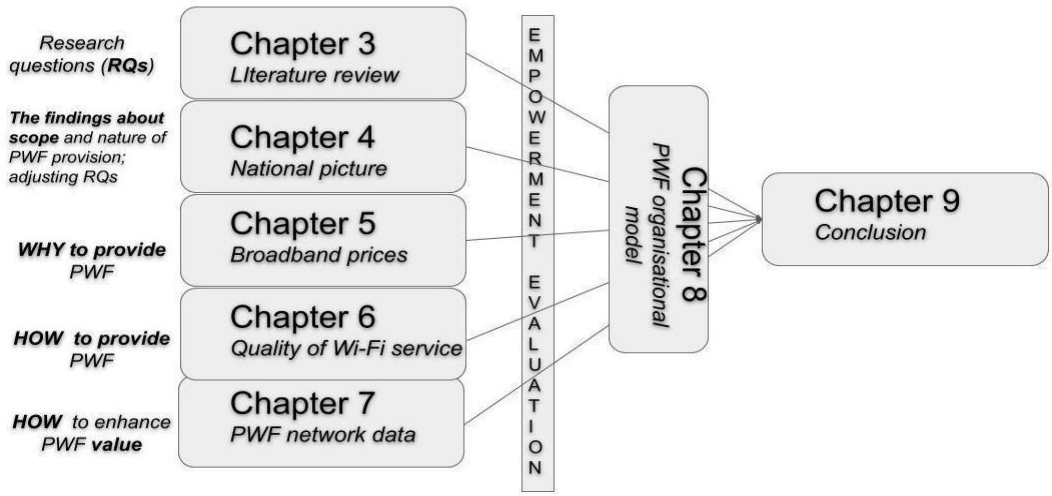

Figure 2. The diagram of the research design

Chapter 4 uses a variety of quantitative methods to analyze data from a 2017 survey among Australian LGA officers, combined with narrative analysis of interviews with government and local government officials and telecommunications personnel conducted in four Australian states in 2016-2018. Methods for analyzing the data of the survey results included correlation analysis, cluster analysis, visual data analysis, including the construction of various graphs and diagrams. Most of the data analysis and visualization has been done in Python software; some of the charts have been rendered using Microsoft Excel software.

Chapter 5 uses various types of data analysis, including correlation analysis, distributional analysis, and data visualization. The chapter also built several variables to get insights into the data. These included the "perceived price of broadband" ratio (the price of broadband in a given county divided by the average annual wage rate in that country), the price of broadband, adjusted for purchasing parity, and the price of broadband, adjusted for the BigMac index. The chapter culminates with a synthesis of the data analysis. As a result, the factor model called to explain the significant differences in broadband prices around the world and high prices for broadband in Australia is proposed.

Chapter 6 deploys linear regression model as a principal research instrument, with a research goal to estimate the relation between the customer evaluation of the hotel's quality and the Wi-Fi quality:

$$HotelQuality\_i = \beta_0 + \beta_1 Wi\text{-}FiQuality\_i + \gamma X + e,$$

where X is a set of control variables and e is the error term.

The analysis of the linear regression model was undertaken in the Stata software environment (see Appendix E). The data comprised components of hotel rankings (*HotelQuality_i)* sourced from www.tripadvisor.com.au website, which are: location, service, cleanliness and value (dataset compiled data from 312 Australian hotels), and the components of data from the national survey among Australian LGAs (session time limitations imposed on PWF networks, traffic limitations and location of PWF networks). Location was used as a linking key for two datasets, and traffic and session time limitations constituted *Wi-FiQuality_i* variables. The hotel data was linked to the geographically closest PWF network data. Additionally, data on population size and density within the areas of jurisdictions of local governments which participated in the survey were included.

Chapter 7 relies on mixed methodology, combining critical analysis of legislation and narrative analysis of interviews with various methods of quantitative analysis of Launceston network metadata. The methods of Launceston metadata analysis included longitudinal analysis, cluster analysis, distributional analysis, data visualisation. The central part of the research was undertaken in Python 3.7 (Jupyter 5.0 in Anaconda package). The description of the Launceston metadata dataset and Python code for analysis and visualisation can be found in Appendices F and G.

Chapter 8 uses the method of synthesis and critical analysis. The synthesis method was used to combine the results from the previous parts of the thesis. A critical analysis was used to look at these results through the prism of the Evaluation Principles (EE). The chapter discusses the rationales for strengthening the role of local governments in PWF infrastructure provision, as well as impediments for this and the possible ways to overcome them. Also, this chapter provides an account of the arguments for private provision of PWF and critically analyzes them. As a result, the chapter presents considerations and recommendations regarding the organizational model for the provision of PWF provision.

Chapter 3: Literature Review

3.1 Introduction

This thesis argues that LGA provided PWFs are public infrastructure. This approach differs from the narrower yet more generally held view of PWF as a service providing free public Wi-Fi. Larkin (2013) points to the multi-layered interconnectedness of infrastructures, using the provision of electricity and computers as an example. Although the former provides the infrastructure for the latter, the opposite also holds because computers regulate the electricity supply industry. The same is true for PWF. While wireless networking software and hardware are indistinguishable from PWF infrastructure, electricity, backhaul networks, and the Internet all serve as infrastructures for PWF. PWF can also be imagined as a series of interconnected layers where the organisational model influences access to metadata and the network's technical characteristics, while the latter, in turn, determine the usability of the wireless network and, consequently, the achievability of PWF policy and investment outcomes.

The conception of PWF as a form of infrastructure brings into view literature from across a range of disciplines. It is useful to develop a framework that brings together relevant literature on the subject from different domains. The organisation of the literature consistent with the layers of PWF infrastructure (see Figure 1 in the Introduction) serves this purpose and includes:

1. Models of PWF provision
2. The role of the technical performance
3. Social and economic effects
4. Innovation and the 'smart city'

The literature review proceeds to examine literature in each category and concludes with a summary of the research gaps to which this thesis contributes.

3.2 Layer 1: Models of PWF Provision

The focus on business models for PWF provision emerged with the development of municipal PWF in the first half of the first decade of this century when technology companies and municipal officials

envisioned free Wi-Fi covering whole cities or even nations (Townsend 2013). In the middle of the first decade, a downturn in public Wi-Fi initiatives was triggered, among other factors, by some notable municipal Wi-Fi project failures (Forlano 2008). These included Philadelphia Wi-Fi in the US (Townsend 2013). Further opposition from telecommunications and legislative restrictions on investing in public Wi-Fi by municipalities in various US states heightened legal hurdles and possibility of public Wi-Fi project failure, and the PWF organisational model had to be reviewed.

However, the combination of an unlicensed spectrum for Wi-Fi, financially affordable Wi-Fi devices and the relative ease in setting up wireless networks created a favourable environment for the proliferation of various PWF organisational models (Ballon et al. 2009; Gillett 2006; Santorelli 2007). In addition to municipal governments, public Wi-Fi networks were deployed by community groups, hobbyists or wireless enthusiasts using the decentralised bottom-up approach, private enterprises, such as hotels, restaurants and shopping malls, and a range of mixed organisational frameworks (Bar & Park 2006; Forlano 2008; Gillett 2006; Jungnickel 2013; Kaiser et al. 2017; Middleton 2007; Park and Lee, 2010; Tapia et al. 2006).

While the focus of this thesis is on investment by LGAs in PWF infrastructure which is defined as 'wireless Internet access network[s] that [are] created with active local government leadership and involvement' (Jain et al. 2007, p. 993), it is useful to consider this model in the context of other PWF models.

3.2.1 Analysing PWF Models

Forlano (2008) and Tapia et al. (2006) each describe four PWF organisational models. Forlano's (2008) model includes private, bottom-up providers, and two types of government PWF provision: publicly owned networks and public-private partnerships. Tapia et al.'s (2006) provider categories comprise community networks, public utilities, cooperative wholesale providers and private consortiums. Here, the community network is PWF infrastructure using a bottom-up approach; public utility PWF is provided by a designated authority of municipality or local government (either a new organisational unit or one established within the existing municipal structure); the cooperative wholesale model is provided by a municipality, which deploys a network for its own needs and sells the excess network capacity to private providers; and private consortium is Wi-Fi network provided by telcos (Tapia et al. 2006).

The only enduring bottom-up community network model of PWF provision in Australia, on available evidence, is the PWF infrastructure in Goulburn, New South Wales (McShane, Wilson & Meredyth 2016). However, community models are popular in North America, Canada and Europe (Jungnickel 2013) where, in addition to specific cultural and socio-economic conditions, a more extensive population base favours the proliferation of bottom-up community models in those countries. The cooperative wholesale model, as described by Tapia (2006), is not present in Australia, where the prevalent model of LGA PWF is outsourcing to telecommunication companies or ISPs.

3.2.1.1 Ownership and operational control of PWF networks

An alternative approach evident in the literature is to classify PWF networks using two dimensions: ownership of PWF infrastructure and operational control (Ballon et al. 2009; Bar & Park 2006; Kaiser et al. 2017). The ownership of PWF infrastructure includes physical components, for example, wireless access points (APs) and peripheral equipment including servers, controllers and switches. Full operational control implies undertaking the role of an ISP (Kaiser et al. 2017) compared with partial control when a party (e.g. an LGA) can monitor network performance and communicate desired adjustments directly to an ISP contractor.

Bar and Park (2006) argue that operational control over the network and ownership of PWF infrastructure can be attributed to either a municipality, a single private player, or 'multiple others'. This approach to classification results in nine types of PWF models. Ballon et al. (2009), drawing on Bar and Park's (2006) classification, outline six models of PWF provision. These are the private-private, private-wholesale, public-public, public-wholesale, community grassroots and the open site model, where, in the hyphenated categories, the first word denotes ownership of infrastructure and the second operational control. In the community grassroots model, there is no single infrastructure owner, and technically savvy community volunteers are responsible for the ISP function. The open-site model implies that the local government provides access to backbone infrastructure for whoever is interested in deploying PWF (Ballon et al. 2009; Kaiser et al. 2017).

As discussed in chapter 3, it is often difficult to determine the degree of ownership and control of PWF infrastructure by LGA and contractors in Australia because contractual agreements are confidential. The general framework is that municipalities may own elements of the underlying physical infrastructure, such as light poles, storage or other public Wi-Fi assets where equipment is installed. Moreover, the contractor is responsible for the installation and ongoing operation of the PWF service. This broad definition of the organisational setting allows for grey areas, for example, access to PWF

metadata and how PWF assets and service are managed at the end of the contract. These issues require the close attention of LGA officers when planning PWF investment and publishing PWF tender conditions. The lack of availability of public Wi-Fi service contracts means we have little idea about the ownership of network metadata or whether the issue is even covered in contracts.

3.2.1.2 Public-private partnerships (PPP)

Public-private partnership can be defined as ‘an agreement between government and businesses or non-government organisations (NGOs) for the provision of services by sharing of risks and rewards of the venture’ (Sharma 2007, p.205) or more loosely as a cooperative institutional arrangement between the public and the private sector (McShane 2019). While Girth (2014, p.347) argues that ‘public-private partnership and municipal ownership are the two principal models for municipal broadband provisioning’, the margin between ‘municipal ownership’ and ‘public partnership’ can be blurred. The forms and conditions of these arrangements can vary significantly, and it seems little has changed since 2006 when Hodge (2006, p.318) observed that although public-private partnerships were increasingly popular as a global trend, they were a paradox ‘vaguely defined, hotly disputed and poorly evaluated’. The present thesis focuses on the ‘value of different public-private partnerships concerning network ownership, architecture and management’ (Lambert, McQuire & Papastergiadis 2014, p.45.2).

The principal theoretical reason for resorting to PPP by local governments is to transfer risk from the public to the private sector (Alonso-Conde et al. 2007). In practice, local governments can also face legal or regulatory restrictions; for example, as noted in section 2.2.3 below, in some US states, municipal ownership of PWF infrastructure is legislatively prohibited,

McShane and Wilson (2017) observe that PPP has been a prevailing model of PWF provision in Australia over the past five years, especially in major urban centres. At the time of writing, LGAs or state governments and telcos have signed agreements in Tasmania, Victoria, ACT, Adelaide and Tasmania (McShane & Wilson, 2017). Decisions regarding either in-house provision or outsourcing, often through PPPs, are influenced by more extensive ideological and political positions on the role of the state, such as ‘smaller government’ (McShane 2019).

If the analysis shows that active involvement of LGAs in PWF provision is a factor in realising the higher value of PWF infrastructure in the long run, then a political position which locks the local government into a passive role in PWF models requires investigation. As Middleton (2014, p.27) explains, while private control over broadband infrastructure is not inherently detrimental, there are

'times when Internet service providers' commercial practices may constrain individuals' abilities to use their Internet services in ways that they want'.

3.2.1.3 The influence of statutory and regulatory settings on PWF models

Statutory settings, particularly privacy laws, the regulation of telecommunication services and, in some cases, intellectual property laws, may have a significant impact on PWF models. In general, telecommunication is highly regulated in Australia and other countries with strict regulations for local and international spectrum management. There is good reason for this, since various devices may share the spectrum and cause service disruption and interference (Lemstra, Hayes & Groenewegen 2010).

In 1985 the US Federal Communications Commission (FCC) authorised the unlicensed operation of low power spread spectrum systems[4] in the 900–928 MHz, 2400–2483.5 MHz and the 5725– 5850 MHz bands. Wi-Fi technology operates in the latter two bands.[5] These three chunks of radio spectrum were originally designated the Industrial, Scientific and Medical (ISM) bands, which pointed to FCC support for research and innovation (Lemstra, Hayes & Groenewegen 2010). Due to FCC regulation, which was later replicated by other national regulatory bodies, including the Australian Communications and Media Authority (ACMA), Wi-Fi enjoys a relatively relaxed regulatory environment known as the 'public park concept' (Jungnickel 2013). However, as discussed below, Wi-Fi arrangements intended for public use (e.g., the PWF network) attract the additional requirement of a carrier license in Australia. In other countries, such as the US or Germany, public Wi-Fi initiatives can also face additional regulatory and legislative restrictions on particular PWF provision models such as PWFs established by a municipality, or strict regulations related to intellectual property protection.

For example, the early years of PWF infrastructure deployment in the US from 2001–2005 were characterised by active lobbying against PWF initiatives by telcos and litigation against municipal investments in PWF infrastructures by telcos (Forlano 2008). At first it was difficult to limit the scope of investment in telecommunications in the US since law 47 USC § 253(a) states that no 'State or local statute or regulation ... may prohibit or have the effect of prohibiting the ability of any entity to provide

[4] Spread spectrum techniques were developed for military applications and patented by Hollywood actress Hedy Lamarr and composer George Antheil in 1942. These techniques have high immunity to interference and radio jamming. The ability of spread spectrum to cause low interference to other devices was later used by Australian CSIRO scientists led by Dr John O'Sullivan in the invention of Wi-Fi technology, patented by CSIRO from 1994 to1996. More details can be found in Lemstra, Hayes & Groenewegen (2010, p. 24-29).

[5] On 23 April 2020, the FCC added 6 GHz to the Wi-Fi spectrum, considered to be 'the biggest upgrade of Wi-Fi in 20 years' (Kastrenakes 2020). In Australia, however, at the time of writing, ACMA has not implemented a similar amendment to regulations.

any interstate or intrastate telecommunications service'. However, in early 2004, the US Supreme Court issued a controversial decision ruling that municipalities were not 'entities' and allowed the state court to impose restrictions on LGA PWF provision (Gillet 2006). Since then, one-third of American states have introduced various limitations on PWF municipal investment (Gillet 2006; Guttentag 2018). In some cases, there were outright prohibitions on the construction of public broadband networks; in others, they were more subtle restrictions such as prohibition to any government-owned network from offering a service below cost, which in many cases effectively prevented US LGAs from investing in providing free access to PWF infrastructure for end users (Guttentag 2018).

Germany also provides another example of legislative hurdles that deter LGAs from investing in PWF infrastructure. The Störerhaftung Law (the Liability of Intermediaries) transfers the legal responsibility for illicit acts conducted on PWF networks to the network's owner or management when the offender cannot be identified (Obergfell & Thamer 2017). Consequently, German LGAs, cafes, restaurants, hotels and shops would not invest in PWF infrastructure. As Giovanella and de Rosnay (2017) point out, the Regional Court of Hamburg held that in 2016, the owner of a café offering free Wi-Fi was liable for not blocking ports used by unknown clients to share copyrighted files. The effect of this legislative pressure led to the extinction of various PWF provision models except for community 'grassroots' PWFs such as Freifunk (Free Radio), a non-commercial grassroots PWF initiative in Germany. In that case, the decentralised architecture with no single owner effectively avoided legal enforcement (Heer et al. 2010). However, in 2014, Freifunk was involved in a lawsuit in a district court of Berlin-Charlottenburg concerning the violation of intellectual property rights due to downloading, sending and receiving copyrighted files by Freifunk users. However, the Court opted not to stifle the remaining German PWF model and ruled not to impair the 'business of free radio' Giovanella & de Rosnay 2017, p. 14).

In Australia, contrary to the United States or Germany, there are no legislative impediments for in-house LGA PWF provision. However, providers of Wi-Fi services in Australia need a carrier licence unless the service is provided only to a 'same area' or an 'immediate circle' (Attorney General 2016, p. 7). The term 'immediate circle' is defined by Section 23 of the Telecommunications Act 1997 (Cth). For example, if the entity is a body corporate, an immediate circle consists of the body corporate itself, together with an officer of the body corporate and any related body corporate. For individuals and partnerships, the immediate circle consists of employees of those individuals and partnerships. The term 'same area' is defined by Section 36 of the Telecommunications Act 1997 (Cth), which states that places are in the same area if they are the same property or form a combined area.

When a wireless service extends beyond the boundaries of the ‘same area’ or is provided to persons other than those of the ‘ immediate circle’, the provider must apply for a carrier licence (ACMA 2016). Since 2015, following passage of the Telecommunications (Interception and Access) Amendment (Data Retention) Act (2015), (hereafter the Data Retention Act) telecommunication carriers are required to retain network metadata for a minimum period of two years. Hence, if LGAs in Australia operate PWF services, they are subject to this obligation. The perceived risk and complexity of this obligation is another reason why LGAs outsource provision, and as a consequence they do not have direct access to metadata. As discussed in chapter 3, Australian PWF service contract provisions together with the *Privacy Act 1988* (Cth), effectively restricts LGA access to the PWF metadata, which could be used to measure PWF network performance and provide opportunities for urban analytics.

3.3 Technical Performance

The quality and reliability of telecommunication infrastructure is critical to its effective and uninterrupted usage (Beulen et al. 2005). For the purposes of this thesis, the quality of PWF infrastructure is defined by bandwidth as experienced by user download and upload speeds imposed by the ISP and the reliability of connection (Potter and Clement, 2007); by restrictions imposed on the network by the ISP, such as broadband throttling (intentional slowing of the connection); session time allowances and traffic caps per-unit-of-time (Han et al., 2016; Kandula et al. 2008).

However, there are no universal standards for the quality of wireless broadband connections in terms of the average download and upload speeds, while the actual parameters of average broadband speed vary across countries and different regions within the same countries (Ono & Zavodny 2007). In 2007, the Canadian-based Community Wireless Infrastructure Research Project published a list of PWF network characteristics which could be used to assess network performance against characteristics such as speed, reliability, coverage area and quality guarantees (Potter & Clement 2007). The document contains standard (desirable) speed for public wireless networks in Canada and other ‘advanced broadband nations’ (Potter & Clement 2007, p.11) such as Japan, South Korea and the US. These standards provide a valuable base for comparison. For example, even a decade after the standards were published, average PWF speeds of 12, 25 and 40 Mb/s, which were typical of wireless broadband speeds available in Japan in 2005, appear to be beyond the reach for most OECD countries, including Australia (Richter 2015).

3.3.1 PWF Infrastructure: a Matter of Technical Underperformance?

Reflecting on Potter and Clement (2007), who as part of the Community Wireless Infrastructure Research Project published a list of desirable PWF network characteristics, Middleton (2007, p. 1) pointed out that PWF infrastructures typically do not meet 'standards of good public infrastructure' due to technical underperformance, particularly regarding slow and sluggish wireless connections. Sambasivan and Aoki (2017, p. 5922) drawing on the results of a survey of PWF users in India, argue that poor network characteristics result in user frustration and abandonment. While the importance of quality PWF networks seems almost self-evident, it is often ignored by research which focuses on the practices of PWF usage. For example, Picco-Schwendener and Cantoni (2015) explored the usage of the PWF network in Lugano (Switzerland) by tourists and found that 92.7% of returning users tended to connect from the same location. However, the main issue raised by Lugano PWF users in the authors' survey was low PWF network quality and speed. Moreover, the authors did not specifically address the issue, and it might be hypothesised that PWF quality in a particular place may have influenced user preferences to return for repeat access. In the Australian context, Lambert, McQuire & Papastergiadis (2014, p.45.7) investigated the importance of factors that 'make a particular Wi-Fi service "work" in a particular public space'. The researchers identified those factors as 'design of a space, its material attributes and location, the existence of other amenities and attractions, and a proximate demand for free Wi-Fi' (Lambert, McQuire & Papastergiadis 2014, p.45.13). However, they did not consider the quality of the PWF connection in each particular place as a factor of influence.

Soon after building the PWF network in Goulburn (NSW, Australia) in March 2013—a community enterprise partly designed to demonstrate Goulburn's progressive credentials—its severely limited technical functionality was 'more likely to frustrate users than leave them with a feeling that Goulburn was a progressive community' (McShane, Wilson & Meredyth 2016, p. 208). After resolving performance problems by adding additional APs and Internet gateways to the network, Gouldburn's PWF network in Goulburn began to thrive (McShane, Wilson & Meredyth 2016).

Popular culture complements available research by depicting the importance of Wi-Fi quality for user experience. For example, the film 'Parasite' (2019) directed by Bong Joon-ho features a scene where a man tries to connect to his neighbour's Wi-Fi. This process forces him into the most inaccessible parts of his already cramped semi-basement apartment. The character proclaims 'Glory the holy Wi-Fi' after re-establishing the connection the following day. This fictional account illustrates everyday users' frustrations and the importance of Wi-Fi connectivity when its availability and quality are not guaranteed.

3.4 Rationales for Investing: Economic and Societal Effects of PWF Infrastructure

Depending on whether the literature considers positive outcomes of PWF a priori, as theoretical effects, or as facts grounded on observation and experience, it is possible to refer, respectively, to the rationales and outcomes for investing in PWF infrastructure. Sometimes the border between two types of studies is blurred; for example, where a qualitative study speculatively asserts that investing in PWF infrastructure leads to positive outcomes, such as fostering innovation or economic growth, without backing it by verifiable evidence based on a robust methodology.

The deployment of PWF in North America and Europe began in the early 2000s soon after incorporation of Wi-Fi technology in computers by major manufacturers (Lehr et al. 2004; Townsend 2013). Wi-Fi enthusiasts in local communities as well as LGAs, realised the potential of using the unlicensed wireless spectrum to provide unrestricted Internet access to the public (Gillett 2006). This early interest addressed concerns about digital inclusion and bridging the digital divide, and, these remain the principal motivations for PWF investment (Du Bois & Chigona 2018; Rao & Parikh 2003; Tapia & Ortiz 2008; Tapia, Kvasny & Ortiz 2011). In addition to making Internet access more affordable, rationales for investing in PWF include fostering economic growth and innovation, tourism promotion, supporting device and sensor networks in the 'smart city', as well as the emerging theme of using PWF metadata for data analytics and better urban governance (Bar and Park 2006; Lambert, McQuire & Papastergiadis, 2014; McShane 2019; Rennie, 2018; Shumow, 2017; Tapia, Kvasny & Ortiz 2011).

3.4.1 Facilitating Digital Inclusion

Fostering digital inclusion (i.e., bridging the digital divide) is a long-standing topic in PWF literature (Bar and Park 2006; Driskell &Wang 2009; Fuentes-Bautista & Inagaki 2005; Gumpert & Drucker 2003; Middleton & Chambers 2010; Philip et al. 2017; Rennie 2018; Straubhaar 2012; Torrens 2008). Economic and social factors, such as homelessness, income, age, gender and ethnicity, affect digital inclusion (Middleton & Chambers 2010; Robinson et al. 2015). Demographic and spatial characteristics are important determinants of digital inclusion or exclusion: people in rural, sparsely populated and remote areas and those in the third-world countries are typically digitally excluded (Baller et al. 2009). Broadband penetration is gradually increasing throughout the world, partly through technological developments (Akamai 2015). The digital divide may have narrowed, but it has

also deepened, which means that the implications of not having adequate Internet access are increasingly severe (Keeley & Little 2017; Thomas 2020). In Australia, rural areas are most affected by digital inequality (Erdiaw-Kwasie & Alam 2016; Park 2017).

Scholars draw attention to the fundamental role of the PWF infrastructure in providing personal services for the underprivileged, such as health and wellbeing, banking or accessing education and social services (Humphry 2014; 2019). Low network quality may hinder the effectiveness of PWF in bridging the digital divide (Potter & Clement 2007).

In the US context, Shumow (2017) as well as Humphry (2014, 2019) and Rennie (2018) in the Australian context, all employ an ethnographic methodology to analyse how PWF is culturally and economically situated to investigate digitally underprivileged communities. This body of work encompasses urban neighbourhoods in Miami, street inhabitants in Sydney and Aboriginal families in the Northern Territory.

In the American context, Shumow (2017, p. 225) points out that community alternatives to commercial broadband, which could make Internet services cheaper, are effectively blocked by the 'monopolization and conglomeration among telecom giants, as cable and Internet providers continue to merge and create systems of high-pricing, slow speeds, compared to global averages in major industrialized countries, and little or no competition'. In the Australian context, the level of broadband prices and the high level of market monopolisation has also been criticised (White 2016). Humphry's (2014, 2019) research has demonstrated that digitally underprivileged Australians, particularly young homeless people, mostly have mobile phones which they use to access the Internet in public libraries, accommodation centres or via public Wi-Fi hotspots. This dependence on free Internet access, together with the design and regulation of urban spaces, defines the everyday mobilities of digitally underprivileged young Australians. To describe 'the practices of marginalised actors to make their media work in the face of uneven, precarious and costly connectivity', Humphry (2019, p. 1) proposes the term 'survival infrastructuring'.

Rennie (2018) also uses an ethnographic approach to investigate the policies aimed at enhancing the digital inclusion of Australian Indigenous communities. Among other measures, such as informal Internet training groups, delivering PWF infrastructure to remote communities has gained traction among policymakers in the Northern Territory. Rennie (2018) points out that even if the government invests in upgrading backhaul Internet infrastructure (such as NBN satellite connections), this does not address the problem of account set-up and billing for families who live in traditional communities. In

these circumstances, free PWF which uses NBN satellites as backhaul is an effective solution for enhancing remote user connectivity.

These studies illustrate that PWF can provide Internet access for those who cannot afford commercial broadband. Moreover, this occurs even though PWF may have traffic caps, for example, PWF users in Northern Territory Indigenous settlements have a traffic allowance between 100 and 300 megabytes per day (Rennie 2018). For those without any alternative, the subjective value of even a severely limited PWF connection is arguably higher than unlimited and fast broadband for someone who takes it for granted or who may have various means of access.

3.4.2 Civic Engagement and Space Activation

Some authors argue that PWF infrastructure can activate social space and promote civic engagement. Powell (2009, p. 7) argues that municipal Wi-Fi will reconfigure urban spaces by creating 'spaces of innovation, and spaces for community information and local media'. Moultrie et al. (2007) suggest that PWF infrastructure will foster innovation by facilitating simultaneous access to the Internet and social space and in this way, creating 'innovation spaces'. Lambert, McQuire & Papastergiadis (2014, p. 45.4) summarise the objectives of investing in PWF infrastructure in the Australian cities of Adelaide, Brisbane, Canberra and Geelong as 'lead[ing] to innovations in creative and technology industries'. However, neither of these claims is evidenced by the literature, which may be partially attributed to the methodological difficulties in quantitatively measuring the effects of PWF infrastructure investment (see section 1.6 in the Introduction).

Space activation is a recurrent theme in PWF literature (Fuentes-Bautista & Inagaki 2005; Middleton & Chang 2008; Warf, 2009). In the Australian context, a notable example of facilitating civic engagement and space activation is the Goulburn PWF in New South Wales. This network was initiated by cooperative efforts of the local community and businesses. The local council, which initially refused to support the initiative, subsequently provided a small grant. Goulburn, which before the deployment of PWF infrastructure had experienced prolonged economic decline, serves as an example of PWF-led community revitalisation, since the combined effort in deploying and establishing of PWF network in Goulburn fostered economic optimism and self-esteem of the local community (McShane, Wilson & Meredyth 2016).

Shumow's (2017) study of PWF deployment in a Miami African American neighbourhood, discussed above, explores the effects of PWF infrastructure on the social life of the community and argues that free wireless Internet access contributes to crime reduction and facilitates the education of the local community. The long term benefits of the latter are difficult to assess given the time-frame in which the study was conducted. However, social and economic factors are interconnected, particularly in the long run because education is widely recognised as 'an important determinant of economic well-being' (Hanushek & Woessmann 2010, p. 60). The next section will examine the literature concerning economic development and innovation in relation to PWF infrastructure.

3.4.3 Facilitating Economic Growth and Fostering Innovation

From the early years of Wi-Fi, investment in PWF infrastructure was thought to promote economic development and attract businesses to the areas where these infrastructures were deployed (Anayo & Horst 2016; Bar & Park 2006; Tapia, Kvasny & Ortiz 2011).

In serving the connectivity needs of citizens, business travellers and tourists, PWF infrastructures were expected to facilitate local economic growth by making the locations with PWF service more attractive for business investment (Tapia, Kvasny & Ortiz 2011). This trend enjoyed rapid uptake particularly in the US where 'economic development and quality of life initiatives' (Sawhney 2003, p.28) were increasingly linked to Internet access in public spaces.

However, the literature lacks evidence to explain how PWF infrastructure facilitates economic growth or innovation. One exception is a study by Sobolevsky et al. (2017) which seeks to estimate the effect of PWF deployment on local economic activity by measuring transactions in various retail and hospitality businesses before and after PWF deployment. The methodological obstacles which impede the quantitative investigation of the link between PWF investment and economic growth are considered further in chapter 5.

Innovation is another major rationale for investing in PWF infrastructure that is found in the relevant literature. Wi-Fi technology in itself serves as a platform for and an object of experimentation and innovation because it operates in a relaxed regulatory environment with relatively low cost and easily deployed off-the-shelf equipment (Lemstra, Hayes & Groenewegen 2010). Suitable for the deployment as a local infrastructure, PWF contrasts and challenges the dominant paradigm of large 'Hughesian'

technical systems[6] (Egyedi & Mehos 2012) and was viewed as an alternative to the dominant telecommunication market, with potential to become a Schumpeterian disruptor (Audeh 2004; Gunasekaran & Harmantzis 2008; Hüsig & Hipp 2009). However, Mackenzie disagrees, because Wi-Fi is probably 'not a crucially important innovation in itself, just another ordinary ingredient in the mixture of digital communication networks' (2006, p. 270).

Milgrom et al. (2011) argue that the openness of the PWF spectrum facilitates innovation in Wi-Fi devices and business models. For example, the integration of Wi-Fi and cellular networks allows 'offloading' of mobile traffic, especially data downloads to PWF networks. Further, the 'primary benefits of the unlicensed spectrum may well come from innovations that cannot yet be foreseen' (2011, p. 2).

Potts (2014) also advocates the innovative capacity of PWF as a platform for practical and policy experimentation by local governments and as a test-bed for encouraging innovation and leveraging new economic activities. In this scenario, the objectives of investment in PWF infrastructure are to facilitate the discovery and creation of new knowledge rather than achieve known goals and outcomes.

The interpretation of the link between PWF infrastructure investment and fostering innovation has evolved since the turn of the twenty-first century. In the early years of PWF, innovations associated with PWF provision to local communities were attributed variously to 'a new element in the broadband internet' (Bar & Park 2006, p. 108); a 'community innovation' (Egyedi & Mehos 2011; Powell & Shade 2006); innovative services, including e-governance (Kim 2018; Tapia et al. 2006); and technical innovation, such as the development of mesh PWF networks (Gunasekaran & Harmantzis, 2008). Some analysts bridge innovation with investment in PWF infrastructure without explaining or defining the actual type of innovation (for example, Heer et al. 2010).

During the last decade, attention to the innovative role of PWF infrastructure has shifted to viewing it variously as a 'playground for technological experiments' (Evenepoel et al. 2012, p. 4) associated with 'innovative programs that advance digital inclusion and empowerment' (Tapia, Kvasny & Ortiz 2011, p.222); a carrier and enabler in a smart city context (Anthopoulos 2017) and a platform for user-created innovation (Lambert, McQuire & Papastergiadis 2013, Schaffers et al. 2012).

[6] The notion of large technical systems originates from Thomas P. Hughes's book *Networks of Power: Electrification in Western Society 1880 –1930* (1983) and it refers both to large infrastructural systems as a class of phenomena and to an approach to analysing the social and technical changes in their interconnectedness (Olsen et al. 2012).

Since 2015, one can observe growing scholarly attention to the opportunities that PWF provides for innovative data-driven solutions in a smart city context, a trend which is considered in the next section.

3.5 Smart City Context: Possibilities for Experimenting and Innovation

The previous section considered innovation in the general context of possible positive outcomes of PWF infrastructure investment. This section will focus on the innovative use of PWF metadata to inform better urban governance. This topic brings together the first and fourth levels outlined in Figure 1 by considering how the PWF organisational model defines an LGA's potential to access, innovate and experiment with metadata.

The 'smart city' is a complex concept with multiple interpretations depending on the research perspective adopted (Cocchia 2014). Following Hashem et al. (2016), the smart city can be described as an urban area with extensive deployment of typically interconnected IT and digital devices, such as CCTV cameras and sensors to monitor light, rubbish, water, parking and other services; plus nodes for PWF and other wireless and wired networks. It is also characterised by the extensive use of network data for enhancing and optimising the functioning of urban infrastructure. Of the various systems enabling 'smart' city functions, public wireless networks and the metadata they generate are most relevant to this thesis.

3.5.1 The influence of 'smart city' and 'Big Data' on PWF studies

The emergence and growth in popularity of the 'smart city' and 'Big Data' concepts have significantly impacted scholarly rhetoric concerning PWF infrastructures (Kontokosta & Johnson 2017; Lambert, McQuire & Papastergiadis 2014; Louw & Von Solms 2019; McShane & Wilson 2017; Townsend 2013). It is useful to trace the recent surge in literature focusing on 'smart city' and 'Big Data' themes. Figure 3 shows the growth in the number of scholarly publications which feature these terms in different combinations together 'public wi-fi' or its cognate, 'municipal wi-fi'.

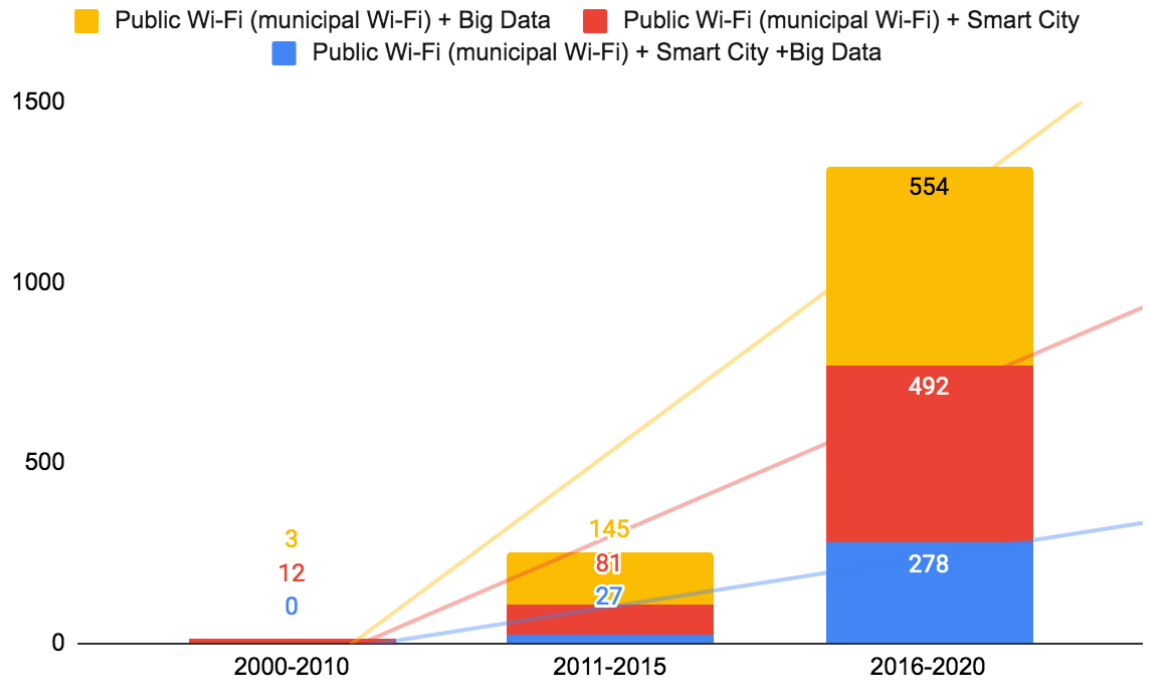

Figure 3. Surge of smart city' and 'Big Data' themes in PWF research, 2000–2020

Source: The author.

Findings are based on keyword search results on Google Scholar and Scopus databases, February 2020. The chart reflects the number of published research that features the combination of keywords 'public Wi-Fi' / 'municipal Wi-Fi', 'Smart City', and 'Big Data'.

3.5.2 More useful than 'Big': Contextualising PWF metadata in 'Big Data' Literature

As shown in Figure 3, the recent research on PWF reveals a growing trend that associates PWF with the concepts of 'smart city' and Big Data'. However, the qualifier 'big' in 'Big Data' may be misleading if interpreted in purely quantitative terms. For example, Cui et al. (2016, p. 29) define Big Data as 'data sets the size of which is beyond the ability of typical database tools to capture, store, manage, and analyze'. Regardless of volume, the real value of big data is their ability to provide insights by analysis, such as data-informed optimisation of urban management by alleviating traffic congestion (Allam & Dhunny 2019; Al Nuaimi et al. 2015; Hashem et al. 2016)

Real-life PWF metadata does not occupy significant storage space,[7] and in this formal sense it is not 'big'; however, it can be significant in terms of its potential usefulness in urban analytics (Kontokosta et al. 2017). Ger Baron, the former leader of the Smart City Initiative in Amsterdam, summarises the contrived dichotomy between small and big data: 'analytics don't have to be focused on [so called] big data to help cities be smarter. The analytics can use small data, as long as it points towards better ways to help citizens' (Fitzgerald 2016, p.6).

3.5.3 Analysis of PWF Metadata as an Innovative Instrument of Urban Management in the Smart City

Several researchers claim that local governments could utilise PWF infrastructure for smart city analytics (Kontokosta 2016; Kontokosta et al. 2017; McShane and Wilson 2017; Picco-Schwendener et al.,2019). For example, Kontokosta (2016) argues that metadata analysis retained from the PWF in Manhattan New York will contribute to understanding fluctuations in urban activity. The author explains that the erratic swings of activity beyond average values may serve as a tool for assessing the effects of place-based interventions and policies for community well-being. Other relevant studies include Kontokosta et al.'s (2017) argument that PWF data analysis can enable real-time city censuses. Picco-Schwendener et al. (2019) present a framework which uses PWF metadata to classify PWF users into one of three categories: locals, business travellers or leisure tourists, for the purpose of making statistics of the wireless network usage more precise.

Nevertheless, the scholarly footprint on the topic of metadata retention in PWF provision is small, and the documented evidence for using PWF metadata by LGAs for city analytics is virtually non-existent. In the Australian context, this lack is partially explained by the absence of relevant expertise, and the practice of restrictive service contract provisions, which, as described in chapter 3, block LGA access to metadata. While there is legislative protection of user privacy in telecommunications regulation (the Privacy Act 1988; the Telecommunications (Interception and Access) Amendment (Data Retention) Act 2015), this is deemed as either insufficient or ineffective. For example, Green (2019, p. 9), who generally acknowledges the importance of PWF infrastructure as 'free public Wi-Fi is a service that every city should provide', nevertheless laments the 'the hidden dangers' of PWF data retention. Green (2019) also argues that the poor, being core PWF users, are especially exposed to the risks of privacy breaches. However, Green does not explain the mechanism of such privacy breaching or what

[7] For example, the database containing metadata from Launceston PWF collected during four years (provided to the author by the Launceston City Council) takes less than 25 Mb in storage. The Launceston PWF is the largest public wireless network in Tasmania.

represents the notion of a ‘hidden danger’. Others criticise the idea of user data retention and analysis because seemingly anonymous data can be traced back to individuals and violate their rights to privacy (Madden et al. 2017, Morozov 2011; 2013; Richards & King 2014; Schroeder 2014; Solove 2004).

3.6 Summary and Knowledge Gap

This chapter reviewed relevant literature related to models of PWF provision, the technical performance of PWF infrastructure, rationales for PWF investment and its expected outcomes, and the position of PWF within emerging ‘smart city’ developments by focusing on the potential uses of PWF metadata. These topics were correlated with the layers of PWF infrastructure (see Figure 1). Each layer of the pyramid is interconnected: for example, poorly configured PWF networks (mismanaged at Layers 1 and 2) are generally ignored by users (Middleton et al. 2006). As a result, the positive effects which potentially exist in Layer 3 (tourism promotion, bridging the digital divide, etc.) are not activated. Further, any innovative use of the PWF network, for example, analysing PWF metadata for better city planning (Layer 4) would not be supported.

3.6.1 Identifying the Knowledge Gap

Although much has been written on the different aspects of public Wi-Fi provision in the last two decades, considerably less research has been undertaken in the Australian context. Although Lambert, McQuire & Papastergiadis (2013) and McShane et al. (2014) found there were approximately 30 known PWF Australian PWF deployments, there has been no significant analysis of LGA PWF provision subsequently. Chapter 3 will address this issue by providing a major national review of Australian PWF provision.

While Australia’s position regarding PWF initiatives lags behind many OECD nations (McShane et al. 2014), it remains unclear whether a hypothetically more affordable commercial broadband in Australia might compensate for this lag. Chapter 4 addresses this question, comparing the affordability of broadband in Australia and OECD counterparts by introducing the concept of a ‘perceived broadband price’. It contends that argues Australia falls behind in PWF availability and affordability compared with commercial broadband, reinforcing the need for PWF inclusion

While a requirement for the technical performance of PWF to meet standards of 'good public infrastructure' (Middleton 2007, p.1), the effect of PWF quality on user satisfaction is undetermined (Middleton 2007; Potter & Clement 2007; Sambasivan & Aoki 2017). More specifically, there is little evidence to support whether or not it is sufficient for PWF to meet a minimum standard of user expectations beyond which users remain indifferent to changes in quality, or whether there is a consistent correlation between PWF quality and user satisfaction?

Mellinas (2017) attempted to investigate the issue of user satisfaction by using a proxy of Wi-Fi service speeds in hotels as a criterion of Wi-Fi network quality. However, the study demonstrated no significant correlation between the speed of hotel Wi-Fi and the hotel ranking.

Chapter 5 of this thesis re-addresses this unexpected result, using data for Australian hotels. It also examines whether there is a link between the limitations of PWF and speed of the nearest hotel Wi-Fi, which can provide insights about the effects of geographical segregation on broadband quality in Australia.

While some authors view the practice of retaining user metadata as a threat to confidentiality and human rights (Greenleaf 2015; Suzor et al. 2017), the actual privacy risks of PWF to user identity are not examined in the literature. Further, both the impediments to LGA retention of PWF metadata and analytics and the possibilities for innovation lack investigation. These issues are addressed in chapter 6.

The most significant gaps in the literature concern the relations between the achievability of PWF provision outcomes, such as facilitating digital inclusion or harvesting innovative and experimental potential attributed to PWF infrastructures (Potts 2014), and the effectiveness PWF organisational models. Wi-Fi technology has innovative and market-disruptive potential by operating in a relaxed regulatory environment with an abundance of relatively affordable off-the-shelf equipment (Lemstra, Hayes & Groenewegen 2010). However, as argued in chapters 7 and 8, the innovative potential available to LGAs is stifled if their role in PWF infrastructure is limited to funding the project or outsourcing elements to a contractor.

Chapter 4: Public Wi-Fi Provision by Australian Local Government Authorities

PUBLISHED PAPER 1

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The authors listed below have certified that:

1. They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise.

2. They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication.

3. There are no other authors of the publication according to these criteria.

4. There are no potential conflicts of interest.

5. They agree to the use of the publication in the student's thesis and its publication on RMIT repository database consistent with any limitations set by publisher requirements.

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Contributor	Statement of contribution
Ian McShane	Led drafting of the manuscript, contributed to data analysis and survey design
Viktor Grechyn	Led the survey design and data analysis and contributed to writing the manuscript.

ABSTRACT

Investment by Australian local government authorities (LGAs) in public Wi-Fi provision has grown substantially in recent years. Public Wi-Fi represents the first significant venture of LGAs into telecommunications, a field of national jurisdiction, and thus is a precursor of wider local investment in digital communication technologies, particularly the IoT and other 'smart city' infrastructure. However, there has been little published analysis of public Wi-Fi provision and use in Australia. This knowledge gap limits understanding of the rationales, business models, uses and impact of investment in these networks, and offers little guidance for local authorities and communities contemplating wider ventures in the field of digital networks. This article draws on a national survey of public Wi-Fi provision by LGAs, together with interview data and critical analysis of policy and institutional settings, to present an overview of local public Wi-Fi provision in Australia. The data analysis highlights some familiar problems associated with LGA infrastructure investment and service delivery, as well as some novel challenges posed for local managers by digital communications networks. Following an empirical mapping of public Wi-Fi provision in Australia, we explore three significant themes that our research in this field highlights: accountability and transparency, ICT competence and evaluation.

Keywords: public Wi-Fi, accountability, evaluation, data access, smart cities

4.1 Introduction

The story of Australia's pioneering role, through the work of CSIRO researchers in the 1990s, in developing a form of wireless local area network (WLAN) technology later marketed as Wi-Fi, is well known. Indeed, such is the invention's status— in Australia at least—that in 2016 the National Museum of Australia (2016) added CSIRO's WLAN testbed to the touring British Museum exhibition *A History of the World in 100 Objects*.

It seems ironic, then, that Australia has lagged globally in public Wi-Fi (PWF) provision[8]. Internationally, municipal governments have been significant providers of PWF. Factors such as Wi-Fi's local range, its relatively low cost and technical simplicity, its dependence on physical infrastructure (light poles, buildings) for fixing network beacons or access points and its operation in open ('unlicensed') spectrum suited the local jurisdiction. Emergent demand from residents, local businesses, and tourists for free broadband access, combined with some apparently attractive partnership deals with telcos, built a strong investment case for some local councils (McShane et al. 2014).

While Australia had several early movers, notably the City of Adelaide, local government provision of PWF did not proliferate until around 2014. As we detail below, PWF is now provided by over 60% of our survey respondents, with more planning network rollouts in the next few years. The entry of local authorities into public Wi-Fi provision is distinctive on several counts. It is the first significant venture of the local jurisdiction into telecommunications provision (constitutionally a national responsibility), although there is little evidence of market failure that warrants its provision as a public good (Potts 2014). Standard ex-ante methodologies such as cost-benefit analysis that inform infrastructure investment are not particularly useful for PWF networks. Further, setting PWF provision apart from other municipal services —and the principal motivation for this article—is a significant lack of knowledge about the rationales, business models, uses and impact of PWF provision.

It is timely to appraise public Wi-Fi provision by Australian LGAs. Provision of PWF within the LGA sector is now sufficiently scaled to facilitate national-level study. We are also seeing more extensive local investment in wireless and telecommunication technologies, particularly the IoT sensor networks and other 'smart city' infrastructure, as well as the impending rollout of 5G commercial cellular

[8] Public Wi-Fi are defined as wireless networks enabling Internet access, available to the public without direct charge. Here our concern is with PWF provided by LGAs. This includes networks provided by third parties contracted by the LGA but excludes Wi-Fi access provided by library corporations (unless access to the public library network is provided outside the building and outside operating hours).

('mobile') networks. We argue that the experience with PWF offers instructive lessons for local authority engagement with each of these iterations.

The article is structured thus: the following section provides some historical and technical background to PWF and its emergence in Australia, with the narrative focusing on Adelaide to illustrate the PWF 'journey' of one Australian city. Then follows an empirical mapping of the current state of service provision in Australia, drawing on quantitative data from a national survey of LGAs conducted in 2017, and qualitative data in the form of interviews and policy and operational documents. We then discuss three significant themes emerging from our research: accountability and transparency, IT competence and the evaluation of an investment in PWF.

4.2 Methods

Primary data were collected through a series of semi-structured interviews (n=27) with state and local government officials and telecommunications company staff undertaken in four Australian states in 2016–2018 and through an online survey of LGA officials conducted in late 2017. Twenty-one of the interviews were conducted face-to-face, with the remaining by telephone. Interviews sought details on rationales, organisational models, technical operation, funding and evaluation, with flexibility in the structure for emerging dialogue (Drever 2003). The survey was designed using Qualtrics software and sent to a contact database of 465 LGAs in metropolitan, rural and regional areas for on-line completion, resulting in 111 usable responses, a response rate of 24%. LGAs not currently providing PWF were also invited to participate, with questions focusing on planning. The survey questions are included in Appendix A. The secondary data included policy documents and reports generated by local and state governments, and some statistical data produced by LGAs and the telecommunications industry. Thematic analysis was used to identify patterns and themes within the qualitative data (Bryman 2012), and quantitative analysis was undertaken using Python software.

The absence of data generated by public Wi-Fi networks themselves—so-called metadata associated with network use— is a gap in our evidence base. As we discuss below, the difficulty of accessing network metadata not only highlights a methodological challenge for researchers in this relatively new field of inquiry, it raises long-standing questions of transparency and accountability in public administration, a persistent theme in this journal (Argyrous 2012; Carnegie 2005; Quinlivan et al. 2014; Stafford & Stapleton 2017).

The research for this article was partly funded by the Australian Research Council Discovery scheme project *Public Wi-Fi as Urban Infrastructure: The Australian Case* (DP150102818). Research involving human participants was conducted in accordance with the Australian Code for the Responsible Conduct of Research, and interviewees and their organisations cited below are anonymised.

4.3 The Development of Public Wi-Fi

The rollout of PWF networks across the globe occurred in two waves, the first beginning with the incorporation of Wi-Fi technology in computers in the early 2000s, and the second following the release of internet-enabled 'smartphones' from 2007 and the rise of 'roaming' and mobile computing. Initial enthusiasm for first wave municipal investment in PWF peaked when prospects for monetising or subsidising investment proved illusory, public-private partnerships collapsed, and legacy telcos—concerned about market competition—successfully lobbied US state legislators to restrict municipal enterprise (Schwarze 2018; Tapia et al. 2006; Tapia & Ortiz 2006). European Union competitive neutrality regulations had a similar impact on dampening city government enthusiasm in that region (Papadias 2009).

Early interest in PWF was not driven solely by technological development but was influenced by distinctive spatial, policy, technological and social settings. For example, the existence of pre-World Wide Web community networks provided a platform for several Canadian initiatives (Powell & Shade 2006). Local government and community models that emerged in parts of North America and Europe built on a tradition of municipal utility provision, local cooperatives, and digital activism in those regions (Sandvig 2004; Troulos & Maglaris 2011). These factors have not been influential in Australia.

The release of smartphones and other mobile devices rapidly altered the economics of telecommunications. As mobile data downloads escalated, mobile network operators sought to alleviate network congestion and minimise infrastructure cost by reversing their opposition to public Wi-Fi, seeking to shift data downloads onto public networks and clear premium 3G and 4G networks for voice (Clarke 2014; O'Higgins 2016). Rather than public networks 'crowding out' private investment as initially claimed, the effect travelled in the opposite direction: some Telcos built Wi-Fi networks, using them to leverage LGA telecommunications contracts. Telstra Air is a prime Australian example of this development.

The other significant second-wave Wi-Fi development was the refinement of ‘mesh’ wireless network technology. This enables signal handover between network access points and frees users to roam within the network range, where they were formerly stationary at wireless ‘hot spots’. With the threat of litigation or regulation receding, the cost of network equipment falling and user demand escalating, the second wave surged.

The scholarly literature on public Wi-Fi has been dominated by engineering and telecommunications policy perspectives (Girth 2014). The corpus has diversified in recent years, with scholars from domains such as geography, digital anthropology and critical infrastructure studies seeking to ‘unblackbox’ digital technologies and highlight their inherent political, material and cultural attributes (Halegoua & Lingel 2018). Some years on, PWF’s role in enabling broadband access is firmly cemented. The European Union has invested 120 million Euros in local PWF infrastructure (European Commission 2019), and global data traffic on wireless devices has surpassed fixed-line traffic (Cisco 2019).

The role of PWF in digital inclusion, identified by many LGAs as an investment rationale, is a long-standing theme in the literature. There is no consensus in the literature on this issue. Humphry’s (2014) Australian research shows the importance of PWF for disadvantaged populations, although many studies suggest that investment has concentrated on central business districts or favoured already advantaged populations, entrenching existing patterns of exclusion (Baker et al. 2009; Fuentes-Bautista & Inagaki 2006; Shumow 2017; Wang et al. 2016). More recent concerns have emerged over privacy, security and data use in the PWF environment, underscoring the growing importance of the technology, particularly in its actual and potential use as a ‘smart city’ technology (Barns et al. 2017; Hornbeck 2018).

Questions initially framed by Middleton and Bryne (2010) and others about institutional arrangements, investment rationales and user needs have prompted a range of case study research, expanding our empirical knowledge (Park and Lee 2010; Picco-Schwendener et al. 2017). Though valuable, much of this work focusses on one or a few cities, with larger-scale comparative studies rare (Baker et al. 2009; O’Higgins 2016).

4.3.1 Public Wi-Fi in Australia: Mapping the Terrain

The decentralised and often trial-based nature of PWF investment challenges a definitive historical account of PWF's development and a comprehensive picture of current offerings. This section first sketches the historical development of PWF, and provides insights into its local specificity, through an account of Adelaide's PWF journey. The City of Adelaide (2017a) aggressively promotes its 'smart city' status, and the progression from rigging a wireless network to support an international conference, through to the installation of a 10 gigabit (Gb) fibre network through the city, is Australia's clearest example of the widening engagement of city governments with digital infrastructure. The second part of this section steps back to analyse the current state of PWF provision by LGAs at a national level through the analysis of our survey results.

The expansion of PWF provision by Australian local authorities cannot be precisely mapped, although our research indicates that in 2012 around 30 municipal networks were in operation (McShane et al. 2014). While there was some local experimentation with public broadband access (by energy companies and community telcos, for example), a distinctive feature of the Australian scene is the lack of civic activity in PWF, compared to Europe and North America. Indeed, our research has identified only one significant community initiative, the PWF network in the CBD of Goulburn (NSW). Again, local contingencies are a factor, including, in the Goulburn case, technical expertise within the community organisers and the cooperation of local businesses that host access points and donate unused bandwidth from their commercial broadband data plans. Significantly, the community venture was launched in response to a rebuff from the city government to establish a municipal network (McShane, Wilson & Meredyth, 2016).

Today, PWF networks are regularly accessed (more than once a week) by over five million Australians (Australian Communications and Media Authority 2017; McShane, Gregory & Wilson 2016). Quantitative and qualitative evidence indicates that PWF access is particularly significant for population cohorts lacking local 3G or 4G mobile connectivity, such as tourists (Picco-Schwendener et al. 2017), or lacking resources to finance generous data plans, for example, young people and older Australians (McShane, Gregory & Wilson 2016).

4.3.2 Adelaide's Wi-Fi Journey

On the available evidence, Adelaide was the first Australian city to build a public wireless network, and tracing the history of this venture provides useful insights on both local contingency and sector-wide developments. Adelaide's public network was spun off a network set-up to service an international computing conference held there in 2002. Startup Adelaide internet service provider (ISP) Internode, which began commercial operations in 1994, provided network services at the event, and subsequently established a partnership with the city and state governments to build the Citylan network, an arrangement where CBD businesses were subsidised to provide free Wi-Fi on their premises. As the interviews revealed, both levels of government were keen to support Internode as a local enterprise, and the company in turn provided free backhaul for the PWF network while negotiating commercial contracts with the businesses (State government official 2016, City of Adelaide official 2016, Internode executive 2016). This arrangement with Internode (the company was subsequently acquired by iiNet, and in turn, by TPG as the ISP industry went through a period of concentration) evolved with the network's expansion through Adelaide's CBD in 2014. State government and city council funding underwrote a stand-alone network, the continued use of Internode to provide network services typifying the public-private partnership model in this field. In 2016 the expanded network renamed Adelaide*free*, recorded over 6 million log-ins (Auhl 2017).

However, as Adelaide officials sought to explore the 'smart city' capabilities of the network, through, for example, analysis of network metadata to plot footfall through the CBD, it became clear that such ambitions were not supported by the contractual arrangements and regulatory regime governing the network. Both the service contract provisions (which did not assert the city's rights regarding the metadata), and Australian telecommunications legislation (which prevents telcos from disclosing potentially identifiable data), effectively restricted the city's access to the type of metadata it sought. This conundrum is explored in detail below.

Expanding our conceptual frame to examine local public investment in digital infrastructure brings into view Adelaide's installation of a 10 Gigabit fibre network in the CBD and north Adelaide areas, as an example of further diversification in this field (City of Adelaide 2017b). While the city and state governments view this investment in terms of economic transformation following the decline of the state's traditional manufacturing base, the investment can also be positioned within a range of strategic responses by LGAs to the perceived limitations of the National Broadband Network (Alizadeh 2017).

Ten Gigabit Adelaide's publicity suggests a strengthening commitment to free PWF, the service quality of which should be further boosted by the new backhaul capacity. However, international

experience shows that local authority investment in PWF can be equivocal. For example, the borough of Islington, which was a pioneer in free Wi-Fi provision in London, ceased its service in 2011 under pressure of Cameron government austerity measures (Jefferies 2011). To what extent, then, is PWF provision prioritised as a local government service in Australia? What informs LGA decision-making in this area? The following section presents data from a national survey of Australian LGAs to clarify these questions.

4.4 The National Picture: Survey Results

The survey results showed a rapid scaling up of PWF provision during the past five years, with plans for further network rollouts within the next three years. Sixty-two per cent of survey respondents were providing PWF. Accounting for the margin of error in our sample, we estimate that the actual percentage of Australian LGAs providing PWF is between 55% and 69%. Of those LGAs which were non-providers at the time of the survey, 60% indicated the probability of offering PWF in the next three years as being greater than 50%, and only 5.6% of respondents answered that their LGAs would not install PWF within the next three years. The survey also sought data on investment rationales and network location.

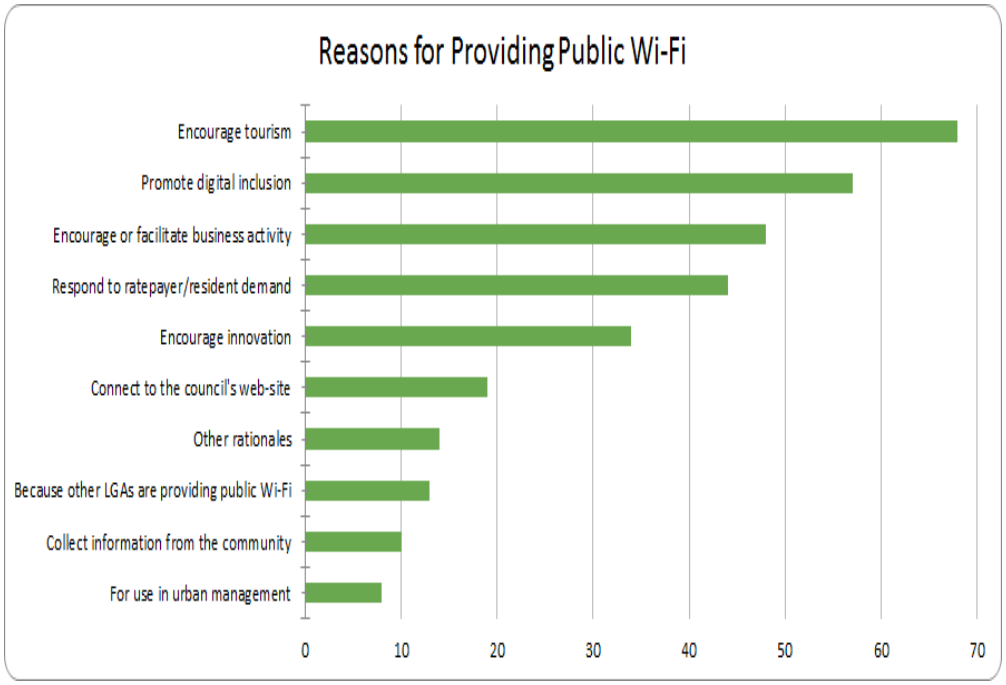

Figure 4. Reasons for providing public Wi-Fi

Source: national survey of LGA officers

The main rationales identified for providing PWF as shown in Figure 4—encouraging tourism, promoting digital inclusion and encouraging business activity—are consistent with the international literature. However, there is a particular research gap, both internationally and in Australia, on whether and how PWF impacts on business activity and innovation. While there are methodological challenges in determining the impact of PWF provision, research in this area is hampered by a fundamental lack of availability to researchers of network data. Additionally, there has been little qualitative research to gather data from users of PWF services (for one example see McShane, Gregory & Wilson 2016). A further observation on rationales for provision is the relatively low use of PWF services as a vehicle for community participation in urban governance.

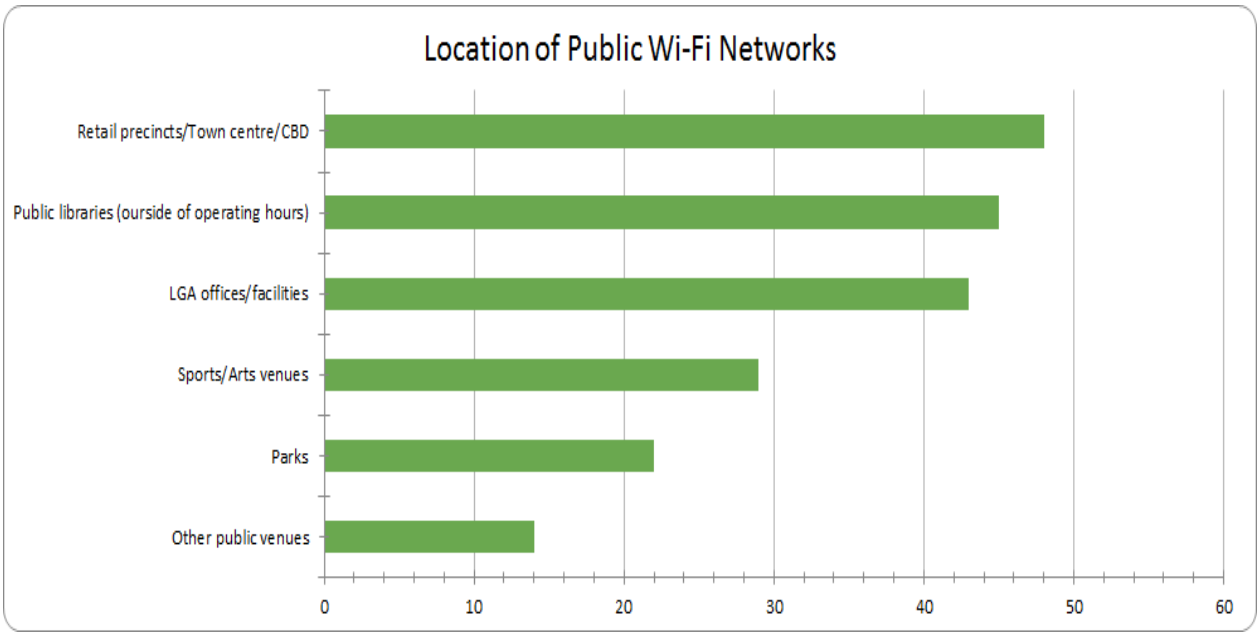

Figure 5. Location of public Wi-Fi networks

Source: national survey of LGA officers

The trend to locate PWF networks in town centres, evidenced in Figure 5, is consistent across the globe and seems an obvious locational choice, given the concentration of people and services in CBD areas, technical restrictions on network range and resource limitations.

However, the survey's locational data suggests the importance of existing infrastructure (institutions, buildings, poles and power and backhaul networks) as a determinant of PWF provision. This may explain the relatively low priority for providing PWF in parks, despite the significance of tourism as a rationale for provision.

All but two participating LGAs that provide PWF impose download and/or access time limits on use. Restrictions on download limits are more stringent than time limitations (see Figs. 6 and 7). The survey did not gather data on how the limits were determined and whether they supported the rationales for providing PWF. For example, if PWF provision is intended to support tourism, do network parameters correlate to tourist numbers, and enable activities such as image uploads, video streaming, or voice communications through 'over the top' services such as Skype? Follow-up contact with LGAs on their evaluation of PWF services did not reveal any clear link between rationales and network design, raising questions about suboptimal investment.

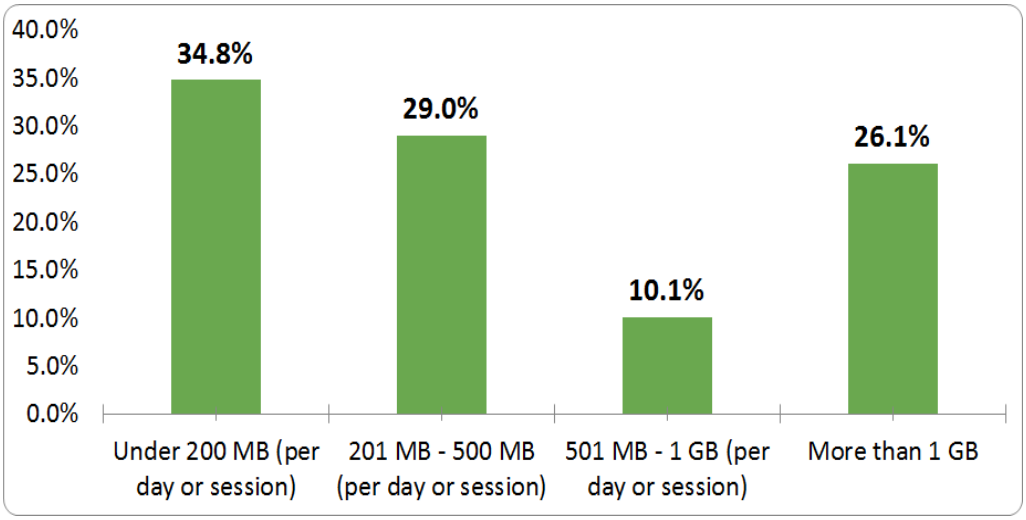

Figure 6. Download traffic restrictions
Source: national survey of LGA officers

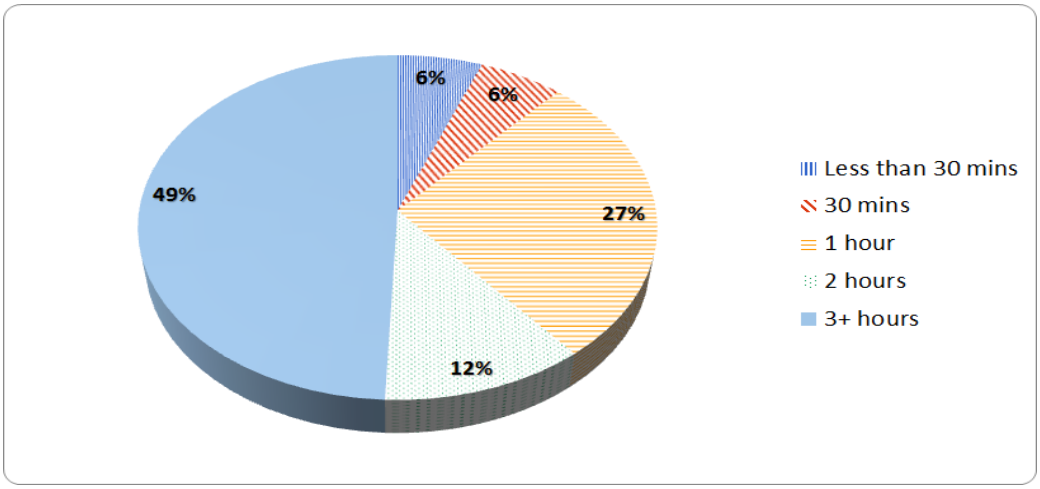

Figure 7. Session and time restrictions
Source: national survey of LGA officers

An apparent lack of coordination between network design and investment rationales is also apparent in the strategic planning of digital infrastructure and services. Thirty-seven per cent (n=41) of survey respondents confirmed that their LGA had a digital strategy or an equivalent document to guide decision-making and investment choices in digital technologies and services.
However, only half of these digital strategies (n=20) included specific discussion of public Wi-Fi provision. A further 14% (n=6) of respondents did not know whether their strategy encompassed PWF. Although the numbers are small, the result supports discussion elsewhere about a 'silo' approach to LGA digital investment (Deloitte 2015; O'Keeffe 2018).

The survey results correspond with the literature on the relatively low commitment by Australian public sector agencies to evaluate policies and services (Maloney 2017; Stewart & Jarvie 2015). To explore a gap in the international literature on PWF, the survey sought details of any evaluation of PWF investment. Around 35% (n=24) of survey respondents indicated their LGA had evaluated their PWF service, with evaluation ranging widely in degrees of rigour or formality. This figure needs to be read in the context that decisions to fund PWF projects are typically time-bound and trial-based (in 69% of cases PWF is provided on a provisional basis and is subject to funding, use and/or council priorities). In twelve cases, evaluation led to no change in the service, eight LGAs increased investment, and one LGA ceased provision. However, our attempts to obtain detailed information on evaluation or performance data met with limited success. We discuss the implications of this issue in detail below.

4.5 Three Key Themes in Public Wi-Fi Provision by Australian LGAs

Having outlined the landscape of PWF provision in Australia, we now discuss three key themes emerging from our research: accountability and transparency, IT competence and evaluation. We argue that exploring these themes in the context of the Australian local government sector's first wide-scale investment in digital infrastructure—PWF networks—may provide critical insights on a rapidly expanding policy and operational field.

4.5.1 Accountability and Transparency

Although PWF provision is a relatively new venture for LGAs, the lack of information sharing, and opportunities to promote peer learning in the early phase of PWF provision is striking. Our requests to discuss service contract details, or sight contract documentation, met with cursory responses, usually justified by commercial-in-confidence claims. As a consequence, we have been able to access only patchy data on the capital and operational costs of PWF provision. This situation is not necessarily associated with our status as researchers outside the LGA sector. The problem of information asymmetry (where many LGAs have valuable information, but few are willing or able to share) appears to be a structural problem. This asymmetry is evident in information on the costs of building and operating PWF networks and methodologies for assessing the impact of this investment. The following response from an LGA official is representative:

> My council has determined that PWF should be implemented as a means of increasing visitation and dwell time. It seems like the motivation is a belief that public Wi-Fi is something we 'should' be doing, but no strong indication of why… I'd like more information on established PWF networks, evaluations against expectations, and end-user satisfaction. (LGA official, Western Australia, 2018).

Other informants were more emphatic about the imperative for PWF provision while puzzling over the difficulties of assigning cost or value:

> It's hard to justify the dollars and cents, but it's just something that council must, just like they provide roads and parks, it's just something they've got to wear and not expect a return on…getting a line item or section of our budget at council; yes, it's a fun one. It's somehow infrastructure but it's nothing to do with the current road and barbeque infrastructures. (LGA councillor, Tasmania, 2016)

A sample of six PWF networks from different Australian regions, based on data obtained from the survey, shows variation in capital costs from $2,000 to $20,000 per installation of access points, while network operational costs (backhaul, maintenance, electricity) ranged from $800 to $65,000 per annum. While spatial and network design characteristics influence these costs, such variation is typical in unsettled or low-competition markets, where a small number of firms provide products or services (Baye et al. 2011). The evidence of one LGA official that annual network operating cost was swiftly reduced from $65,000 to $45,000 per annum when queried suggests the potential vulnerability of LGAs, particularly smaller ones lacking specialist expertise, in procurement decisions.

The second example of information asymmetry is seen in the commissioning by a Queensland LGA of quantitative evaluation of the economic effects of PWF— the only such evaluation in Australia, to our knowledge (an issue discussed in detail below). The 'commercial-in-confidence' status of the report's text and results precluded its public release. The only information on this study that was made available to us was the methodology (comparing levels of commercial activity in certain city areas before and after PWF deployment). Another example comes from the City of Gold Coast, which has one of Australia's most advanced PWF services and is currently building an extensive fibre network. Much of the information in the relevant Council meeting agenda paper and minutes relating to future PWF investment was marked confidential and redacted from publicly accessible version of the document (City of Gold Coast, 2017).

In some instances, confidentiality may be justified, although in the City of Gold Coast's case, sections of the Local Government Act 2009 (Qld) prohibiting councillors and employees releasing confidential information is the only justification cited to support its course of action. That is, no case is made out for why the information is confidential. A more open approach to information exchange—following the principles for sound public administration set out by the Commonwealth Ombudsman (2009) for example—may contribute to overcoming a deficit of evidence-based information that can lead to suboptimal investment.

4.5.2 ICT Competence

The emergence of telecommunications as a new local public service also has implications for the technical and managerial competence of the local government workforce in this area.

While our interview data raises questions of expertise in IT and procurement areas, it also points to the evolution of skills as experience with the operating environment grows. As one official from a mid-sized regional city commented:

> [The public Wi-Fi network] was put in before I started working here at the city. And there was [sic] lots of restrictions put on it. It was very slow because the person who did the spec didn't quite know the difference between the megabytes and megabits and kilobits. So [the contractors] provided what was on the scope of works, but it was really bad. And we were stuck with it for a couple of years... So when it came up for renewal…we went to the same provider… but got them to get new technology and the scope was pretty clear… it ended up

> being cheaper, faster and the technology was one that we were familiar with…and the feedback was outstanding.

Further examples of the rapid evolution of organisational knowledge in this field are revealed in discussion about PWF network data. The initial focus of LGAs on service provision and user experience overlooked detailed consideration of data ownership and use. However, when LGAs began to take a close interest in the use of network data for urban analytics and management, conflicts between regulatory, commercial and urban governance imperatives became evident. Two perspectives (public officials and telcos) on this issue are offered in the following interview quotes:

> We recognised the value of data pretty late into the piece and it was almost an afterthought in our contract. (State government official, 2016).

> I'm sure [the telco] would love to sell [data] to us, but we don't want to pay for that…We did work with [the telco]…around how we can use the data from the network to actually look at how people move in the city…we just couldn't justify the cost. (LGA official, 2016).

> The Telecommunications Act is fairly clear that a wireless service that covers more than one place…should be covered by a carrier licence and once that usage is covered by a carrier licence…you have to keep customer data private….Aggregated data is fine, we can share that and we can run analytics functions… so we can provide all of the data that policy needs and the council needs, but the problem is that they would like to get the raw data…They just want to analyse it and see what comes out if themselves, and they don't necessarily trust us to do that on their behalf. (Telco official, 2016).

> They won't give us IPs [the 'address' through which devices connect to the internet]. They won't even give us MAC addresses [the individual device identifier]. We even told them 'why don't you just do a one-way hash on the MAC address and that way we'll never know?'…[Telcos] are very hyper-sensitive to risk, and that's why they're not going to give us any of that. (LGA official, 2016).

Exploring the potential for capturing and operationalising big data through city-managed networks, though, seems overwhelming for some LGAs (for an example of metadata use see Kontokosta & Johnson 2017). One city official we interviewed noted that there was a tendency to 'cling to' old models of citizen data collection, such as surveys. While these methods may have their limitations, he made it clear that new 'big data' digital collection strategies can lack immediate utility:

> I'm still trying to work out what happens if I have that [traffic data] for every day, every hour, every minute…we're realising … it's nice to have that stuff, but actually what does it mean and can we actually do the quantum leap that we need to do?

In accepting that telecommunications and digital data were emergent concerns for city governments, this official candidly admitted that his council was not alone in being stretched by this, noting 'I think we're all scrambling in government to understand how to connect…'.

In this light, he noted that there will be demand for new positions in council to try and interpret the data from public Wi-Fi and other smart city infrastructure:

> So, in terms of human planning on human resources I think I need data analysts in my team, but to do that I actually need to know where to get the data from and I'm still trying to work that out. (LGA official, 2016).

Current procurement rules recognise the regulatory complexities of the PWF field (for example, expression of interest calls for PWF networks have mandated a carrier licence, see DSG, 2015; DSDBI, 2015), but underscore Barns et al.'s (2017) concern about data and technology capture in the 'smart city' domain. This concern is heightened by commercial interest in the rollout of IoT networks, which is less complex in regulatory terms, but is predicted to generate up to $120 billion in economic activity in Australia over the next decade, at least in the IoT industry association's reckoning (IoT Alliance Australia 2017). The reliance of PWF provision on commercial providers in Australia contrasts with a greater level of institutional pluralism in Europe and North America, where civil society organisations are more active in public broadband and even IoT provision (The Things Network 2018).

There has, though, been some concern about the lack of attention in Australian LGA workforce development to competence in ICT planning, which is seen as critical for strategic decision-making in smart city governance (Ni & Chen 2016). Sixty per cent of LGA respondents to a Government Skills Australia (2015) survey nominated information and communications as a priority training area. However, this area is not directly addressed in the 2013–2020 national LGA workforce strategy (Zivkovic & Kats 2013). Australian LGA peak bodies, like international counterparts, have released 'how to' guides to inform PWF investment (MAV Technology 2015; for a Canadian example see O'Higgins 2016). However, our research suggests that much more attention should be given to local government workforce issues in the ICT field.

4.5.3 Evaluation

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A decade on from Hartmann's (2009) observation that few municipal authorities had evaluated the outcomes of investment in PWF, the situation appears little changed. To reiterate, two-thirds (67%) of survey respondents had undertaken no evaluation of their PWF service provision. Of the one-third of respondents who had undertaken evaluation, more than half declined to make the results available.

Accepting criticism of simplistic assumptions about the progression from 'program' to 'evaluation' in formalistic policy-cycle models (Stewart & Jarvie 2015), it is likely that multiple factors contribute to this situation. For example, competitive influences on LGA decision-making (around 10% of our survey respondents invested in public Wi-Fi because other LGAs are providing it) may override commitment to evaluation or the public release of evaluation results.

However, following on from the above discussion about human capital in the broad area of ICT at local government level, the central issue we highlight here is not simply the lack of initiation of evaluation, or use of its results, but the lack of adequate conceptual tools required to evaluate the benefits, or disadvantages of wireless networks.

To explore these issues further, we conducted interviews on the topic of evaluation with seven survey respondents. Our interviewees understood evaluation in two main senses: either as the collection of statistics on user numbers and trends, or as an assessment of the network's technical performance.

For some LGAs, the business case for investing in PWF required little elaboration. As an official from a Victorian coastal shire with high tourist visitation commented:

> It's very hard to be a major tourism arrangement and not offer free Wi-Fi…When international tourists come in they [have] just come off the beach in Barcelona where they can get their free Wi-Fi, come down here and you can't get free Wi-Fi…The evaluation is intended to be really just trying to keep an eye on the usage.

However, our research on local government involvement in PWF, suggests a knowledge deficit that is not restricted to less well-resourced local authorities, but endemic to standard models of policy formation and implementation across all levels of government. At the centre of this problem are the limitations of standard economic models for public infrastructure investment, such as cost-benefit analysis. These ex-ante models fail to capture the post-hoc innovation or user-generated value of

digital networks, potentially leading to sub-optimal or poorly articulated investment choices, and constrained evaluation of network uses and effects. The prime example here is the Internet itself. An artefact of cold war politics, its initial developers could hardly have predicted the ensuing social and economic benefits (Ryan 2013). The key point, though, is that the openness and public ownership of the internet encouraged experimentation and adaptation. Alternative approaches, for example, an aggressive public-private partnership, may leave little room for the participation of local officials and citizens, privatising metadata obtained from public networks and discouraging access to distributed knowledge and user-generated social innovation (Bar & Borrus 1997).

The survey revealed that almost 70% of PWF networks were developed on a pilot or test basis, with their future depending on the availability of funding and/or on council priorities. While impact evaluation, which can take various forms, is recognised as important for policy learning and decision-making regarding the future of public infrastructure projects funded on a trial or pilot basis (OECD 2013), it may be relatively complex or costly. Notwithstanding this, 43% of our survey respondents acknowledged the importance of this form of evaluation. At a more basic level, the technical analysis of PWF network performance is within easy reach of all LGAs, being straightforward and comparatively cheap to undertake, and relatively standardised. However, the gap between the high percentage of trial provision, and the low percentage of survey respondents (33%) which had undertaken any evaluation, suggests that much of the sector's PWF provision is contingent.

4.6 Adelaide's Exceptionalism?

Adelaide offers an instructive contrast to the pattern of ad hoc and trial-based implementation of PWF in Australia indicated by our data. What can be learned from this example? Looking beyond Adelaide's own rhetoric, our analysis and interviews with government and market players in the city point to three interrelated factors in Adelaide's story: support of a higher government, municipal entrepreneurship and leadership and operational stability. First, state-level policy and financial support, as a partner in the Adelaide network's establishment, has been significant, pioneering the multi-level government partnerships that have subsequently emerged in Victoria and Tasmania. Second, a strategic vision locating PWF provision within a wider program of digital infrastructure and connectivity was clearly articulated by the city's chief information officer and supported across the organisation. Third, the long-term relationship with ISP Internode provided a stable technical platform as the city expanded its investment in the network. Adelaide is a good example of innovation by mid-size and small cities, conforming to Shearmur and Poirier's (2015) model of a municipal innovator, mobilising a particular form of innovation that these authors identify as characteristic of small to

medium enterprises. These authors argue for the increasing importance of city-level initiatives, as innovation policy supersedes state-level industrial policy (think, for example, of South Australia's former reliance on manufacturing industries) as a focus of economic development. Adelaide projects itself as an optimal size for innovation, sufficiently scaled for requisite organisation capacity, but small enough for nimble decision-making (City of Adelaide 2017a). However, Adelaide also embodies the largely stand-alone investment pattern *within* the sector. This contrasts with parts of Canada, where active regional networks have established around digital infrastructure investment (O'Higgins 2016). Recent survey data showing the dissatisfaction of international tourists with the availability of public Wi-Fi in regional Australia (Tourism Research Australia 2019) mounts a challenge to the current stand-alone approach by Australian municipalities that lack Adelaide's capacity.

4.7 Concluding Remarks

This chapter has argued that, with an escalation and diversification of LGA investment in digital communication networks gathering pace, it is instructive to analyse in detail the jurisdiction's engagement with PWF. In addition to undertaking the first 'mapping' of public Wi-Fi provision by Australian LGAs, our survey and associated qualitative research identified three issues of concern raised by investment in PWF—transparency and accountability, ICT competence and evaluation. We argue that these concerns need to be addressed before more elaborate investment plans in the 'smart city' domain are hatched.

The three issues covered in this chapter (accountability, LGA staff competence, and evaluation) can be addressed through the application of the EE "ten principles" (see Table 1 in chapter 1). These three problems are interrelated and should be optimally tackled together, for which purpose the EE principles serve as a practical guide and roadmap. The EE principles provide a framework for LGA officials to improve their IT and project management skills in parallel with enhancing the quality of wireless infrastructure provided to local communities.

In addition to wider market liberal policy settings, the increasingly complex regulatory environment of telecommunications—seen in the passage of the Telecommunications Interception and Access Amendment (Data Retention Act) 2015 - points to the continuation of PPPs with telcos and technology companies as the preferred model for PWF provision and local investment in digital infrastructure generally. This trend suggests continued tensions around data ownership and use. Notwithstanding (or perhaps because of) restrictions on the use of network data, the interview evidence cited above

indicates that it is clearly of commercial value. The Productivity Commission (2017) has contrasted the rapid growth of data collection and analysis in the private sector with the slow progress of public agencies in making data available for use. For Barns et al. (2017), the privatisation of urban infrastructure and services has limited the availability of data for integrated and coordinated urban management. The exchange over PWF network data availability and use, cited above, illustrates well the Productivity Commission's (2017, p. 2) contention that:

> The substantive argument for making data more available is that opportunities to use it are largely unknown until the data sources themselves are better known and until data users have been able to undertake discovery of data.

Stepping back from the complexities of this issue, though, our interview excerpts show that PWF metadata has commercial value for private providers, which should be in view as PWF contracts are negotiated.

Some of the tensions that we have discussed are particular to the PWF environment. IoT networks, for example, do not carry the metadata content that may reveal user identities and are not subject to the same level of regulatory oversight that hampers analysis of network use. Conversely, increased vulnerability of relatively unsecured IoT networks to compromise existing policy, indicates a sectoral requirement to enhance ICT maturity, and move from an ad hoc approach to optimised ICT systems and governance, as modelled by Clarke and Brookes' (2015) 'maturityscape' continuum. Expanding LGA involvement with wireless networks including PWF, IoT, and 5G (which engages a host of urban policy and planning issues, from the use of autonomous vehicles, through to the location of dense antennae arrays), requires pushback on metadata access and overall capacity building in the digital infrastructure field.

Our survey findings about information asymmetry in the field of PWF procurement and evaluation call for associations active in the 'smart city' field, such as the Australian Smart Communities Association, to tackle the structural constraints on information sharing. The explanation offered here draws on economic theory on new or unsettled and low-competition markets, together with a critique of (untested) confidentiality claims associated with public-private partnerships and market-based procurement. We have argued that more information sharing can provide guidance on procurement and performance matters, and suggest that basic evaluation on impact and technical performance of PWF networks is well within the grasp of LGAs. However, the significant gap in our understanding of how to evaluate the post-hoc benefits of networks—what innovations or unforeseen developments (if any) arise from LGA investment in PWF, sets a future research challenge in this field.

The present chapter has examined the overall picture of LGA PWF investment in Australia. The now turns to an overview of the macro context in which PWF provision in Australia takes place, particularly the level of broadband priced in Australia compared to other countries and the factors which determine broadband prices.

Chapter 5: What Influences International Differences in Broadband Prices?

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Contributor	Statement of contribution
Viktor Grechyn	Developed the study design, drafted the manuscript, led data analysis and results' interpretation.
Ian McShane	Contributed to writing the manuscript and data analysis.

ABSTRACT

Broadband prices differ significantly throughout the world. However, discussion of factors influencing international differences receives limited attention in the academic and policy literature, which is largely concerned with broadband prices in particular countries. Focusing on landline broadband, this exploratory article helps fill a knowledge gap by discussing some methodologies for comparing broadband prices between countries, and suggesting five factors that influence broadband prices: supply, demand, governmental policy and regulation, average price level throughout the economy as a whole and physical/infrastructural factors. In this discussion, we also examine where Australia sits in relation to global broadband prices.

Keywords: broadband, comparative prices, price factors, Penn effect, Australia

5.1 Introduction

Broadband prices vary significantly throughout the world. In Ukraine, for example, the monthly price for an unlimited 10 Mbps landline connection is about 3.4 USD, very low by comparison with Australia, which is typically $54 USD (Numbeo 2016). However, in Bolivia, although average income levels are close to those in Ukraine, the monthly price for 10 Mbps is $81 USD, which is very expensive by comparison with Australia (Numbeo 2016).

Why such dramatic variations? What factors influence such significant difference in prices for basically the same service in different countries? The direct comparison of absolute prices for broadband provision, which is the typical measure used by popular broadband 'league tables' is not particularly informative without considering other factors that influence broadband prices. While these comparisons show significant variation between countries, they provide limited explanation of why this is so, or how such comparisons are arrived at. The published literature in this field has also paid little attention to factors that influence broadband pricing in international comparative terms, focusing instead on broadband penetration, policy and regulatory and marketing issues.

This exploratory article helps fill a knowledge gap in this area by discussing methodologies for comparing broadband prices between countries, and identifying some factors that influence broadband prices. In doing so, we also examine where Australia sits in relation to global broadband prices.

In this article the term 'broadband price' means the approximate average cost of a landline (fixed) broadband connection in a given country. In the numerical examples we use data from OECD fixed (landline) broadband basket 'Med 4' (short for Medium 4: there are six grades in each of three OECD landline broadband baskets: low, medium and high). The Med 4 basket refers to a monthly data allowance of 50 GB with a speed of 25 Mbps and above, delivered across cable or ADSL. We also we use data from Numbeo (i.e. a crowd-sourced global database of different statistics) which refers to unlimited data at 10 Mbps speed, cable or ADSL.

These sources estimate average landline broadband service in terms of data speed. When we refer to broadband prices in general without mentioning any numerical examples, we mean the average trend (e.g., broadband prices are higher or lower in country A than in country B). The data from OECD and Numbeo sources are illustrative (rather than definitive); however, they are useful in reflecting overall trends in landline broadband prices for the countries mentioned.

The structure of the article is the following: first, we provide an overview of the relevant literature on broadband price, then discuss the relationship between broadband prices and international price levels.

Having observed the variations evident from this simple or unadjusted price comparison, we then examine adjusted broadband prices by introducing the concept of perceived price, seen through two indexes: the ratio of broadband price to average wage, and the ratio of broadband price to Big Mac. The article then suggests five major factors that influence differences in international broadband prices. These are supply, demand, governmental policy and regulation, average price level and physical/infrastructural factors. Although some of these factors are discussed in the literature, they are generally considered under the banner of broadband penetration, which provides a limited and indirect insight to comparative broadband prices.

5.2 The Broadband Literature and Price

The extensive governmental and industry data on broadband includes price along with a range of other indicators (penetration, speed, demographic influences, uptake by population cohort, spatial characteristics of provision and so on), but pays limited attention to specific factors influencing price; see for example Organisation for Economic Cooperation and Development (OECD 2016a; 2016b); the International Telecommunications Union (ITU 2015); the Federal Communications Commission (FCC 2015); the Regional Telecommunications Independent Review Committee (RTIRC 2015); and Akamai (2015). The emphasis in the policy literature on determinants of broadband penetration (generally measured by subscriptions) provides some useful, if indirect, insights on factors influencing price. However, the existing literature contains some inconsistencies that point to a requirement for detailed empirical research on price factors. For example, Flamm (2005, p.36) argues that 'two factors often associated with broadband penetration, income and population density, unsurprisingly seem to be among the most important determinants of broadband penetration'. However, the OECD (2016c) finds a relatively weak positive correlation of .35 between density and penetration. Bouckert et al. (2010), Falch (2007) and Polykalas and Vlachos (2006) identify regulatory and market settings as significant determinants of penetration. The spatial dimensions of the 'digital divide' have been a persistent concern of academic analysts and governmental bodies, and some of this literature has drawn attention to differences in broadband prices and speed between urban and rural areas (Rogers 2016; RTIRC 2015; Schneir & Xiong 2016).

Polykalas and Vlachos (2006) examine broadband competition and broadband penetration in fifteen member states of the European Union (EU) that share the same regulatory framework. These authors analyse such factors as the existence of alternative infrastructure, the level of broadband competition and the historic evolution of broadband penetration, and conclude that broadband penetration and long-term growth of high-quality broadband services is stimulated by competition. Drawing on UK Office

of Communications data (OFCOM 2011), Curran and Poland (2011, p.34) also conclude that 'high competition levels lead to high penetration ratios and particularly only the competition in the access market could guarantee a long term growth of high quality broadband services'.

Falch (2007) finds that policy settings in the EU, South Korea, Japan and US have influenced national differences in broadband penetration. While factors such as the macro-economic environment and demographics are largely beyond the influence of government, Falch argues, policies on broadband infrastructure and access, and longer-term programs such as education, were also important factors in broadband penetration. Where Flamm (2005) found that level of income was a significant determinant of broadband penetration, Falch (2007) found that it was not a decisive factor in explaining national differences.

There has been long-standing academic interest in examining broadband investment strategies and pricing models from the perspective of broadband providers. McLean and Sharkey (1993) deploy game theory methods to investigate broadband prices for a regulated telecommunications supplier offering heterogeneous services on a broadband network. Falkner et al. (2000) provide an overview of pricing concepts for broadband IP networks, while Biggs and Kelly (2006) examine the relationship between pricing strategies and the growth of the broadband market within countries. Nevo et al. (2016) analyse usage-based pricing for residential broadband and conclude that the investment in fibre-optic networks is likely to be recoverable in some markets.

While this review is necessarily brief, it is sufficient for us to conclude that Flamm and Chaudhuri's (2007, p. 314) observation that price, 'though theoretically the most interesting determinant of Internet service choice, is also the least explored and understood' still holds some truth. Price is widely acknowledged as a factor in broadband diffusion or penetration, but there have been few attempts to examine in detail the determinants of broadband price or differences between countries.

5.3 Comparing Price

Before we analyse factors influencing broadband prices, it is useful to set the scene by comparing prices between countries. To undertake this task accurately, the basis for comparison should be consistent. This is complicated by different broadband technologies (ADSL, fibre, cable, fixed wireless, mobile wireless etc.) and different service levels (in terms of bundled services, speed and data caps). Price comparisons are available from multiple sources, ranging from standard

governmental and industry bodies (Akamai 2015; OECD 2016a; ITU 2015), to the crowd-sourced global database of reported consumer prices and other statistical data (Numbeo 2016). For the purposes of this article, we mainly refer to the data provided by the OECD, which is precise and detailed, and to Numbeo, which is the most current data source on broadband prices throughout the world.

An important context in which to view broadband prices is the wider *level of prices* of different countries. This means that the effect of the comparatively large GDP per capita (and thus the average income) in developed countries might be partially offset by the comparatively high cost of broadband access in those countries. This is referred to as the Penn effect: a rich country (compared to a poor one) appears to be wealthier than it really is (Samuelson 1994; Summers & Heston 1991).

For example, $100 USD in Bolivia or Ukraine has greater consumer purchasing power than in Australia. To adjust for the impact of relative values of different countries on GDP, the concept of GDP per capita, ppp (gross domestic product adjusted to purchasing power parity) is used. Generally, GDP per capita is greater than GDP per capita, ppp in wealthier countries while in middle or low-income countries the opposite tendency occurs (see Figure 8).

The cross-country broadband prices and GDP per capita statistics suggest that broadband prices throughout the world are subject to the Penn effect (see Figure 9). As we can see, generally the wealthier is the country (in terms of GDP per capita), the higher is the price for broadband. For example, Poland, Hungary and Slovakia, which are all in the bottom-left corner of the plot, all have comparatively low GDP per capita and broadband prices, while Norway, Switzerland and Luxembourg enjoy comparatively high GDP per capita levels and broadband prices. Roughly, the countries which are above the trend line have comparatively more expensive broadband (with respect to GDP per capita level), while states below the trend line enjoy comparatively less expensive broadband. Among the former are Australia, Switzerland and USA, among the latter are Korea, Slovakia and Poland. Luxembourg is also below the trend line despite its quite high broadband price due to its strikingly high GDP per capita level.

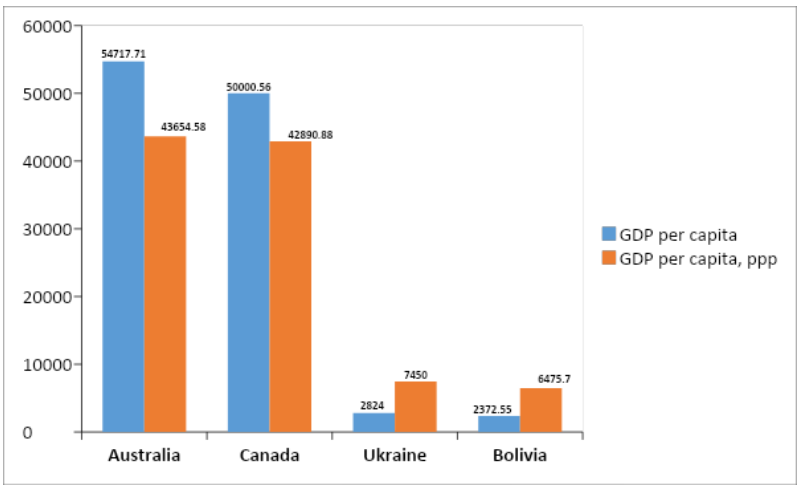

Figure 8. GDP per capita and GDP per capita, ppp in Australia, Canada, Bolivia and Ukraine (2015, US dollars)
Source: tradingeconomics.com (http://www.tradingeconomics.com/country-list/gdp-per-capita, http://www.tradingeconomics.com/country-list/gdp-per-capita-ppp)

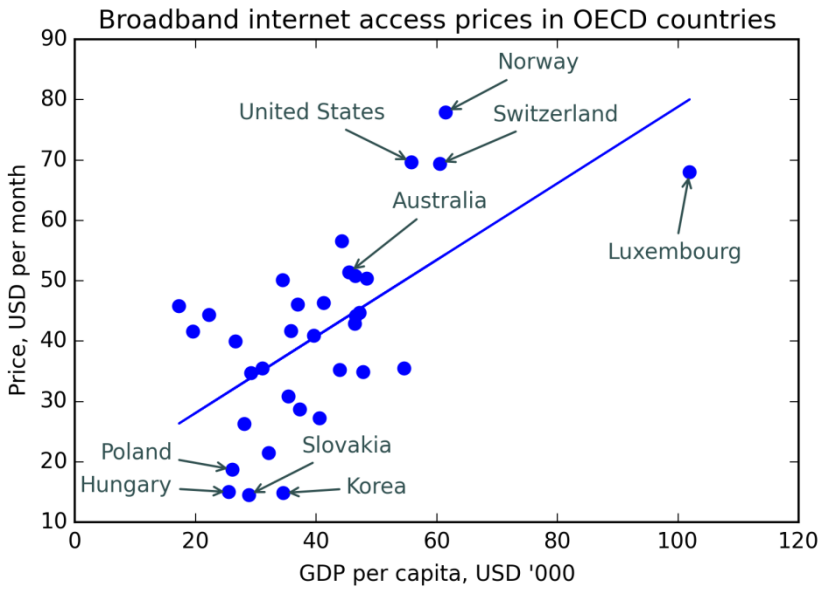

Figure 9. Scatter plot relating GDP per capita, thousands USD to broadband prices, 2015

Source: OECD Statistics (http://www.oecd.org/sti/broadband/oecdbroadbandportal.htm)

The difference between GDP per capita and GDP per capita, ppp reflects the difference in price levels between countries only partially, as factors such as the level of incomes (described as the Penn effect), the peculiarities of local economies (e.g., differences in the costs of labour and capital) or inflation may also significantly impact broadband prices.

To make the difference in price levels in different countries more comparable, the OECD publishes a monthly comparison of price levels based on exchange rates, evaluating the same representative basket of consumer goods in every OECD member country (OECD 2015a). To better explain the differences in price levels between different countries, in 1986 *The Economist* introduced its Big Mac index (The Economist 2013). The Big Mac index appears to be a good proxy for comparing price levels in OECD countries. In June 2016, correlation between the Big Mac index and OECD comparative price levels was 0.84, calculated on data from OECD (2015a) and *The Economist* (2013). Correlation between the prices of broadband provision in OECD countries and OECD comparative price levels is lower, sitting at 0.61 on the scale, possibly because the factors that determine broadband prices in OECD countries are less standard than the factors which determine the prices for burgers throughout the countries, calculated on data from OECD (2015a) and OECD (2016a).

If we go beyond OECD states and examine the broadband prices and comparative price levels (for which we deploy ppp as a proxy) for a broader list of 124 countries (i.e., countries from the Numbeo database), we find there is an insignificantly low correlation between broadband prices and purchasing power parity rates. This suggests it is likely that factors determining prices for consumer goods, and prices for broadband provision, differ significantly. Thus, we might look to factors such as income level, geography and demography, infrastructure provision, regulatory and market arrangements, and perhaps other factors, as broadband price determinants.

To summarise, the broadband price in OECD countries is mostly determined by the factors akin to those that determine prices for consumer goods (but to a lesser extent than a Big Mac is). However, analysing a wider range of 124 countries (for which Numbeo data is available), we hypothesise that factors other than those influencing the price of consumer goods cause broadband prices to deviate significantly from the price of consumer goods

5.4 Perceived Broadband Prices

In 2015 the ITU and UNESCO established the Broadband Commission for Digital Development, to promote broadband adoption as a strategy for achieving the UN Millennium Development Goals (ITU 2015). To facilitate cross-country assessment, the Commission uses an index that compares fixed broadband price to Gross National Income (GNI) (ITU 2015). This index is useful for ranking countries according to the share of fixed broadband expenditures in the economy (or the proportion of broadband expenditure in total expenditure), but it provides limited insight to broadband affordability.

To achieve this, it is more useful to compare broadband price to wages. This comparison enables us to calculate what we call the *perceived price* of broadband in different countries, or the ratio of the broadband price in each country to the corresponding average level of income:

$$\text{Perceived price} = \frac{average\ broadband\ price}{average\ income\ rate}$$

This formula rests on a presumption that the more people earn, the less is the subjectively perceived price for a service or commodity. In a marginal case, if someone has an infinite sum of money, they may not care about prices at all. This exercise ranks Australia ninth among the OECD 'cheapest' broadband countries (or, more precisely, among the countries with the lowest ratio of broadband price to average income rate). The first-ranked countries, that is, those with the lowest price/income ratios, are Korea, Finland and Ireland. Australia sits one rung below Japan. The countries with the highest perceived broadband prices are Portugal, Chile and Mexico. The results are set out in Table 2, with the distribution of prices shown in Figure 10.

Table 2. Broadband price to average wage ratio ('perceived' price) for OECD countries

Country	Broadband price, USD	Average wage, USD	Broadband price/Average wage ratio and rank	Country	Broadband price, USD	Average wage, USD	Broadband price/Average wage ratio and rank
Korea	14.83	29.979	0.49 (1)	Germany	44.67	41.716	1.07 (18)
Finland	27.23	45.353	0.6 (2)	New Zealand	46.04	43.125	1.07 (19)
Ireland	35.46	52.532	0.68 (3)	Canada	56.55	49.59	1.14 (20)
Denmark	44.19	63.674	0.69 (4)	United States	69.66	58.714	1.19 (21)
Belgium	35.24	47.537	0.74 (5)	Norway	77.90	65.037	1.2 (22)
Austria	51.36	45.115	0.77 (6)	Italy	41.63	32.041	1.3 (23)
Switzerland	69.32	88.761	0.78 (7)	Hungary	14.98	10.66	1.41 (24)
Japan	28.65	33.542	0.85 (8)	Poland	18.73	12.257	1.53 (25)

Australia	51.36	59.407	0.86 (9)	Spain	50.05	30.476	1.64 (26)
Iceland	50.73	58.127	0.87 (10)	Czech Republic	21.41	12.773	1.68 (27)
Israel	30.80	33.799	0.91 (11)	Estonia	26.25	15.082	1.74 (28)
Sweden	42.84	46.164	0.93 (12)	Greece	39.91	19.567	2.04 (29)
United Kingdom	46.30	49.677	0.93 (13)	Turkey	41.54	16.344	2.54 (30)
Netherlands	50.31	51.442	0.98 (14)	Slovenia	35.46	13.647	2.6 (31)
France	40.85	40.471	1.01 (15)	Portugal	34.68	12.257	2.83 (32)
Luxembourg	67.95	66.966	1.01 (16)	Chile	44.36	15.523	2.86 (33)
Slovak Republic	14.47	13.647	1.06 (17)	Mexico	45.81	13.212	3.47 (34)

Source: Broadband price: OECD (2016a), OECD (2015b), author calculations.

However, if we perform the same exercise with Big Mac prices (i.e., divide the Big Mac price by average income rates in corresponding countries), we find that Australia has the lowest price/income ratio, followed by the Netherlands and Sweden. This suggests that broadband prices in Australia are 'higher' than prices for hamburgers (considering the scale and the relation to the average level of prices).

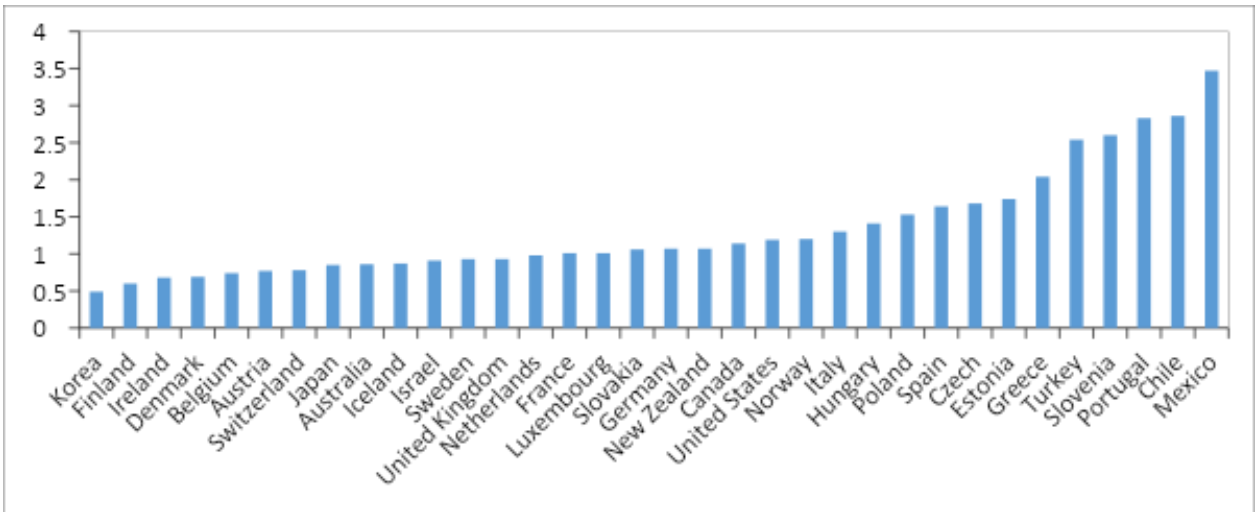

Figure 10. Broadband price (USD)/Average annual wages (USD'000) ratio

Source: OECD (2016b), OECD (2015b), author calculations

An alternative way to investigate comparative broadband prices is to plot where prices in each OECD country sit with regard to the average price level (for which the Big Mac index is proxy). To investigate this, we divide the broadband price by the Big Mac price in every country, choose the median value in the resulting range (which gives us Japan and a value of 9.58) and normalise all the values in the range to the value of Japan. Therefore, the value for Japan becomes equal to 1 (100%), and the values for other countries are lower or higher than 1 reflecting the degree to which broadband is more or less expensive in those countries compared to Japan as the benchmark. The results are set out in Figure 11.

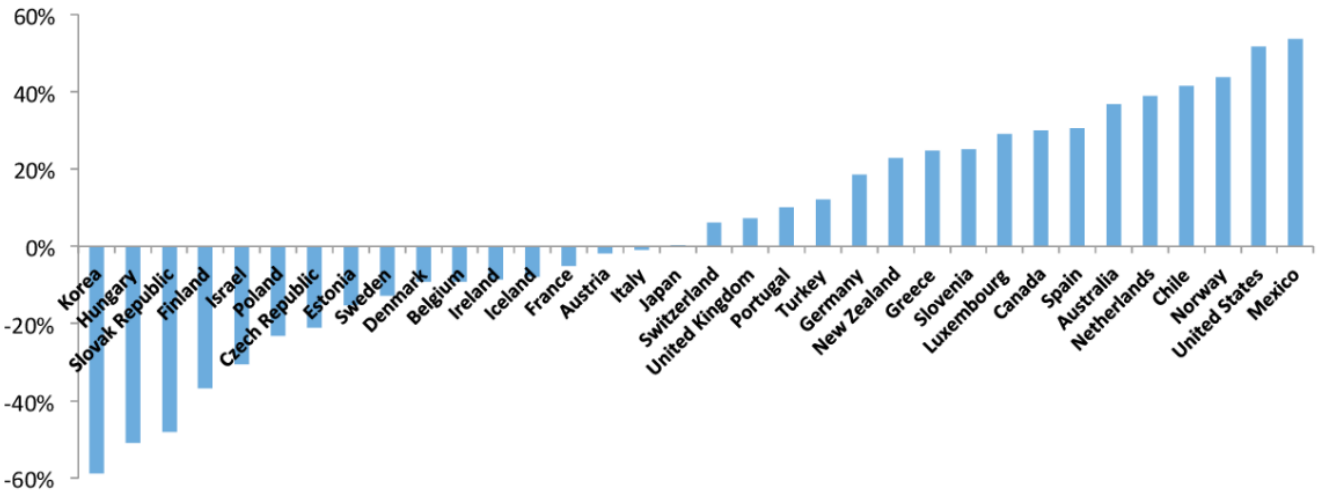

Figure 11. Comparison of prices for landline broadband in OECD countries (% of undervaluation or overvaluation corresponding to the relative Big Mac Index)

Source: The Economist (http://www.economist.com/content/big-mac-index), OECD (2016a), OECD (2015b), author calculations

So, the broadband price in Australia is 36.8% higher than the benchmark value of Japan. On this scale, the countries with the most undervalued broadband (OECD countries, based on broadband/Big Mac prices comparison) are South Korea and Hungary and the countries with the most overvalued broadband are USA and Mexico.

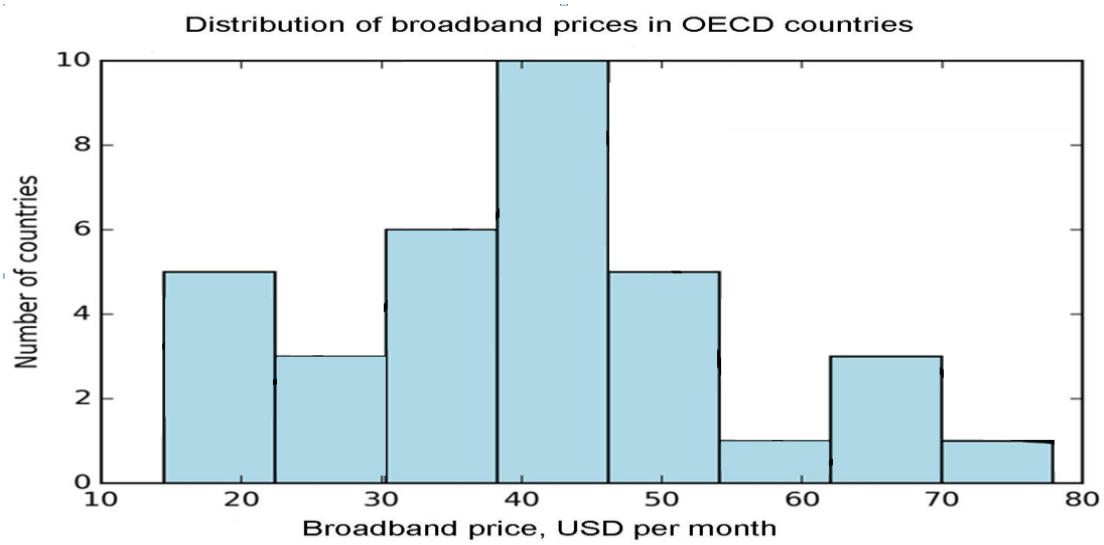

Figure 12. Distribution of broadband prices in OECD countries

Source: OECD 2016a , author calculations

Among OECD countries, the most 'popular' broadband price range is about 40 USD. Australia, with a monthly average broadband price about 51.36 USD, sits in the upper-average price range (see Figure 12). However, when we compare the broadband price to average annual wages (in thousands USD), we see that Australia has comparatively cheap broadband, given the average income level. The 'cheapest' broadband among the OECD countries (adjusted to average wages) is in Korea and Finland (see Figure 11).

5.5 Factors Influencing Global Broadband Prices

As we have seen, there are multiple methodologies for comparing broadband prices across countries, ranging from the highly aggregated (the ratio of price to national income) to the more granular and, we suggest, more meaningful to households (the ratio of price to wages). In this section we look behind these comparisons to examine the factors that influence broadband prices and cause such significant price differences between countries. We suggest there are five types of factors:

- supply factors (shaped by market patterns, degree of competition etc.)
- demand factors (where income levels play a crucial role)
- regulatory and policy factors
- average price levels within countries, and
- physical/infrastructural factors (topography, population density, telecommunications infrastructure).

Demand and supply factors are basic for determining the equilibrium price for most goods and services in the economy. However, in the case of broadband services there are certain peculiarities. For broadband, low demand is not associated with low price (as generally happens in the market) but rather with an inflated price. This is because broadband provision incurs significant infrastructure costs, which will be distributed among few customers in a low demand scenario.
For example, Zimbabwe and Ethiopia both have very low comparative average price levels, but lack of telecommunications infrastructure means the broadband prices in those countries are among the highest in the world.

The low broadband prices in Ukraine (world's lowest in 2015, according to Numbeo) are strongly influenced by that country's infrastructure legacy. The Soviet heritage of extensive telecommunications infrastructure, installed for state security purposes, facilitated the launch of dial-up Internet access in the 1990s, and the updating to cable and fibre in later years.
This trajectory is shared with other post-Soviet countries in eastern and central Europe, where landline broadband services are comparatively cheap. It is interesting that sixteen of the first twenty countries with the cheapest landline broadband (according to Numbeo) are countries from the former Soviet bloc.

Other country specific factors also come into play. An additional reason why Ukraine is currently the cheapest country for broadband can be attributed to three devaluations of its national currency (hryvna) in 2014. While the currency was devalued by 300%, Internet providers raised their prices quite moderately (by 50–100%). This is not due to governmental price regulation (Internet broadband prices in Ukraine are unregulated), but because consumer prices for most locally produced goods and services have been raised significantly less than the national currency has devalued.

Regulation ('state effects' in Flamm's (2005) term) may also affect supply in many cases. For example, Aron and Burnstein (2003) argue in the US context that governmental subsidies of local telephone services suppressed penetration of broadband, while legislative reclassification of broadband services could lead to changes in the broadband market framework and modify supply chains (Ford & Spiwak 2014). However, if we set broadband regulation within the wider neo-liberal settings promoted by the ITU and other supra-national institutions, we find significant convergence in policy and regulatory models (such as the 'ladder of investment' favoured within the EU (Bourreau et al. 2010), that may call us to question the influence of regulation as a factor in price differences. In Australia, though—at least on Fletcher's (2009) account—it has been the ineffectiveness of regulatory action in

promoting market competition that has influenced broadband prices, rather than any more forceful or directive posture of the state.

Topography (or what Flamm (2005) calls the 'terrain effect') is another physical factor that directly influences the cost of broadband supply, and accordingly its price. We began this article by comparing Ukraine and Bolivia. These countries are quite close in GDP per capita (see Figure 8), but contrast significantly in broadband prices. High broadband prices in Bolivia are triggered by physical, spatial and infrastructure factors. A landlocked and mountainous country, Bolivia is denied direct access to international communications cables, which carry almost 100% of trans-oceanic internet traffic (Starosielski 2015). Hence, Bolivia currently outlays significant revenue to rent optical fibre access from Chile, Brazil or Argentina (Vargas 2014).

In Australia, demand is fuelled by high GDP per capita and correspondingly high average income rate (59,400 USD in 2015), with the capacity to pay positively affecting prices. Telecommunications infrastructure in Australia is generally modern and extensively provided, in common with top OECD countries. However, telecommunications coverage is also quite uneven, being well developed in cities but worse in terms of price and data speed in rural areas. This causes unevenness of broadband pricing in different regions, a challenge that was met in the pre-Internet telecommunications environment through the prescription of universal service obligations (Gregory 2016; Hopewell 2014; RTIRC 2015;White 2016). Regulatory factors in Australia are shaped by a shift in telecommunications policy to market liberalism, involving a three-stage privatisation of the public monopoly (and currently biggest national operator) Telstra, starting from the early 1990s. This made the company more effective in terms of profit maximisation, but many customers in remote regions felt left behind as on-line services developed. The failure of private operators to provide broadband infrastructure throughout the country led to the re-emergence of a government monopoly in the form of NBN Co.

Recent years have seen a process of consolidation and oligopolisation among Australian broadband providers. This has been dictated by the market circumstances presented by a comparatively low density of population (3.06 people per sq. km): only providers with a large customer base can achieve scale economies and profitability. Taking the other factors into account, broadband appears to be cheaper in more populated areas. Population density, one of the physical and spatial factors, is inversely related to the price of landline broadband. The correlation between population density and the price of landline broadband in OECD countries is -0.31,calculated on open (World Bank 2015) data for density of population (people per sq. km of land area) and OECD data for broadband prices. Although the correlation is low, the density of population is only one factor among other factors, so its influence on broadband price is expectedly moderate. It is interesting, though, that Australia and

Canada, which are quite close in terms of GDP per capita ratio, density of population and telecommunication market patterns, have also quite close absolute values for broadband prices compared to the average level of prices. The role and significance of every factor influencing international differences in broadband prices can be only measured by econometric modelling, which would require a separate and more detailed study.

5.6 Concluding Remarks

Despite the prolific literature focusing on broadband penetration, regulation, marketing and the digital divide, there is a gap in our understanding of the factors that influence the significant differences in broadband prices throughout the world. In this brief study, we have undertaken two tasks. First, we have suggested some datasets and methodologies that contextualise and clarify inter-country price differences. Second, we have suggested five groups of factors that influence price differences: physical and infrastructural factors, regulation, the average level of prices, demand and supply factors. Of these factors, infrastructure is crucial: a lack of essential broadband infrastructure stifles the effect of other factors.

The role of the different factors in shaping broadband prices throughout the world calls for further analysis. An extended study of the effects of different factors could usefully incorporate regression analysis that would estimate the relationship between factors mentioned in this article and broadband prices in a sample of countries. A significant challenge posed for such an analysis would be choosing proxies or estimations for qualitative categories as ‘regulatory factors’, ‘infrastructure’ or ‘topography’.

As to Australia’s comparative position, we have argued, the broadband price in Australia is influenced by demand (demography) and physical and infrastructure (topography and telecommunications infrastructure) factors, in addition to the terms under which market liberalisation was introduced. However, evaluation of the broadband price to Big Mac price ratios suggests that it is overvalued in Australia by 36.8%, compared to the benchmark value of Japan. Some analysts warn about the lack of entry-level wholesale (NBN) pricing, and inflated profit margins of ISP retailers, as checks on broadband adoption for low-income Australians (de Ridder & James 2013; Morsillo 2012). Notwithstanding the importance of understanding that broadband consumers are not uniform, viewed at country level the average price for landline broadband is still moderate, taking the Australian average level of income into account.

The analysis above has shown that in Australia broadband prices, even after being adjusted to purchasing power parity, are still high if compared with other countries in the world. This underscores the actuality of investing in PWF by LGA, through which way they will provide an opportunity to connect to the Internet for tourists or categories of population who cannot afford commercial broadband. Further, by providing alternative broadband infrastructure, local governments can oppose the threat of oligopolisation or monopolisation of the local telecommunications market and the uncontrolled rise in prices for telecommunications services.

This chapter's finding of the inflated character of broadband prices in Australia, coupled with the fact that about two million Australians still cannot afford broadband (Wilson et al. 2019), highlights the importance of government provision of essential Internet access to the public. One strategy for this is investing in PWF. Providing broadband access to the public correlates with EE principles of social justice and social inclusion. At the same time, for the PWF infrastructure to be functional enough to achieve the goal of social justice through broader digital inclusion, it is necessary to strengthen control and improve the evaluation of this infrastructure by the LGA to ensure its sufficient quality, which is in line with the EE principles of community ownership and capacity building.

The thesis turns to consideration of the role of the technical parameters of Wi-Fi connection in the success of the wireless infrastructure project.

Chapter 6: Wi-Fi Customer Satisfaction in Australian hotels: Implications for Public Wi-Fi

This chapter is based on an article authored by Viktor Grechyn and submitted to the Journal of Hospitality and Tourism Technology (Manuscript ID JHTT-01-2020-0025), which is currently under review.

ABSTRACT

The chapter aims to investigate the influence of Wi-Fi speed in Australian hotels on customer satisfaction and use it as a proxy for exploring the issue of the quality of public Wi-Fi provided by LGAs in Australia with a rationale of tourism promotion.

The chapter uses a mixed quantitative-qualitative approach and adopts econometric regression, analysis of survey data, interviews and case study as methods to explore the role of Wi-Fi quality on customer satisfaction and tourism promotion. Data on average hotel Wi-Fi speed and hotel ranking were combined with data describing the quality of public Wi-Fi provided by the geographically nearest LGA. These were complemented by analysis of surveys and interviews among LGAs, which are public Wi-Fi providers, and data describing public Wi-Fi usage in Canberra.

The effects of hotel Wi-Fi speed on customer satisfaction was shown to be significant. The analysis also showed a statistically significant correlation between Wi-Fi quality in hotels and traffic allowance or time limitation on public Wi-Fi networks provided by the nearest local government. It is likely that increases in quality of public Wi-Fi would have a similar impact on tourist satisfaction with destination cities as it has with hotels. The quality of Wi-Fi appears to be an important factor in hotel customers' satisfaction and sharing tourists' experience via eWOM (electronic word of mouth).

One limitation of the survey of Australian LGAs was the absence of a question concerning the average speed of the public Wi-Fi network. Preliminary contact with a limited sample of LGA officers revealed they are often not aware of the average upload and download speeds on their local PWF networks. To avoid receiving unreliable or omitted answers, it was decided not to include the variable of public Wi-Fi average speed in the survey. Researchers are encouraged to test the influence of public WI-Fi technical parameters on tourists satisfaction when the necessary data is available.

The chapter includes implications for hotels and city councils providing Wi-Fi service for tourism promotion and argues that delivering better Wi-Fi service significantly and positively impacts user satisfaction and hotel ranking via eWOM.

This chapter fulfils an identified need to study the role of technical characteristics of Wi-Fi in tourists' satisfaction and disputes existing research which found no connection between Wi-Fi speed and hotel customers satisfaction.

6.1 Introduction

ICT has profoundly affected the hospitality and tourism industry. Regarding the communication aspect, Wi-Fi has become the standard for wireless networks within municipal and hospitality arrangements which target tourist experience and satisfaction (Berezina et al. 2016; Bulchand-Gidumal et al. 2011; Cobanoglu et al. 2012; Dong et al. 2015). Among the diversity of wireless infrastructure models available, governmental (municipal, citywide) PWF provision of free Wi-Fi service is interesting from both a theoretical and policy-making perspective. In the situation of a market failure in local communities, except in those rare occurrences when commercial operators provide PWF services in cities, (Sinky et al. 2017), governments can provide free public Wi-Fi services. Through PWF provision, they target a range of positive outcomes, such as fostering digital inclusion, facilitating tourism or promoting a positive city image—rationales beyond those of profit-seeking businesses (McShane and Grechyn 2019).

While Australian tourists were found to value hotel Wi-Fi higher than breakfast (Kucukusta 2017), the quality of wireless connection may hinder tourist experiences, both in hotels and on open-air sites where coverage is provided by municipalities as 'public Wi-Fi'. Quality of service, interpreted broadly, is a key determinant of customer satisfaction because it influences customer loyalty and the image and/or ranking of the location or service provider by referrals or electronic word-of-mouth (EWOM) communication (Lang 2011; Moliner-Velázquez, Fuentes-Blasco & Gil-Saura 2019). However, as the next section explains, the extent to which hotel and municipal wireless infrastructures affect user satisfaction remains unclear. Measuring the economic effects of PWF, as well as the influence of wireless quality on tourist satisfaction with travel destinations, is associated with specific difficulties described in the methodology section. Given these difficulties, the influence of Wi-Fi service quality in hotels on tourist satisfaction can serve as a proxy for assessing influence in the broader case of PWF infrastructures, which are accessible in general public spaces rather than the enclosed boundaries of hotel venues.

The primary research question addressed by this chapter is whether the quality of Wi-Fi (in terms of average upload and download speeds) is important for tourists in Australian cities, and, if so, what is the significance? For this purpose, the chapter uses combined data sourced from the website www.hotelWi-Fitest.com (average speed of Wi-Fi in different hotels throughout the world) and www.tripadvisor.com.au (for a ranking of Australian hotels by location, cleanliness, value and service). The goal is to estimate the impact of Wi-Fi speed on customer satisfaction in Australian hotels, and thereby, contribute to a broader discussion about the role of technical performance of public PWF infrastructures in promoting tourism.

The chapter proceeds as follows. The next section overviews the literature concerning the Internet and Wi-Fi infrastructures in promoting tourism. After that, the tripartite section 'Background and Data' explains the technical characteristics of PWF, illustrates the importance of PWF performance in a Canberran case, and in subsequent sections describes the data used for econometric modelling. The closing three sections contain the methodology for the econometric analysis of the influence of Wi-Fi speed in Australian hotels on customer satisfaction, a description of the results, and the conclusion.

6.2 Literature

Tourism promotion and improving the tourist experience is one of the most common rationales for investing in PWF infrastructure. The Internet has had a significant and growing impact on tourism over the last two decades. The 'Internetization'(Etemad et al. 2010) of the tourism industry includes implementation of online selling platforms (online hotel reservations systems, ticket bookings and other tourism-related purchases); communication with customers (as well as counteragents and suppliers); and leveraging off social media, eWOM and online advertising platforms for tourism marketing (Nezakati et al. 2015). While Larsen (2007) argues that the travel experience consists of three parts, namely planning, the trip and memories, all are effected by the modern tendency of going online for journey planning (Pan & Fesenmaier 2006; Xiang et al. 2017); shopping during the trip; general information search (Xiang & Gretzel 2010); and posting, sharing feedback, impressions and journey memories via eWOM (Munar & Jacobsen 2014; Yoo & Gretzel 2011).

Although numerous studies (Law, Buhalis & Cobanoglu 2014; Li et al. 2017; Xiang et al. 2015) have identified the game-changing impact of the Internet on the tourist industry, considerably less analytic attention has been paid to the specific role of Wi-Fi infrastructures in tourism promotion. However, because Wi-Fi infrastructure provides access to the Internet, all the possibilities and advantages of the

World Wide Web (in general sense, regardless of the technology) open to the tourist industry can be also attributed to wireless amenities for Internet access.

Moreover, due to its untethered nature, Wi-Fi technology perfectly suits the needs and lifestyle of tourists, who lack the habitual convenience of home or office Internet access. Further, in many cases they have to pay considerably higher rates for mobile data compared with domestic plans. Tourists need to stay connected and their high prioritisation of (free) Wi-Fi is well known in the hospitality industry, and particularly in hotel management (Schuckert et al. 2015; Xu & Li 2016). Consequently, hotel Wi-Fi is gradually becoming a 'must-have' service in the modern hotel industry (Berezina et al. 2016; Bulchand-Gidumal et al. 2011; Phillips et al. 2017; Schuckert et al. 2015).

In the Australian context, several studies have investigated the role of the Internet and wireless infrastructure in tourism with a focus on Chinese tourists. In 2017, Chinese tourists spent $10.4 billion in Australia followed by New Zealand, which at $2.5 billion spent far less (Budget Direct 2019). A 2019 Australian Trade and Investment Commission report found that a lack of free Wi-Fi is a significant barrier for Chinese tourists together with inadequate tourism infrastructure such as roads (Austrade 2019). The report found that 49% of Chinese tourists use social media for travel planning, and 36% travel review sites; hence, 'the lack of free Wi-Fi ... is a significant barrier and limits opportunities to post real-time experiences' (Austrade 2019, p.8). Kucukusta (2017) also found finds that the quality of the wireless Internet is of even greater importance for Chinese tourists than hotel breakfast or the quality of the coffee.

Customers are generally more satisfied with hotels that provide high-quality service, represented in the star-rated hotel classification (Martin-Fuentes 2016). The research available concerning free Wi-Fi in hotels was mostly explored from the binary position of whether it was provided or not by the hotel. For example, Mikulić et al. (2016) found that in Zagreb hostels Wi-Fi was a 'dissatisfier' rather than a 'satisfier' factor in tourist experience, which means that the Wi-Fi service was expected. However, non-availability of hostel Wi-Fi had a lower impact on customer dissatisfaction than factors such as quality of public transportation, quality of hostel accommodation or hospitality of the hostel staff. According to the authors of the study, this ranking was explained by the ubiquity of affordable mobile connection and high popularity of free Wi-Fi service in Zagreb hostels. Liu et al. (2015) found that the availability of free Wi-Fi impacts the choice of 'hutongtels' (accommodation in traditional Chinese courtyards), mainly preferred by younger tourists.

Yet, the importance of the quality of Wi-Fi services on customer satisfaction remains unclear because there is a lack of detailed data. Common sense implies that customers would prefer and expect high-quality Wi-Fi. However, there is a large degree of uncertainty regarding specifics. For example, is it true, as Middleton (2016, p.32) claims that 'Wi-Fi is most valuable when there is no other option, but is poor Wi-Fi better than no Wi-Fi?'

Some information on the importance of PWF technical performance for user satisfaction is available from surveys of commercial, recreational and transport facilities with Wi-Fi services, such as restaurants, hotels or trains (Bulchand-Gidumal et al. 2011; Cobanoglu et al. 2012; Dong et al. 2015). These types of survey typically reiterate the importance of Wi-Fi for businesses and providers, which is the focus of this thesis, but cannot grasp customer propensity for Wi-Fi usage or the degree of their satisfaction as a factor of Wi-Fi technical performance.

A Spanish-language research paper by Mellinas (2017) is unique in that it estimates the relation between Wi-Fi speed in a sample of hotels across six cities (Bangkok, Berlin, London, New York, Paris and Barcelona) and the degree of hotel customer satisfaction. The data were sourced from www.hotelWi-Fitest.com (forspeed of Wi-Fi connection) and www.booking.com (for customer ranking of hotels). The author came to the surprising result that there was no significant correlation between the speed of Wi-Fi and customer satisfaction reflected in user-assigned hotel ratings. This finding was explained by the influence of other factors omitted from the model and low-quality data.

This chapter aims to build on Mellinas' (2017) paper by investigating Australian data with an improved methodology. The combined data includes hotel Wi-Fi speeds from www.hotelWi-Fitest.com, hotel user rankings from www.tripadvisor.com.au, and survey data collected from Australian LGAs in 2017.

The study tests two hypotheses:

Hypothesis 1. The degree of the hotel customers' satisfaction with hotel service correlates with the average speed of hotel Wi-Fi service. If hypothesis 1 holds, it points on the influence of the quality of Wi-Fi in hotels on hotel customers' satisfaction. Quality of Wi-Fi connection for hotels is measured as average speed (the higher is the speed, the higher is quality), and quality for PWF network is measured as maximum traffic allowance and session time caps (the more relaxed are these restrictions, the higher is quality).

The rationale for adding LGA survey dataset to Australian hotels' Wi-Fi speed and hotels' customers' satisfaction dataset is to test hypothesis 2. It uses an approach of comparing attributes of the objects to their spatial relationship (Cueto et al. 2000).

Hypothesis 2. The geographic proximity positively influences the relationship between quality of hotel Wi-Fi and quality of PWF. That is, the quality of hotel Wi-Fi and PWF, which are in the same area, are more likely to be close than the quality of hotel Wi-FI and PWF, which are in different areas.

If hypothesis 2 holds, then it points on the spatial relationships between characteristics of hotels' Wi-Fi and PWF, which in its turn can be explained by the unevenness of the development of local digital infrastructure in Australia.

The empirical estimation results provide support for both hypotheses suggesting the hotel Wi-Fi quality increases customer satisfaction and is likely to increase in the LGAs with better PWF quality. The next section provides more detail on background, data and methodology.

6.3 Background and Data

6.3.1 Technical Characteristics of PWF Infrastructure

It is necessary to determine how critical the quality of Wi-Fi connection is for tourists and other users of PWF services. The quality (or technical performance) of a digital network facility for accessing the Internet can be expressed through its upload, download speeds and latency. Additional characteristics (or limitations) of the public Wi-Fi network are the time of the session and traffic caps. These limitations do not always apply; for example, a PWF in Adelaide does not impose traffic or time limitations on PWF users. According to the results of the national survey of PWF provision, most PWF networks in Australia impose download, time limitations or both. Almost 35% of LGAs limited download traffic to 200 Mb per session, and around half of LGAs restricted session time to only 30 minutes (McShane & Grechyn 2019). For reasons provided, the national survey did not include a question about average PWF network speeds. According to the assessment based on the limited practical evidence available to the author, network speed of PWF networks in Australia rarely exceeds1 Mbps. For example, on 13 August 2019, the author tested the speed of PWF network in Adelaide in 15 different locations during the single day (from 2 pm until 10 pm) using the ‘Wi-Fi Analyzer (WiFiMan)’ mobile application (see Appendix D). The AdelaideFree network, which is considered ‘the largest and most performing City Wi-Fi network in Australia’ (City of Adelaide 2019),

recorded an average speed of 0.84 Mbps for download, and 1.92 Mbps for upload. This speed was sufficient for making Skype video calls and watching videos in 720p resolution.

By way of comparison, a testing of PWF in Melbourne also conducted by the author revealed significantly worse results. In the CBD area near metro stations, MelbourneFree Wi-Fi demonstrated a strong signal. However, the 'WiFiMan' application often failed to detect actual download and upload speed due to the inability to sustain connection with the access point and to transfer traffic. The speed recorded near Parliament station and Victoria Library did not exceed 0. 25 Mbps, while the connection was intermittent and would not allow video Skype calls.

The reasons for low Wi-Fi performance was not, due to 'overgrazing' of Wi-Fi bandwidth by users, but limited by backhaul connectivity or deliberate throttling of bandwidth by the service provider (Han et al. 2016; Kandula et al. 2008). PWF service providers must ensure that technical characteristics of wireless infrastructure meet minimal user requirements. First, there must be sufficient speed otherwise the PWF infrastructure will not attract users. In those cases where the provider imposes PWF network limitations, a sufficient level of network performance must be sustained. The following example demonstrates how strict session time limitations can result in a rapid plunge of PWF usage.

6.3.2 Canberra PWF Infrastructure

An example from Canberra (ACT) illustrates how technical limitations of a PWF network negatively influence its popularity. The daily allowance in the Canberra PWF network is 250 Mb (ACT Govt 2018), which is only sufficient to support email and basic browsing rather than more traffic-demanding online activities. In the initial period after the network was launched, the number of users increased rapidly, which can be explained by a desire to try the free Wi-Fi network and experiment. However, during the first year of the Canberra PWF operation, the numbers of users plunged (see Figure 13). It seems that most users who connected to Canberra PWF at least once were not happy with its quality and abandoned the network after the first connection. Further, only the dedicated users (a minority), who did not mind the technical limitations remained as core customers and consumers (see Figure 14).

Figure 13. Number of unique users of the PWF network in Canberra November 2014–November 2018.

Source: built by the author on open-access data from https://www.data.act.gov.au/Infrastructure-and-Utilities/CBRfree-Wi-Fi-Monthly-Reports/sptb-jhn6

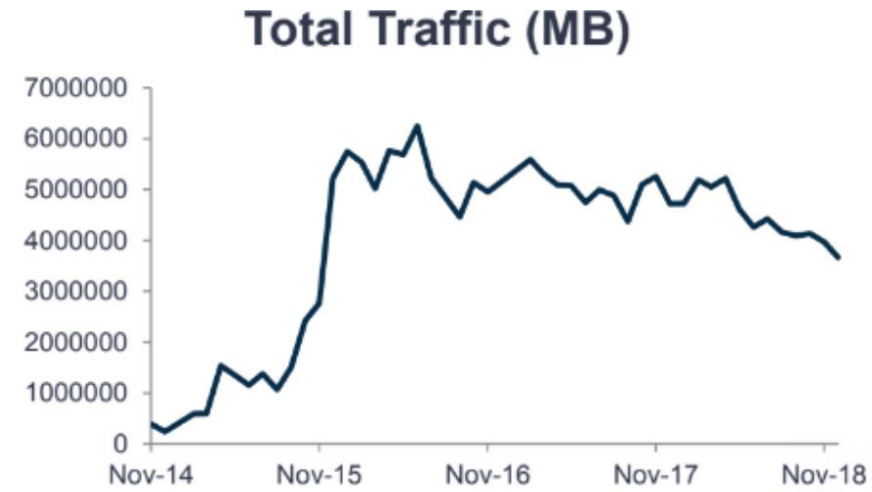

Figure 14. Aggregate traffic used on the PWF network in Canberra from November 2014–November 2018

Source: built by the author on open-access data from https://www.data.act.gov.au/Infrastructure-and-Utilities/CBRfree-Wi-Fi-Monthly-Reports/sptb-jhn6

6.3.3 Data Collection

The dataset combines data from 312 Australian hotels (Wi-Fi speed in hotels and user rankings collected on hotelWi-Fitest.com and TripAdvisor websites), and 111 responses to the national survey among LGA officers. The data on average Wi-Fi speed in Australian hotels were collected from the website www.hotelWi-Fitest.com and the data on hotel rankings from www.tripadvisor.com.au (see

Figure 15). For facilitation of the data collection, a Google Chrome browser extension available at www.hotelwi-fitest.com was installed into the web browser to facilitate average Wi-Fi speeds while searching the hotels in local LGAs that participated in the survey, as described below.

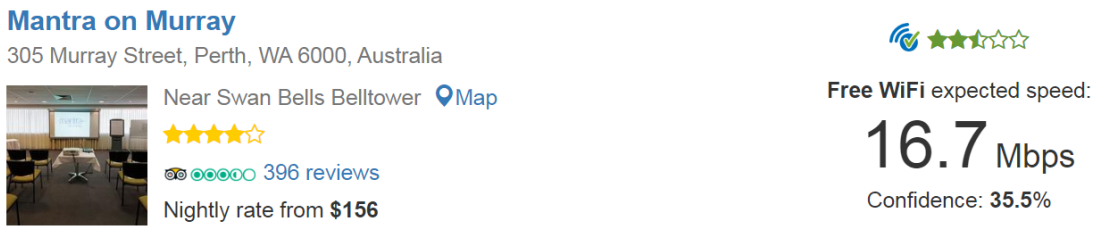

Figure 15. The Interface extension of www.hotelwi-fitest.com at TripAdvisor
Source: screenshots taken on 11 September 2019

A survey of LGA officers was undertaken in late 2017 and targeted a range of questions related to PWF provision, such as the organisational form of provision (in-house or contracting out), locations where PWF was deployed evaluation of PWF and others. The survey was designed in Qualtrics software and sent to 465 Australian LGAs resulting in 111 usable responses: 24% (McShane & Grechyn 2019). In the context of the present chapter, two variables are of particular interest: time and traffic limitations of public Wi-Fi sessions. The variable TrafficLimit (traffic cap) can take values from 1 to 4, which represent different levels of the traffic allowance on the nearest PWF network, from less than 250 Mb to more than 3 Gb. The variable TimeLimit (limitation of the maximum allowed time of the session) also has four possible values, from less than 30 minutes to more than 3 hours (session time allowance on the geographically nearest PWF network). The principle of merging the two datasets was that each hotel parameters (Wi-Fi speed and rankings) were linked to the survey answers of the geographically closest LGA. Between one to eight hotels were related to each LGA location, depending on the availability of data. The idea was that the merging of two datasets would allow additional tests to be made for internal validity and correlations; for example, relations between characteristics of PWF network (in terms of data allowance and speed) and characteristics of hotels in that area (Wi-Fi speed and customer satisfaction).

Table 3. Summary Statistics (Wi-Fi speed, customer satisfaction and other variables)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Land area sq km	310	4,644	26,842	1	372,301

Population	310	90,942	268,686	116	2.360e+06
Population density	310	787.9	1,152	0.00282	4,152
Wi-Fi speed	312	4.446	6.323	0.280	44.40
Location of hotel	312	4.410	0.376	3	5
Value of hotel	312	3.987	0.530	2.500	5
Service in hotel	311	3.738	0.714	2	5
Cleanliness in hotel	312	4.042	0.499	2.500	5
Traffic Limitation	191	2.277	1.161	1	4
Time Limitation	191	3.963	1.149	1	5

Table 3 above provides information on the number of observations for each variable, mean value, standard deviation, and minimum and maximum value for each variable.

6.4 Methodology

Estimating economic and user satisfaction effects of PWF infrastructure is associated with methodological difficulties attributed to data collection and validation of the model. In Australia, local governments usually deploy PWF infrastructure within comparatively small areas (considering a citywide scale), such as certain streets or intersections in CBDs, parks or areas around libraries, museums, information centres, etc. (McShane & Grechyn 2019). To estimate PWF effects, an analyst needs data from the lowest levels of aggregation, such as separate city blocks or clusters of city blocks. These levels of aggregation correspond, according to the methodology of the ABS, to mesh blocks (MB) and statistical areas of level 1 (SA1), see Figure 16. While some types of data, such as census data, can be accessed on the lowest two levels, economic data are only available on higher levels of aggregation.

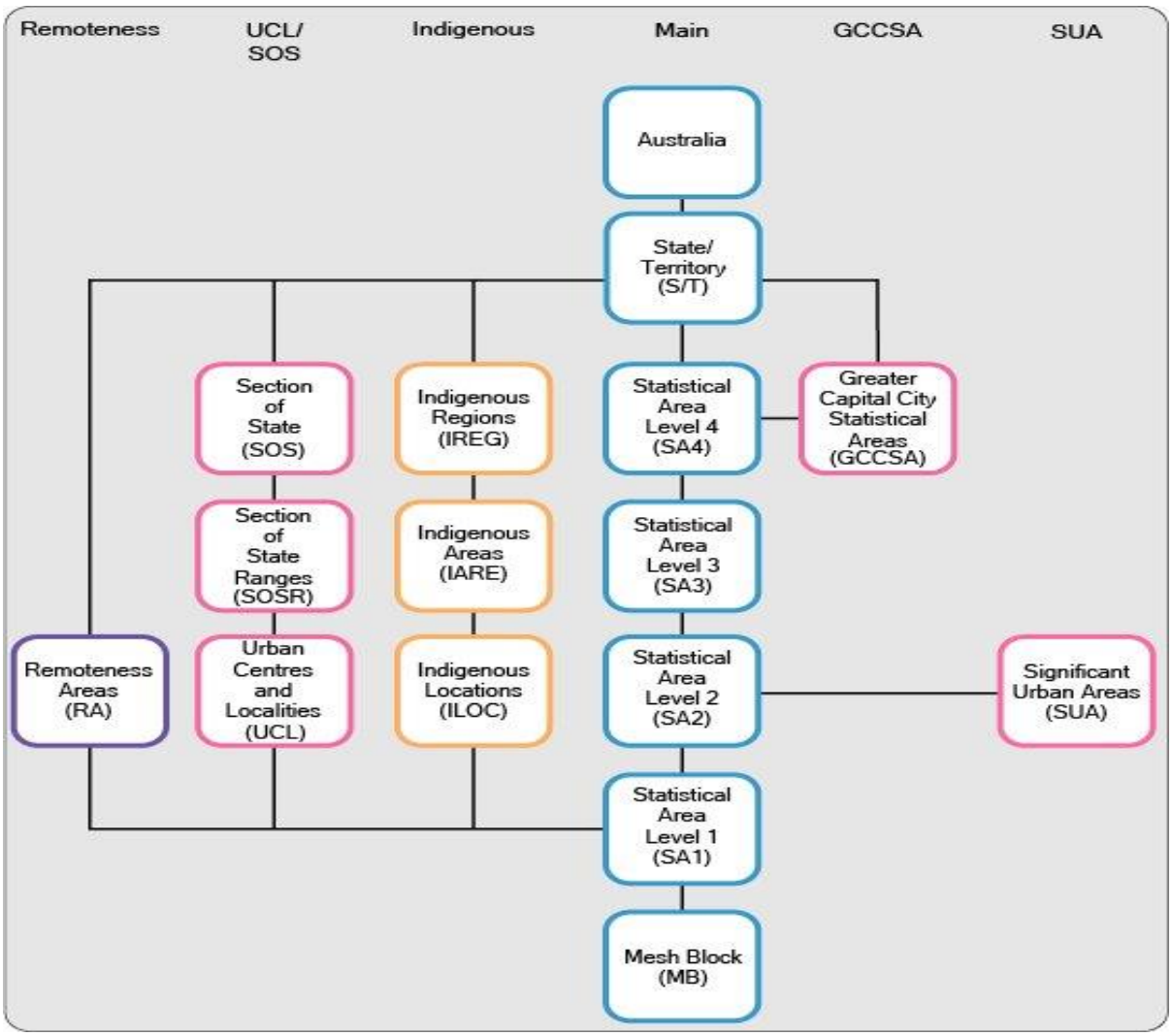

Figure 16. The geographical levels of statistics aggregation according to Australian Statistical Geography Standard and ABS

Source: Australian Bureau of Statistics

The first difficulty is non-availability of low-aggregated economic data, which can be addressed through collecting data by the researcher (which is not always possible) or through other statistical sources. For example, Sobolevsky et al. (2017) used Mastercard data on sales (aggregate sum of cashless transactions during specific periods) to estimate the effect of the availability of free Wi-Fi service on the level of sales. The authors reported that deployment of wireless infrastructure resulted in 2.3% of additional sales growth and a 2.4% increase in transactional activity.

The second methodological difficulty relates to achieving the internal validity of the results, which was the case in a paper by Sobolevsly et al. (2017). Certain urban areas can be more commercially active than neighbouring areas, and the correlation between the availability of free Wi-Fi and higher rates of sales does not prove the causation. Sobolevsky et al. (2017) recognised this problem and

acknowledged the practical difficulty of addressing the issue through a difference-in-differences analysis; that is, by comparing effects of Wi-Fi deployment against a baseline (areas which have the same spatial and socio-economic characteristics but do not have Wi-Fi). This is because in a complex urban system it is impossible to find even two areas with precisely the same parameters.

Estimation of the effects of free Wi-Fi service in enclosed commercial or recreational spaces such as hotels is much more methodologically feasible. In this situation, the estimated influence of Wi-Fi service quality in hotels on tourists' satisfaction may shed light on the extent of potential effects achieved by PWF infrastructures accessible in general public spaces rather than the enclosed boundaries of the hotel venues.

We estimate the relation between the customer evaluation of the hotel's quality and the Wi-Fi quality using a linear model as follows:

$$HotelQuality\_i = \beta_0 + \beta_1 Wi\text{-}FiQuality\_i + \gamma X + e, \quad (1)$$

where X is a set of control variables and *e* is the error term.

The dependent variable, *HotelQuality_ i* , is measured as the scores assigned to a hotel *i* based on customer satisfaction with one of the following categories: the Value of hotel, Services in hotel, Cleanliness in hotel and the Location of the hotel. The main independent variable, Wi-FiQuality_i, is measured as Wi-Fi speed in Mbps in hotel *i* (as reported by the independent source, www.hotelWi-Fitest.com).

For the set of explanatory variables, we tried several options:

1. Dummies for characteristics of the LGA that is geographically nearest to the hotel such as population, population density and area in square kilometres.

2. The set of LGA controls as in 1) plus additional control variables for the quality of PWF provided by the geographically nearest LGA such as traffic limitation or session time cap.

Figure 17 presents the histogram of the distribution of the original Wi-FiQuality variable. The data is significantly skewed with relatively few hotels providing a extraordinarily good service and most hotels providing a relatively slow Wi-Fi service.

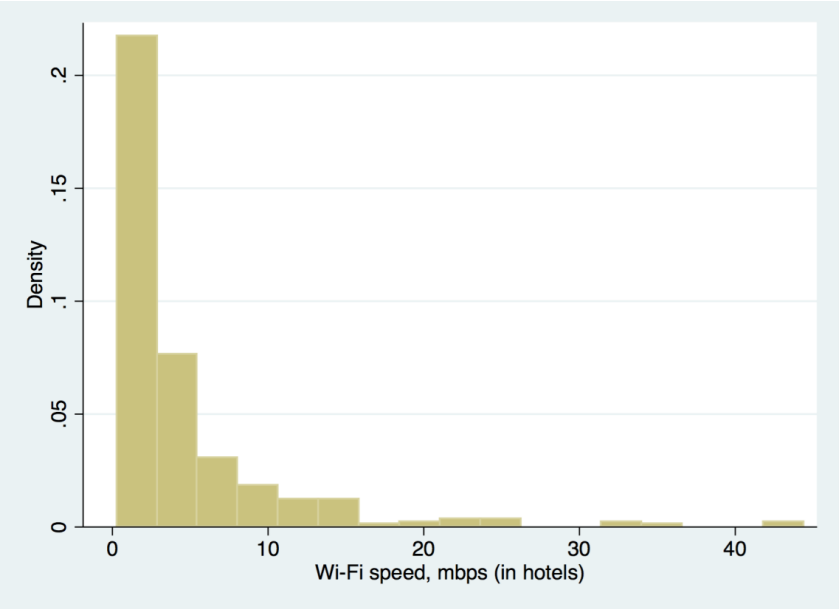

Figure 17. Histogram of Wi-FiQuality, aggregate data.

Source: author's calculations

Therefore, for estimation purposes, we transform Wi-FiQuality into logarithms. The resulting distribution is close to the normal (see Figure 18).

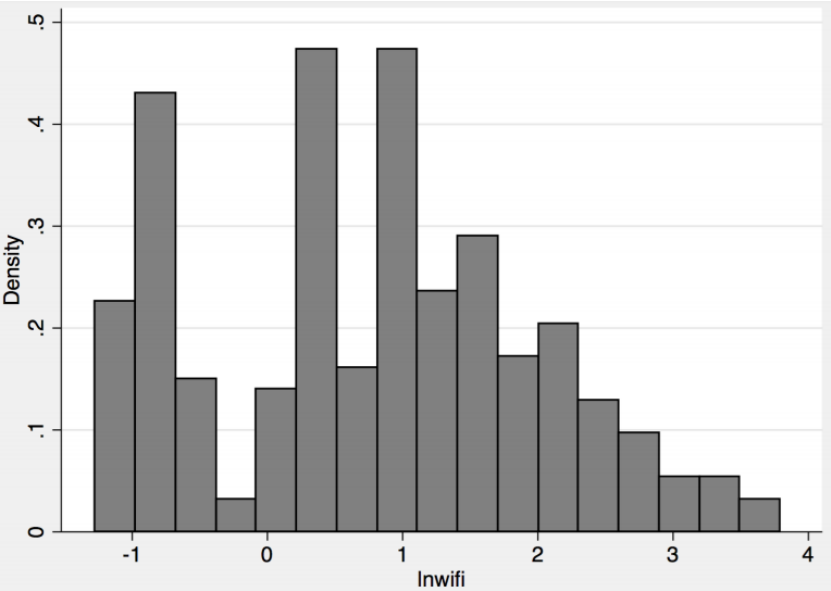

Figure 18. Histogram of Wi-FiQuality on a logarithmic scale, aggregate data.

Source: author's calculations

We conducted a formal test of errors normality for each of the estimations. The hypothesis that the Skewness and Kurtosis of the errors are normal cannot be rejected for four out of six models estimated

(see Table 4). For the remaining two models, we rely on the asymptotic theory for the inferences given that the sample size is significantly large (190 observations) so that the central limit theorem applies.

Table 4. Errors Normality Tests: Skewness/Kurtosis tests for Normality

Model	Obs	Prob (Skewness)	Prob (Kurtosis)	chi2(2)	Prob>chi2
(1)	190	0.5007	0.2582	1.75	0.4165
(2)	189	0.3315	0.3807	1.73	0.4208
(3)	189	0.3315	0.3807	1.73	0.4208
(4)	190	0.0027	0.0035	14.67	0.0007
(5)	191	0.1269	0.5892	2.65	0.2654
(6)	191	0.5093	0.0132	6.32	0.0425

6.5 Results

We estimate model (1) using OLS. The results are presented in Table 5 (LGA dummies are included in the regression but omitted in the Table).

Table 5. Regression results

	(1)	(2)	(3)	(4)
VARIABLES	Value	Service	Cleanliness	Location
lnWi-Fi	0.225***	0.376***	0.167***	0.0552
	(0.0373)	(0.0430)	(0.0369)	(0.0340)
Constant	3.816***	3.354***	3.491***	4.332***
	(0.113)	(0.131)	(0.112)	(0.103)

Obs	312	311	312	312
R-squared	0.604	0.710	0.479	0.344

The results suggest that the quality of Wi-Fi has a positive and significant impact on customer satisfaction with the hotel. This holds for three different measures of customer satisfaction (as reported in Columns (1), (2), and (3) of Table 5).

The model analysed is likely to suffer from an endogeneity problem. For example, more expensive hotels are more likely to have better evaluations if these hotels invest more in facilities (including Wi-Fi quality) to increase customer satisfaction.

Given the structure of the data, we conducted a 'placebo test': that is, using the same dataset, evaluate the relationship between Wi-Fi quality and customer evaluations of some feature of the hotel that is unrelated to Wi-Fi. For this purpose, we use evaluations of 'Cleanliness' or 'Location' of the hotel as a dependent variable. Columns (3) and (4) of Table 5 reports the results. When the dependent variable is 'Location', the coefficient on Wi-Fi becomes insignificant, as expected. That is, there is no statistically significant correlation between the Wi-Fi quality and customer satisfaction with the Location of the Hotel.

One could argue that the Cleanliness of the hotel should not be correlated with Wi-Fi quality either. Conversely, a significant correlation reported in Column (3) is a sign of the endogeneity problem mentioned above. However, the coefficient on the Wi-Fi is twice as small for the 'Cleanliness' measure as that of the 'Service' measure, indicating that the correlation between the quality of Wi-Fi and customer satisfaction is much lower when the measure of satisfaction is not directly related to the Wi-Fi quality. Notice as well that the coefficient on Wi-Fi quality is even smaller in magnitude for the 'Location' measure of customer satisfaction. Moreover, the comparison of the goodness-of-fit measures of the model, the R-squared reported in the last row of Table 5, suggests that the model that includes the last two measures of customer satisfaction (Cleanliness and Location) has low goodness of fit. That is, the explanatory power of our primary variable of interest, Wi-Fi quality, is very low for these two variables.

On the contrary, the goodness-of-fit for the measures of customer satisfaction based on Value or Service in the hotel is relatively high: R-squared are 0.604 and 0.710 for Value of the hotel and service in the hotel, respectively.

The interpretation of the coefficient of interest is as follows. If the Wi-Fi quality increases by one per cent, then the customer satisfaction with the services provided by the hotel will increase by (0.376/100) units. It means that starting with the average speed across Australian cities included in the sample, 4.446122 Mbps, and increasing that speed to the maximum speed in the sample, 44.4 Mbps (a 1000 per cent increase), the hotel could increase its customer satisfaction by approximately 3.8 points, other things equal.

The results reported in Table 4 are very robust to the inclusion of different controls for LGA (that is, when the control set X is based according to 2) or 3) described above). Thus, the empirical estimation suggests that, for Australia, the impact of Wi-Fi quality on customer satisfaction with the hotels is strong and significant. Further exploring the data, we ask whether the quality of the Wi-Fi in the hotels is related to the Wi-Fi limitations imposed by the local authorities and reported in the survey of LGAs. The results of a simple regression of Wi-FiQuality on the categorical variable TrafficLimit, containing values from 1 (corresponding to 'Under 200 MB (per day or session') to 4 (corresponding to 'More than 1GB') are reported in Table 6.

Table 6. Traffic Limitation and Time limitation at LGA level and Wi-Fi quality

	(5)	(6)
VARIABLES	lnwifi	Lnwifi
Traffic Limit	0.461***	
	(0.0630)	
Time Limit		0.247***
		(0.0722)
Constant	-0.147	-0.0741
	(0.180)	(0.300)
Observations	191	191

R-squared	0.175	0.049

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Surprisingly, the analysis shows a statistically significant correlation between the Wi-Fi quality in the hotel and the traffic allowance or time limitation on the nearest PWF network. These correlations could be explained by the economic characteristics of the region and by spillover effects: for example, in the regions with better backhaul Internet infrastructure and with a higher level of incomes, local governments and hotels would be in a better position to provide quality Wi-Fi service. This suggestion resonates with a comment from a LGA representative of LGA in Wudinna in South Australia, located 570 km from the state capital, Adelaide, provided to the author at the end of 2017:

> Being a rural community, access to Internet service bandwidth is a major barrier to Wi-Fi installations. In the medium term it was hoped that NBN would provide some solutions, however, this appears to be less likely now that the area will be serviced by Skymuster Satellite rather than fibre access to the network. Significant speed and accessibility issues exist at private Wi-Fi providers such as the hotel and motels in town, so solutions for public access appear to be a little way off. (LGA official, South Australia 2017).

Also, while the quality of PWF infrastructure and the speed of hotel WI-Fi correlate with the density of population in the area, it is apparent that in more populated areas LGAs do have, on average, better financial and infrastructural capabilities than areas with low density (which are mostly located they have in areas with low population densities in rural or remote areas).

6.6 Limitations of the Study and Further Research

The limitations of the survey undertaken among Australian LGAs included the absence of a question about the average speed of the public Wi-Fi network. The preliminary contacts with a limited sample of LGA officers revealed that they are often not aware of the average upload and download speeds on their local PWF networks. Further, LGA officers from a sample testing group revealed to be much better informed about such network parameters as session time limitations and traffic caps. To avoid receiving a variable with a lot of non-reliable or omitted answers, the question about public Wi-Fi average speed was not included in the survey. The variables describing the technical parameters of the network were limited to average session time and traffic allowance. Even if the author had access to data on the average speed of public WI-Fi, it would not be possible to make an investigation of public

Wi-Fi customers satisfaction similar to that undertaken on the sample of hotel customers, due to the absence of the consistent data on the level of satisfaction of public Wi-Fi customers. In these circumstances, the approach deployed in this research appears to be an optimal solution. It allows a projection of insights related to hotel customer satisfaction onto the situation of public Wi-Fi providers, which aim to promote tourism in their localities. Future researchers are encouraged to test the influence of public Wi-Fi technical parameters on tourist satisfaction once the necessary data is available.

6.7 Final Remarks

This chapter found that unlike the results of the study by Mellinas (2017), the quality of Wi-Fi service, expressed through its speed, is a significant factor of hotel customer satisfaction and impacts the image of hotels via online ranking and sharing by eWOM. According to the results of the analysis, it is a good strategy for hotels to increase the speed of Wi-Fi networks. If the Wi-Fi quality rises by one per cent, the customer satisfaction with the hotel increases by 0.376/100 units, or 0.1 per cent (which is an increase of the customer satisfaction by 0.00376 units, which the maximum value for customer satisfaction being five units). This finding reiterates the well-known point about the importance of Wi-Fi amenities in tourist infrastructure, further providing evidence of the impact of the quality of Wi-Fi provision. Also, importantly, the satisfaction grows steadily as the speed of Wi-Fi network increases (the other possible scenario not confirmed by the results is that the hotel customers become indifferent to the variations in the speed of Wi-Fi network after it reaches a certain threshold).

The quality of public Wi-Fi, in a general sense, can be described as a combination of the average speed of Wi-Fi connection and imposed restrictions, such as the allowed time of the session and quantity of traffic. While hotel management has a commercial incentive to provide quality Wi-Fi service, the motivation of local governments is much broader. LGAs provide public Wi-Fi for a range of rationales, but encouraging tourism is ranked highest (Grechyn & McShane 2018). However, the link between the rationale for tourism promotion and the network design is not clear, and often public Wi-Fi cannot sustain popular tourist activities such as voice communications or web browsing at a comfortable speed (McShane and Grechyn 2019). In light of the importance of the quality of Wi-Fi demonstrated by hotel customers, local governments are more likely to realise their goals in the sphere of tourism promotion such as fostering digital inclusion, facilitating tourism or promoting a positive city image by investing in quality public Wi-Fi service. The deployment of quality public Wi-Fi infrastructure by LGAs in Australia may be associated with the specific difficulties of organisational and financial nature, the analysis of which are beyond the scope of this chapter.

This chapter has shown that the quality of Wi-Fi (for example, connection speed) is an essential factor in hotel customer satisfaction. This can be extrapolated to the case of PWF infrastructure: the success of a project, or how much PWF infrastructure will meet the expectations of the public, depends on the characteristics of this infrastructure. To ensure the appropriate quality of a PWF service, it is necessary to have comprehensive planning, quality execution and evaluation of the PWF, which are all aimed at constant improvement and quality control. Such approach is in line with the improvement principle of EE, which states that comprehensive evaluation with greater involvement of stakeholders in project planning and execution contributes to the success of the project (Fetterman & Wandersman 2005). The thesis now turns to the role of PWF metadata. It will consider the legal aspects of privacy, the issue of access, and the possibility of using PWF metadata in urban analytics.

Chapter 7: Can PWF Metadata be Accessed for Better Urban Management?

This chapter is based on the conference proceedings: Grechyn, V 2019, 'Public Wi-Fi metadata in data-driven urban governance', *Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance,* Melbourne, 3-5 May 2019, pp.103-110, <https://doi.org/10.1145/3326365.3326379>

7.1 Introduction

Internet and digital communications have influenced and changed practically every sphere of modern life (Castells 1997; Hood & Margetts 2007; Kowalski et al. 2014). While analysis of this change is contested—Castells (1997) for example labels the present era as an 'informational age' whereas other scholars are suspicious of epochal rhetoric (Morozov 2013) — there is broad agreement on the profound impact of digital communication technologies. The increasing dependence of the social, economic, political, scientific and administrative realms on network technologies (and particularly the Internet) have led to the emergence of the concept of the 'network society' (Castells & Cardoso 2006; Wellman 2018). In the network society, a vast and continuously growing amount of data is created, received and transmitted in digital networks, the processes which contributed to the growing popularity of the term 'Big Data' (Schroeder 2014; Townsend 2013; Wellman 2018).

The term 'Big Data', which has arguably become a cliché during the last five years, should not be understood literally, that is as vast amounts of data, even if such interpretation is also possible (see chapter 2 for details). Instead, the term 'Big Data' refers to the high and yet growing importance of data and data analysis in the new modernity. Focusing more specifically on the topic of this thesis, a growing volume of research devoted to 'Big Data' in combination with the keywords 'public' (or 'municipal') 'Wi-Fi' and 'Smart City' can be observed in the recent five years (see chapter 2 for details). However, the available research on the intersection of these three themes is mostly international (Kontokosta & Johnson 2017; Mehmood et al. 2017; Nuaimi et al. 2015), with very little attention paid to the Australian context, recognising the diversity of that context also (McShane & Wilson 2017). Particularly under-investigated remains the topic of the role of PWF metadata in urban governance and urban analytics (McShane 2019).

The present chapter aims to address this research gap and scrutinise the issues of retaining, accessing and analysing PWF metadata in Australia. Current regulatory and contractual settings in which PWF operate in Australia impose significant barriers to accessing and using PWF metadata. This chapter

argues for a change to this situation. The chapter builds on discussion in chapter 3 regarding the importance of LGAs accessing metadata that is currently retained, indeed protected as a valuable commercial asset, by PWF contractors. Further, this chapter contests the current view, embodied in telecommunications and privacy regulations, that PWF metadata contains personal information and could be used to identify individual users.

7.2 Local Government Access to PWF Metadata

As shown in chapter 3, local government aspirations to push forward urban analytics and explore the nexus of PWF infrastructure and 'smart city' capabilities are hindered by the contractual arrangements of PWF provision and the telecommunications regulatory regime, which together hinder LGA access to PWF metadata. The telco's reluctance to provide PWF metadata to local governments is motivated by commercial interests, apparent in the possibility of selling metadata reports instead of giving direct access to the metadata (see chapter 3), but also by cautiousness caused by the legislative prescriptions about personal information, as defined in the *Privacy Act 1988* (Cth), Section 12: '[personal information] is information or an opinion (including information or an opinion forming part of a database), whether true or not, and whether recorded in a material form or not, about an individual whose identity is apparent, or can reasonably be ascertained, from the information or opinion'.

According to the national survey of Australian LGAs, 62% of respondents provide a PWF service to their communities (Grechyn & McShane 2018). Among this group, over two-thirds contract out PWF provision through public-private partnership (PPP) arrangements, while only a minority organise PWF service in-house. The motives to avoid in-house PWF provision by LGAs might be various, with financial and resource constraints serving as factors which discourage local governments from independent digital ventures. However, the imposition from 2015 of requirements to retain metadata under what is known as Data Retention Obligations (DRO) also plays an important role, as detailed below. The resource and staff limitations in relation to the choice of PWF model are considered in Chapter 7; here the focus is on the issue of access to PWF metadata.

This chapter builds on primary and secondary data, which includes interviews and email communication with LGA officers and one general manager of a company which is a PWF contractor for LGAs, national survey results, Australian legislation and PWF network metadata provided by the Launceston City Council. The analysis relies on mixed methodology, combining critical analysis of legislation and qualitative data with quantitative analysis of Launceston network metadata.

7.2.1 The Impact of the Data Retention Obligation

The Oxford English Dictionary defines metadata as ‘a set of data that describes and gives information about other data’. The data is described as ‘symbols that represent the properties of objects and events’, while information is ‘processed data’ (Ackoff, 1989, p. 170). Consequently, communication metadata is a set of data which describes communication sessions, for example, the location of a session, its duration, traffic (amount of data) transmitted, and so on. Without access to PWF metadata, LGAs cannot undertake the essential monitoring of the technical parameters and performance of PWF infrastructure. Neither can LGAs experiment with the potential usage of PWF metadata in urban analytics.

In the case where a local government authority decides to provide PWF in-house, it may be considered a communication service carrier (see chapter 2 for details) and subjected to DRO (Telecommunications (Interception and Access) Amendment (Data Retention) Act 2015; Parliamentary Joint Committee on Intelligence and Security 2015). DRO is a legislative requirement for all communication service carriers which prescribes the retention of a particular set of communications data (metadata) for at least two years (ACMA 2016). DRO is applied to telecommunication companies (telcos) as well as to private or public parties which provide communication services of any kind (communication service carriers).

The *Telecommunications Act 1997* (Cth) distinguishes between carriers, who are persons or organisations that own a telecommunications network unit used to supply carriage services to the public, and Carriage Service Providers, who use a telecommunications network unit to supply carriage services to the public. The former require a carrier license, the latter not; still, Carriage Service Providers must comply with service provider rules and obligations, particularly that of retaining and storing for two years network metadata (ACMA 2016; Telecommunications (Interception and Access) Amendment (Data Retention) Act 2015).

There are six categories of communication metadata to be retained (Attorney General 2016):

1. The subscriber of accounts, services, telecommunications devices and other relevant services relating to the relevant service.
2. The source of a communication.
3. The destination of a communication.
4. The date, time and duration of a communication, or of its connection to a relevant service.

5. The type of a communication or of a relevant service used in connection with a communication.
6. The location of equipment, or a line, used in connection with a communication.

DRO prescribed by the first category vary depending on type of communication. For example, for telephone conversations it could be the unique identifying number attached to a phone, while for Internet sessions it is the IP address allocated to the Internet session or MAC address of the device (Attorney General 2016). The IP address (Internet Protocol address) is an identifier consisting of two parts (one for the network and one for the node, or host) used to locate every device on the network. The MAC address (Machine Access Control) is a 48-bit globally unique identifier which is assigned to every Wi-Fi-equipped mobile device (Martin et al. 2017).

Understanding what concretely constitutes telecommunication metadata and what metadata must be retained under the DRO proved to be confusing not only for the general public but also for high-ranking officials. For example, George Brandis, the former Attorney General, in a notorious 2014 interview struggled to define the government's proposed metadata retention laws, answering the interviewer's question in a confusing and contradictory way. This is a revealing example: if the highest law officer in the land had trouble with the concept of metadata, then it is understandable that laypersons might be perplexed by the concept (Grubb 2014).

While DRO makes it more complicated and onerous in the minds of local authorities to operate public Wi-Fi (McShane & Wilson 2017), arguably, establishing and administering metadata retention is not an overly challenging or technically tricky process. Anyone capable of deploying and configuring a public Wi-Fi network with more than one AP will most probably have sufficient technical knowledge to enable metadata retention (Murray's Blog 2016). For example, Murray's Blog (2016) provides a succinct and comprehensive description of the system of metadata retention for a public Wi-Fi network established in an Anglican Church in Sydney by a young technology enthusiast who serves there as warden. On this account, the complexities of complying with DRO may be overstated.

In contrast to current regulatory settings and prevailing opinion in the local government sector, this thesis also argues that metadata generated by PWF networks is much less exposed to privacy breaches than other types of communication metadata. In this light, it is reasonable that PWF metadata could be made publicly available as open data, or 'information that anyone can find, explore and reuse' (Australian Government 2017). These considerations are detailed in the next section.

7.3 The Case for Public Access to PWF Metadata

Public Wi-Fi metadata is considered potentially identifiable communication data and accordingly there are strict controls over its access and use (Attorney General 2016). According to Part 3 of the *Privacy Act 1988* (Cth), personal information may not be used for any purpose different from its primary purpose (where the primary purpose of communication metadata is usage in criminal legal proceedings) unless individuals who are identifiable by metadata have consented to the use of the metadata for some different purpose.

Data or information is considered personal if this information is 'about an identified individual' (OAIC 2017). This chapter argues that PWF metadata does not pose any significant risk to the privacy of individuals and should not be considered personal information. Notably, individuals cannot be identified through PWF metadata in normal circumstances and without access to auxiliary datasets which are themselves confidential and subject to the terms of privacy and telecommunications legislation. As a consequence of this argument, this thesis argues that PWF metadata should be made publicly available in the form of data commons. The next few paragraphs explain why privacy risks associated with PWF metadata are negligible.

Telcos who provide commercial communication services are required, either by law or by a matter of practical necessity (for example, for billing operations), to hold certain information about their customers, for example, their names, residential addresses, and so on. By contrast, PWF providers do not hold any personal information about the users of PWF networks, retaining only the following components of PWF metadata from the network: 1) IP address; 2) MAC address; 3) the time when the device authenticates; 4) the time when the device terminates the session; 5) location of the session or Access Point to which the device was connected (Attorney General 2016).

7.3.1 Impracticability of PWF Metadata Identification

Let us consider these components of PWF metadata in more detail. First, IP address: on a PWF network, the connected devices are assigned dynamic rather than static IP addresses (Lemstra, Hayes & Groenewegen 2010), which means that a device receives a new IP address every time it connects to the open public wireless network. Hence, no stable association between the IP address and the device connected to the PWF network can be made.

Location and duration of the PWF session is also not data which can identify individuals. I argue that the only component of PWF metadata which can lead, at least theoretically, to the identification of an individual, is the MAC address. However, to make identification real, three conditions must be met simultaneously:

1. The user of PWF service must also be a customer of a commercial communication service (e.g., fibre broadband at home or mobile broadband).
2. The same device is used for accessing a PWF service and the paid broadband service, so two metadata datasets are created (i.e., PWF metadata and commercial broadband metadata), and both of these datasets contain the MAC address of the user's device as a matching key.
3. There is simultaneous access to two datasets containing user logs.

If at least one of the above three conditions does not hold (e.g., a person uses different devices for accessing the PWF network and paid broadband), the user of the PWF service will not be identified. For example, McShane, Wilson & Gregory (2016) found that 16.5 per cent of Australians had four or more devices, whereas the average number of owned devices was 2.62 per person. In view of this finding, it seems reasonable that at least in some cases people in Australia use different devices for PWF and commercial communication.

The key which theoretically permits identification of an individual is the MAC address; so, if all of the three above conditions hold, and the MAC address found in PWF metadata is also found in some commercial communication metadata, then it is possible to identify an individual since the telco or ISP which provides the commercial communication service to the customer usually holds some personal details about the customer (e.g., name, residential address, billing details etc., or combination of these). As the discussion above suggests, such a scenario is very unlikely.

7.3.2 PWF Metadata and Open Data Policies

The Australian Government has developed a policy of open data, aiming to foster economic growth, facilitate research and innovation, improve the delivery of government services, strengthen citizen engagement and promote government transparency and accountability (Australian Government 2016). One of the instruments to enhance the openness of sensitive data is de-identification, or removing the association between the data and the data subject (Australian Government 2018). De-identification involves a trade-off between preserving and optimising some of the dataset's utility and minimising

the risk of tracking the data back to a specific individual. In some cases, when data is not sufficiently de-identified, dataset records are exposed to the risk of re-identifying, as it was the case with health data (billing records in the health industry) published by the Commonwealth Department of Health in August 2016 (Teague, Culnane & Rubinstein 2016).

The opening of PWF metadata for public access would create a data commons potentially useful for urban analysts, researchers and anyone interested in the data traces and flows of modern city life, for example spatial and temporal patterns of footprint and intensity of PWF usage. Opening up access to PWF metadata would not pose a risk to the privacy of individuals and does not require prior de-identification, unlike the health data example above, which remained vulnerable to privacy risks even after de-identification. Some examples of PWF metadata analytical frameworks are provided in the next section.

7.4 Analysis of PWF Metadata

This section provides some practical examples of PWF metadata analysis (the data is courtesy of Launceston City Government). During the course of research for this thesis it has been difficult to access PWF network data. Access requests were sent to many LGAs, but only Launceston City consented to provide it. The author also requested access to PWF metadata from a company which is a major contractor of PWF infrastructure projects. The response of the general manager was as follows:

> In terms of sharing PWF metadata, I do not think that I can do that as metadata is considered "private data" and also we do not own the data that we collect, our customers (LGAs) do. As part of our responsibilities as a licensed carrier we provide metadata to security agencies on request. (General manager, PWF network provider, 2018)

Difficulties in accessing PWF network data, and indeed contract details, is indicative of the problem of asymmetrical information in the field of PWF provision. Also, despite the growing interest in the 'Smart City' theme indicated at the beginning of this chapter, openly accessible examples of PWF metadata analysis are virtually non-existent, not only in Australia, but in other jurisdictions as well.

The estimation of urban dynamics in various city areas is used to forecast demand for urban infrastructure and resources, to measure the need for social services and enhance urban planning, for example, future changes in the use of land and transportation needs (Kontokosta & Johnson 2017). The data used for urban analytics include social media content, smart card data (cards which have

embedded chips, e.g., digital travel cards) and mobile sensing data (sourced from mobile devices equipped with motion, location or environment sensors). However, public Wi-Fi network data is rarely included in urban dynamics investigations (Kontokosta & Johnson 2017). One early example of usage PWF network data for urban analytics is provided by Afanasyev et al. (2010), where rhew authors use the data from an extensive (over 500 APs) Wi-Fi network provided at the time by Google in Mountain View (California, US); the data were also provided by Google, where the two leading authors were employees. In this paper, the authors demonstrated an example of the temporal and mobility analysis of the patterns of the usage of Wi-Fi service in Mountain View, considering hours, days and weeks, as well as types of days (i.e., working days against weekends).

Another example is a research of the patterns of urban activity in Manhattan (New York), where Kontokosta & Johnson (2017) used public Wi-Fi network data in combination with auxiliary datasets, such as the US Census American Community Survey. In the European context, Picco-Schwendener et al. (2019) suggested using network data from Lugano PWF (Switzerland) to enhance the accuracy of classifying PWF users into one of the three groups: locals, business travellers or tourists.

To the best of the author's knowledge, there are no extant examples of PWF metadata analysis on Australian terrain. The analysis of PWF metadata provided below seems to be the first such attempt. Although it is basic and straightforward, partially since the absence of the geographical markers in the dataset (such as names or MAC addresses of APs) prevented spatio-temporal analysis, even a one-dimensional analysis (i.e., temporal) reveals interesting patterns of urban activities. In case there is a change to regulation and PWF metadata is for public access in line with the argument of this chapter, the possibilities for urban analytics and measuring the patterns of urban activity would be much more comprehensive.

7.4.1 Description of Launceston PWF Metadata Dataset

The PWF metadata dataset was provided by Launceston City Council. Launceston has an urban population of around 68,000, and is the Australian state of Tasmania's second largest city. The dataset contains logs of the 246,345 PWF sessions which span from June 2014 to October 2017. PWF in Launceston initially had a traffic cap of 200 Mb, which was increased to 500 Mb in December 2015. The allowed duration of the session was one hour.

Appendix G provides the structure of the metadata database. The main limitation of the dataset is the lack of the location of equipment (APs) data logs. It is not clear whether the telco did not collect this data, or they simply did not include it in the report provided to Launceston City Council. The

requirement of including 'location of equipment' data can be addressed by adding the name (or, as a variant, BSSID[9]) of the AP to which the device was connected during the session in PWF metadata (Attorney General 2016; Curran & Furey 2008). Because the locations of the APs are known, the names (or BSSID) of the APs in PWF metadata can be linked to the location of equipment (i.e., latitude and longitude). Also, since the average coverage of public Wi-Fi APs is around 50 metres, and the mobile device normally connects to PWF via the AP with the strongest signal, which is usually the nearest one (Lemstra, Hayes & Groenewegen 2010), the location of the AP provides a good approximation for the location of the PWF session.

7.4.2 Temporal Analysis of PWF Network Activity and Limitation of Launceston PWF Metadata

The higher the number of APs in a city PWF network, the better the granularity with which the urban dynamics can be potentially explored, but only with the condition that all these APs are included in the PWF metadata. Including the AP locations in PWF metadata logs is a DRO requirement for a carrier which operates a network facility (Attorney General 2016), but it also adds a spatial dimension to PWF analysis. For example, it would be possible to see in which areas PWF is used more or less actively and when (e.g., as an assumption, higher levels of morning or evening activity could be observed near cafes or public transport stations).

The basic idea of the urban analytics approach presented in this thesis is investigating the space-time dynamics of urban activity through analysis of time and location logs of PWF metadata.[10] The count of MAC addresses in the PWF metadata dataset approximately corresponds to the number of people who used their devices with that MAC address to connect to the PWF network. Whereas some individuals may use several mobile devices at the same time, while others may share a single gadget, considerations of practicality and observations of people's behaviour by the author in public places imply that most often an individual uses a single mobile device at one time (Figure 19 illustrates this point). Consequently, the number of MAC addresses in PWF metadata over a period of time is a good approximation of the number of people who were connected to the PWF network during that time.

[9] The name of AP often contains reference to its location, e.g., 'NorthTce134', which is the name of one of the approximately 200 APs in Adelaide, SA. The BSSID (basic service set identifier) is the MAC address of the AP, a 48-bit globally unique identifier, e.g., '51:0B:78:11:3B:A7'.

[10] The variable of the location is not included in the practical examples of PWF metadata analysis here due to limitations of Launceston metadata dataset.

Figure 19. A man uses his mobile device near the Victoria Library (Melbourne)
Source: Photo by the author, June 2019

Where location logs are included in PWF metadata, a combination of time and place logs of PWF sessions would allow a spatio-temporal analysis of urban activity (for which the intensity of PWF connections is a proxy).

7.4.3 Data Analysis

This section provides practical examples of PWF metadata analysis, using Python 3.7 (Jupyter 5.0 in Anaconda package) on a real-life PWF metadata dataset. The description of the Launceston metadata dataset and Python code for analysis and visualisation can be found in Appendices F and G.

Figure 20 shows the distribution of the number of connections to the Launceston PWF network on different days of the week. The number of connections to the network on the weekend was significantly smaller than on weekdays. The number of sessions during the weekdays was fairly stable, with a total average of around 38,000 connections on working days over a three-year period. Most connections to the network were undertaken on Tuesday, with activity gradually decreasing towards the end of the working week. From Friday to Saturday, the network activity decreased by 13%, and from Saturday to Sunday, it fell by a further 23.5%.

Figure 21 shows the temporal distribution of connections to the network during the day, as an average over the three years. There is a clear morning-day-night pattern, with most connections to the network undertaken during the afternoon and significantly decreased activity during the early morning and late night. The ‘quietest’ hour observed was from 4.00 to 5.00 in the morning, while the busiest period was from 11.00 until 16.00. After 16.00, the activity on the Launceston PWF network gradually decreased during the next six hours and partially regained the number of connections from 22.00 until 23.00 which was the evening peak of the activity.

During the most active afternoon period, there are two peaks of PWF usage: between 12.00 and 13.00 and between 14.00 and 15.00 (see Figure 21, where yellow and green dashed lines indicate the time of peak activity). The decrease in the number of connections from 13.00 until 14.00, during the lunch break, appears to be counterintuitive. This result contradicts an assumption that during their lunch break people have more time to use PWF than during working hours; this unexpected temporal pattern is consistent over three years and requires further research into the reasons behind it, but is indicative of new insights that can be gained by analysing this data.

Now, let us make a breakdown of the level of activity on the PWF network on weekends and working days. Figure 22 shows the temporal distribution of PWF connections on weekdays and weekends. Both charts demonstrate a bell-shaped morning-day-night pattern of the intensity of PWF usage. On weekdays, the intense afternoon usage of PWF temporarily decreased during the lunch break, which effectively caused two peaks of usage: before the lunch break (from 12.00 until 13.00) and after (from 14.00 until 16.00). On the weekends, however, there was a single peak of usage from noon until 13.00. While people might be more flexible and less dependent on the pre-arranged time for lunch on the weekends, yet it is still not clear why the activity on PWF network peaks in the afternoon hours on working days and drops during the lunch break.

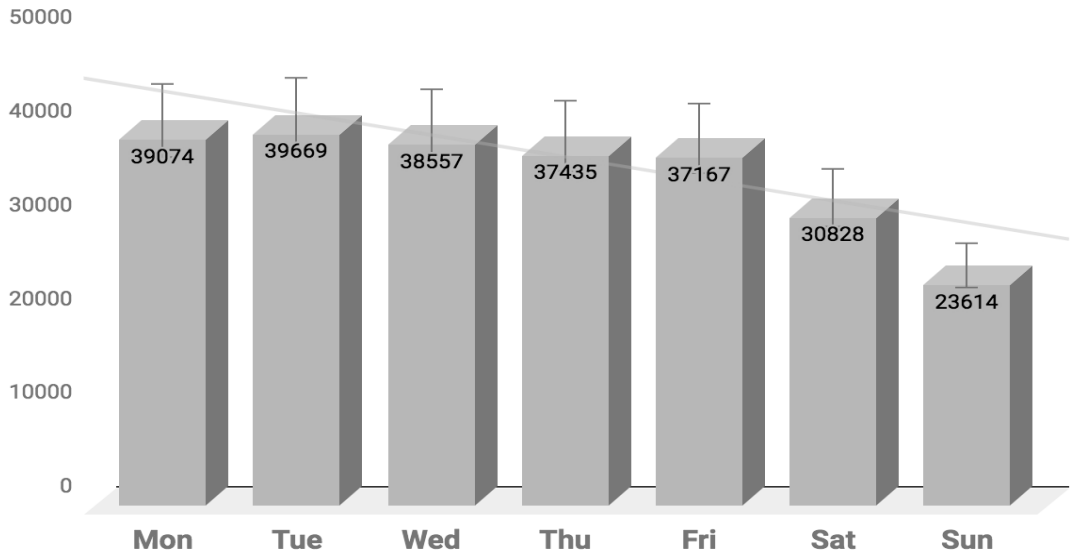

Figure 20. Number of connections to Launceston PWF network on different days of the week, 2013-2017

Source: Launceston PWF metadata, built in 'Google Sheets' web-based software office suite.

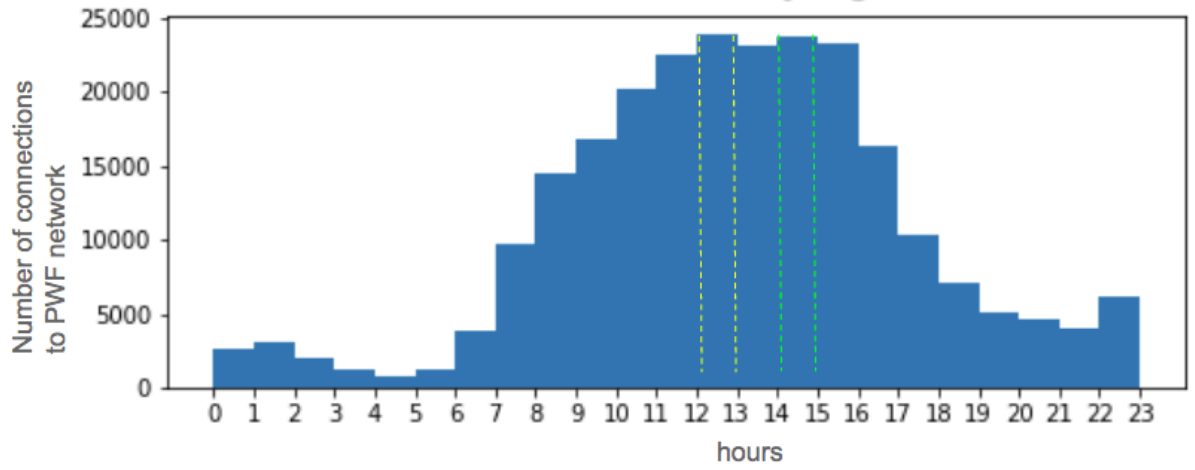

Figure 21. Distribution of sessions by login hour, Launceston PWF network, 2013-2017.

Source: Launceston PWF metadata, the plot is built in Python 3.7, see Appendix F

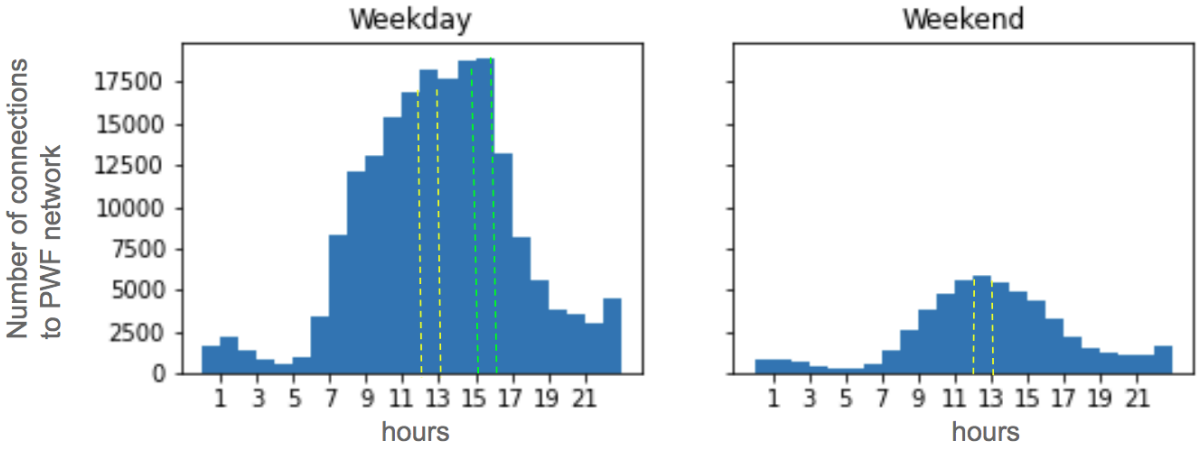

Figure 22. Distribution of sessions by login hour and day type, Launceston PWF network, 2013-2017

Source: Launceston PWF metadata, the plot is built in Python 3.7, see Appendix F

It is informative to determine the number of unique devices which were connected to the PWF network during the period covered by the metadata. This number provides an approximation of the total number of people who used PWF. The analysis shows that over three years, there were around 58,000 connections from devices with unique MAC addresses. Assuming that each device corresponds to a single person, it can be roughly said 55% of people in Launceston had connected to PWF at least once.

Then the question arises: how many of these were frequent users of PWF service, and how many had used PWF service only once (or twice)? For this purpose, it is useful to draw a scatter plot of the distribution of MAC addresses by the number of sessions (see Figure 23).

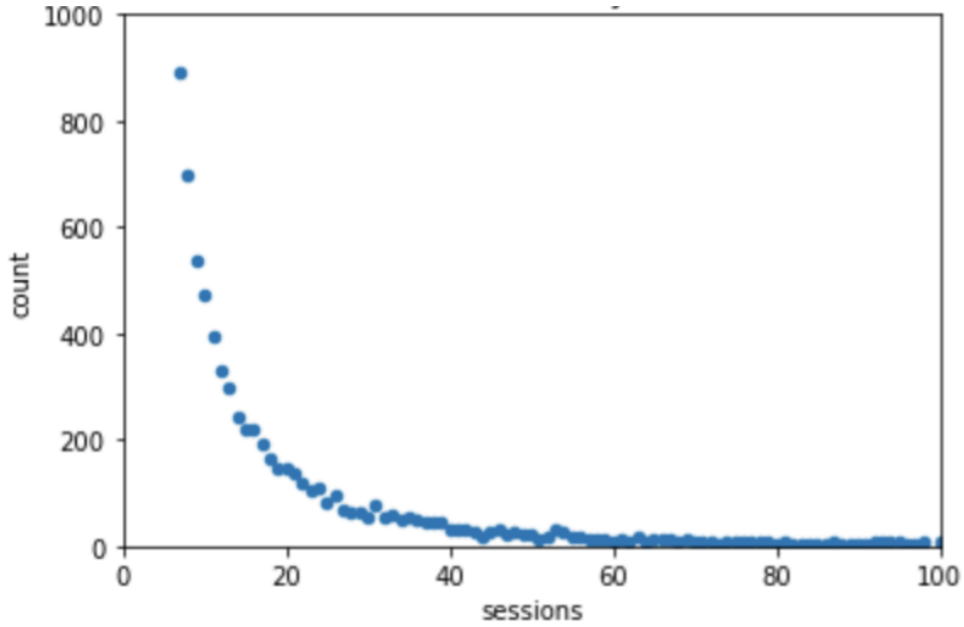

Figure 23. Distribution of MAC addresses by the number of sessions

Source: Launceston PWF metadata, the plot is built in Python 3.7, see Appendix F

The analysis reveals that 58.4% of all devices (34,123 in absolute value) were only connected to PWF network once; 72.8% of all devices were connected to PWF network either once or twice; 78.3% of devices were connected to PWF network either once, twice or three times. One device was connected to the PWF network 404 times, one 694 times, and one record-maker 944 times (which means that that device connected to the PWF network every 1.28 days in the period covered by PWF metadata).

The distribution of the total traffic of the sessions shows that 10% of connections used 91% of the total traffic. Such a proportion is akin to the well-known principle formulated by economist Vilfredo Pareto, who first observed that 80 per cent of wealth was owned by about 20 per cent of the population. The actual numbers, and application of the principle, vary, but the general idea is a highly-skewed distribution (Sanders 1987).

Those who had generated a small amount of traffic might have used PWF for a purpose which does not require a lot of traffic, for example, checking text emails. It is also possible that some of these users were in the areas of PWF coverage and their devices connected automatically to the wireless network, and the idle session produced only minimal traffic. The abundance of low-traffic users of Launceston

PWF, particularly those who used the service only once, merits closer attention by Launceston PWF managers, because it might indicate users' dissatisfaction with PWF network quality. On the other hand, the frequent and intensive users of PWF in Launceston (who are in the minority) might be lacking mobile data or relying entirely on PWF.

7.5 Conclusion

The chapter analysed the role of access and analysis of PWF metadata in PWF provision by LGAs. The Internet and digital communications affect practically every area of modern life, which became especially noticeable in 2020 during the pandemic. At the same time, a growing volume of data is constantly generated in various communication networks. There is a tension between the practical goal of collecting and analyzing these data, on the one hand, and legal and ethical considerations regarding the use of potentially identifiable or confidential data, on the other. This chapter argues that currently, it is practically impossible for a researcher to identify individual users in a PWF metadata database, which sets out a rationale for making PWF metadata open to the public, which could be a valuable resource for research, experimentation and the training of data scientists. This policy recommendation echoes the principles of EE, in particular community ownership, capacity building and community knowledge.

The chapter also demonstrated the analysis of metadata retained from the PWF network in Launceston (Tasmania). Due to the absence of location data in Launceston PWF metadata dataset, it was not possible to undertake clustering of city areas according to the intensity of PWF usage during the day. However, such analysis, if made, will be a useful representation of the general level of urban activity in different city areas, which, in turn, can serve as an additional source of information for urban planning and urban management. In perspective, LGAs can implement the real-time analysis of PWF metadata. It would be especially instrumental in the city areas densely covered with APs, which would allow enhanced granularity of analysis of urban activity.

Chapter 8: The PWF Model: Provision and Infrastructure Control

8.1 Introduction

This chapter builds on the findings of the thesis to argue that in the long term, LGA control over PWF investment is a key determinant of the success of PWF infrastructure investment. As shown by the literature review in chapters 1 and 2, evaluation needs to consider or address the four layers of PWF infrastructure. The first layer is the model of PWF provision, the second relates to technical parameters and their control, the third is socio-economic effects, and the fourth is the possibility for innovation and experimentation by LGA enabled PWF infrastructure. Both the third layer of socio-economic effects, such as fostering digital equality, tourism promotion or economic growth, and the fourth layer of LGA experimentation and innovation related to improved urban governance, depend on the PWF provisioning model (layer one) and technical quality (layer two). Hence, this chapter will focus on the core capabilities of these two layers.

The chapter is structured as follows. First, it overviews the rationales for maximising the control over PWF by LGA, including ownership of the physical PWF infrastructure and its operation. There is a belief that government provision of municipal Wi-Fi is not in the public interest, which has been a strong assertion by telco lobbyists in the US (Giovanetti 2005), but has also made its way into academia (Potts 2014). But what are the arguments for private-sector provision? The sub-sequent section explores this issue and argues that there is no firm theoretical or practical basis for a preference for private sector provision of PWF. Then, the chapter turns to the consideration of the types of impediments or limitations to strengthening LGA controls, which comprise institutional and organisational (internal) controls, contextual (external and economic), and ideological or paradigmatic. Internal impediments arise principally from limited staff expertise and organisational and financial constraints. The external and economic impediments that comprise contextual limitations are those beyond direct LGA influence, which include information asymmetry and oligopolised markets of Internet provision, among others. The ideological, or paradigmatic impediments relate to historically formed socio-political assumptions about the appropriate role of LGAs as a provider of infrastructure and services. Finally, after considering the possible ways to overcome impediments to strengthening LGA controls, the chapter concludes with a summary of the above and re-iterates the benefits of implementing greater control over PWF by LGAs.

8.2 Background: The Importance of LGA PWF Provision Control

The data obtained from the survey of Australian LGAs (chapter 3) revealed that most do not undertake any evaluation of their investment in PWF infrastructures. Moreover, in the majority of cases, LGAs, which claimed to perform an evaluation, did not go beyond data monitoring of technical performance. In some cases, PWF service contractors did not report network monitoring results to the LGA, and consequently, LGA officers did not have operational data to evaluate network utilisation. In other cases, the PWF service contractors reported to LGAs, but the structure of their reports reduced their utility. For example, the PWF service contractor in Adelaide reported the minimum and the maximum number of users connected to the access points during specific two-hour periods during particular days of the week. However, they did not provide data concerning the number of unique connections to the network in general or specified access points over a period, which would better track network usage dynamics. The PWF service contractor declined the LGA's request for altering reported data format, appealing to the difficulties of changing the configuration of the network monitoring system. (LGA official, South Australia, 2019).

It is virtually impossible to track the fulfilment of PWF provision objectives, such as supporting tourism or space activation by measuring the user footprint without accessing PWF network metadata (McShane & Grechyn 2019). Thus, better operational control of PWF provision is important for LGAs, including PWF metadata access and calibrating network technical parameters.

Further, as noted previously, in the long term, ownership of PWF infrastructure by LGAs provides a basis for LGAs to experiment with innovative usages of wireless infrastructure. LGA control can enable long-term strategic goals, including digital equity, such as providing a 'last resort' means for accessing the Internet secure from distorting market influences.

8.3 Motivations for Increasing PWF Provision and Infrastructure Control

The public Wi-Fi market remains unsettled with low levels of competition (McShane & Grechyn 2019) which results in high price dispersion and the absence of 'benchmark' market standards for contracting out PWF provision. A shift to in-house provision by the LGA minimises risks associated with the increase of service price delivery and unfavourable contractual obligations over the long-term. Delivering PWF in-house with LGA ownership of the network and self-sufficient technical support

also frees the LGA from the obligation to pay regular service fees, and limits the relevant expenses to the salary of the LGA staff member. Motivations for in-house LGA PWF infrastructure provision and control are:

1. Enhancing the long-term sustainability of the PWF project and minimising long-term organisational and financial risks (although these offset the theoretical motivation of resorting to PPP as a way to minimise LGA).

2. Ensuring sufficient quality of PWF in terms of the technical parameters of wireless connection with operational control of the local government and the possibility to undertake regular monitoring of the network's technical performance. Control over technical parameters of the PWF network allows the LGA to ensure that the functioning of PWF infrastructure is optimized.

3. Investments in the enhancement of capacities and qualifications of the IT staff of the local government, which in the era of 'digital governance' (Dunleavy et al. 2006), will have positive spillover effects into other LGA activities.

4. LGA PWF infrastructure is a valuable asset which can be utilised by the local government innovatively in ways not necessarily linked to its primary function of providing Internet access For example, PWF infrastructure can be used for urban analytics (see chapter 6).

5. Serving a role of 'last resort' for Internet connection provided by government can only be securely achieved if local government takes control of PWF provision; otherwise, Internet connections are prone to external market-related and other risks (e.g., the 'dissolving' of the provisioning company as described by the LGA in NSW, see p. 4.2 in the current chapter). Importantly, historical evidence from the US is that PWF networks (both municipal and community-run) proved the most robust form of telecommunications during natural disasters. For example, during Hurricane Katrina (New Orleans, 2006) and Hurricane Sandy (New York, 2011), PWF was the only functioning form of communication for residents and workers after commercial services were knocked out[11].

[11] Ironically, in the aftermath of Hurricane Katrina, commercial mobile services (telcos and ISPs) were sufficiently influential in having the PWF network throttled to a miserly 128Kbps, to comply with Louisiana's broadband laws (Poblet, Funfgeld & McShane 2014).

6. Taking control of PWF provision enhances LGA organisational capacity by facilitating a shift from the outdated concept of ‘roads, rates and rubbish’ as a description of local government responsibilities to a more empowering ‘delivery of public services, digital data-driven governance, and (re-)design of public space’. This approach is consistent with the recognition of the importance of digital governance at the local level in Australian federal policy, including the National Digital Economy Strategy, where the ‘emphasis on improving Australia’s position in the digital economy… through e-government and other areas … directly links to broadband internet infrastructure developments’ (Freeman 2016, p. 200).

7. A high-quality PWF can serve as a local trademark and as a source of pride for the local community (Austrade 2019; McShane, Wilson & Meredyth 2016).

The benefits noted above will accrue to the LGA for inhouse provision without relying on intermediaries. It is conventional to outsource specialists during the initial stage physical deployment of the infrastructure and initial network configuration. However, subsequently, the LGA will benefit if the outsourced contractual agreement includes skill development for LGA IT staff, so they maintain network operational control and monitoring, retaining metadata and changing network parameters if required.

8.4 Arguments for private sector Wi-Fi infrastructure provision

Potts (2014) overviews the economic objections to public provision of Wi-Fi infrastructure, which are distorting competitive telecommunication market, capitalisation of ‘free’ Wi-Fi in land value, absence of market failure condition, and finally the argument that even if Wi-Fi is viewed as a public good, it doesn't necessarily have to be publicly provided. As a general observation, most of these objections to the public provision of Wi-Fi infrastructure are purely theoretical and hardly applicable to the practice of PWF provision in Australia. The public Wi-Fi infrastructure provided by local governments in Australia is small and deployed with modest capital investment (see details below), and this essentially neatly localized and small infrastructure poses no real competition to commercial telcos. For the same reason, Wi-Fi infrastructure is not a real factor in the capitalization of land, even though PWF is often deployed in CDBs and other vibrant city areas with already highly-valued land, so the cause and effect might be confused (see Chapter 6 for a similar discussion of causal determinability between PWF and

local sales growth). The arguments that there is no clear market failure condition and that private firms can therefore provide PWF are considered below.

To enable private provision of Wi-Fi infrastructure, PWF must rely on some kind of financial model to cover costs and generate income, such as paid subscriptions or payments for each use of the service (Kaiser et al. 2017). However, Wi-Fi infrastructure, which users pay for directly, is not the subject of this thesis. To make Wi-Fi connections free for at least some categories of users, private companies can adopt the "club" model (Bar & Park 2006). This is an example of Telstra Air, Telstra's Australian Wi-Fi network, which is also part of the Fon global Wi-Fi network. Fon's global network began more than a decade ago as a residential Wi-Fi sharing initiative, and today, together with telcos around the world, is the world's largest Wi-Fi network with over 21 million hotspots (FON 2020). In Australia, however, Telstra Air's services are widely criticized by customers for being extremely poor (Product Review 2020), contributing to a broader debate about the quality of privately provided services where the incentive to reduce costs is greater than the incentive to invest in quality (Laffont & Tirole 1993). In addition, while eligible Telstra customers can connect to the Fon Air service for free as long as they pay for their prepaid or postpaid mobile plans, customers not using Telstra can only buy Telstra Air guest passes to be able to use the network (Telstra 2020), so Telstra Air is not a free service for end users in a general sense.

Finally, there is also an advertising-driven private Wi-Fi infrastructure business model, which may make it commercially feasible to provide free-of-charge PWF service. On the international stage, NYLink in New York, which is a consortium of city government and private investors, is an example. The city government provides the municipal infrastructure - former payphones that have been converted by private investors into free Wi-Fi hotspots with lightboxes to display advertisements. NYLink is fully financed by private investors from displaying advertisements on the lightboxes (Sobolevsky et al. 2017). However, even such a seemingly 'ideal' model, in the sense that it costs nothing to taxpayers and gives everyone the opportunity to use Wi-Fi for free, could be criticized. For example, Basch et al. (2018) observed that NYLink lightboxes frequently ran advertisements for alcohol with no health or age warnings between May and September 2017, so the positive effects of PWF, as well as the city government's health promotion efforts, were compromised by health-hazardous NYLink advertising policy[12].

[12] In April 2019, alcohol advertisements were banned from New York city property, including bus shelters and LinkNYC kiosks. Source: https://brooklyneagle.com/articles/2019/05/01/alcohol-ads-banned-on-new-york-city-property/

However, it should be noted that the private model, which is free to end users, has not been implemented in Australia until now, although there has been some movement in this direction. In 2017-2018, the Sydney City Council repeatedly sought expressions of interest for the construction of PWF through a tender process with the condition that the project was to be implemented at zero cost for the city government[13]. The key objectives for the Service Providers willing to submit proposals included installing "a high-quality free Wi-Fi service" at "no cost to the Council for planning, installation and ongoing operation of the network" with "the maximum feasible coverage area"(City of Sydney 2017, p. 11). However, as of 2020, there is still no PWF infrastructure in Sydney, or even publicly announced plans to deploy PWF soon, which may point to the fact that the terms of the PWF tender were not commercially feasible.

Even if an advertisement-funded model of quality PWF, which is delivered to the public at zero cost, can be implemented in large cities such as New York or Sydney, in cities with smaller populations it may not find sufficient scale to be effective from a purely commercial point of view. Thus, even though the pure market failure condition for PWF provision is not met in theory, this is certainly the case in Australian practice, especially for the smaller cities and towns, which are also often underprovided with traditional broadband infrastructure.

To date, by far the dominant involvement of the private sector in Wi-Fi in Australia has been as contractors to LGAs, in what can be loosely described as public-private partnerships (PPPs) where private contractors deploy and maintain PWF using urban infrastructure elements owned by local governments. However, as the analysis that follows demonstrates, there are significant limitations on this arrangement as an effective way to provide PWF, strengthening the argument of this thesis for greater LGA involvement in PWF infrastructure.

There is a wealth of literature on the rise of PPPs as a dominant arrangement for public service provision in the new public management era in both Australian and international contexts (Huanming et al. 2018). However, PWF projects implemented in Australia are awkwardly classified as public-private partnerships, despite the concept's rather vague boundaries. Hodge & Greve (2011) point to five possible interpretations of PPP: a specific project or activity, an organisational form, a policy or statement as to the role of the government in the economy, a governance symbol, or a historical and cultural context. PPP projects in Australia are usually characterized by high capital costs. For example,

[13] The 2017 tender document (EOI #: E1317) has been removed by Sydney City Council from their website. It has been saved by the author and is now available for viewing at http://www.dreamsplans.com/sydneywifi2017.pdf The 2018 conditions (EOI #: E0718) in the part concerning the provision of Wi-Fi infrastructure duplicates the terms of the 2017 tender document, and was also removed from the website of the Sydney City Council.

according to the list of PPP projects compiled by Hodge & Duffield (2010), the average cost of PPP projects in 2010 was $ 0.51 billion in Victoria and $ 0.63 billion in South Australia[14]. This is hundreds of times higher than the capital cost associated with investing in PWF, although we have limited specific data on this subject (see chapter 4 for details). For example, the capital investment of Adelaide*Free* PWF, the largest PWF network in Australia, is several hundred times less than the capital investment of an average PPP project in South Australia[15]. But even without taking into account the amount of capital investment, as follows from this thesis, local governments currently view PWF as investment in a service rather than that in infrastructure.

In a narrow sense, PPP can be defined as the alliance between the capabilities of the government and the private sector to implement a project (Hodge & Duffield 2010). In this light, contracting out PWF can be categorised as a PPP. As Hodge & Greve (2005, p.309) point out, "the Australian PPP movement has been built on these four foundations: privatization, competition, outsourcing, and service purchasing". This "Australian PPP movement" is generally based on a combination of governance and ideological principles associated with New Public Management (NPM) (see chapter 2), such as smaller government, zero budgeting or performance indicators (Hodge, 2011). Hodge and Duffield (2010, p. 404) note that "the aims of the PPP philosophy seemed to fit the NPM ethos like a glove". Contracting out PWF also exposes the main disadvantages of PPPs for local authorities and their publics. For example, requests by the author for details of PWF contracts have been repeatedly denied by the LGAs on the basis of commercial confidentiality. This response typifies the lack of transparency and accountability that (Hodge & Greve 2007) consider to be problematic with PPP arrangements.

In addition, some international scholars criticize PPP projects for the fact that the public, represented by the government, eventually loses control over the infrastructure or regains control of degraded assets (Whiteside 2017; Loxley & Hajer 2019). Likewise, if PWF is contracted out, the local government risks losing PWF as a public infrastructure at the end of the contract period, especially if the local government cannot secure funds to pay for further maintenance and operating costs.

Are there arguments in favour of contracting out or PPP (whichever terms we use) in the case of PWF? First, the transfer of project risk from the public to the private sector is the major argument in favor of a public-private setting. The potential for risk transfer is associated with the acceptance of project cost

[14] The author was unable to find more recent aggregated PPP capex data for Australia, but the numbers are likely to be even higher if we take into account inflation since Hodge & Duffield (2010) undertook their analysis.
[15] In 2013, the capital investment in the AdelaideFree network, covering the Adelaide CBD, as an increase in the capacity of the then existing CityLan network (see chapter 4.3.2 for details) amounted to $ 1.5 million (Crozier 2013).

overruns by the private partner (Hodge & Greve, 2017), and sometimes with the transfer of reputation risk associated with project failure from the public to the private sector (Forrer et al. 2010).

In the case of PWF, as implemented by local Australian governments, financial risk cannot be effectively transferred. The reason is simple: according to a nationwide survey among Australian LGA (see Figure 24), the vast majority of PWF projects (77.14%) are funded from local budgets, while the remaining are funded from state or Commonwealth budgets or grants. Contractors might bear some risk if they had under-estimated the cost of provision to meet service standards specified in the contract, even though we know little about since the PWF contracts are under the veil of commercial confidentiality. However, the major risk remains with the LGA, in case if the contractor is not able to provide PWF infrastructure of sufficient quality or if it simply "dissolves", an actual case which was reported to the author by the LGA officer in Western Australia. Moreover, the risk is also passed on to the public, because if the LGA or funding bodies are not able and or willing to provide additional funding in the event of an unpredictable increase in project costs, the local community will no longer be able to access functioning PWF.

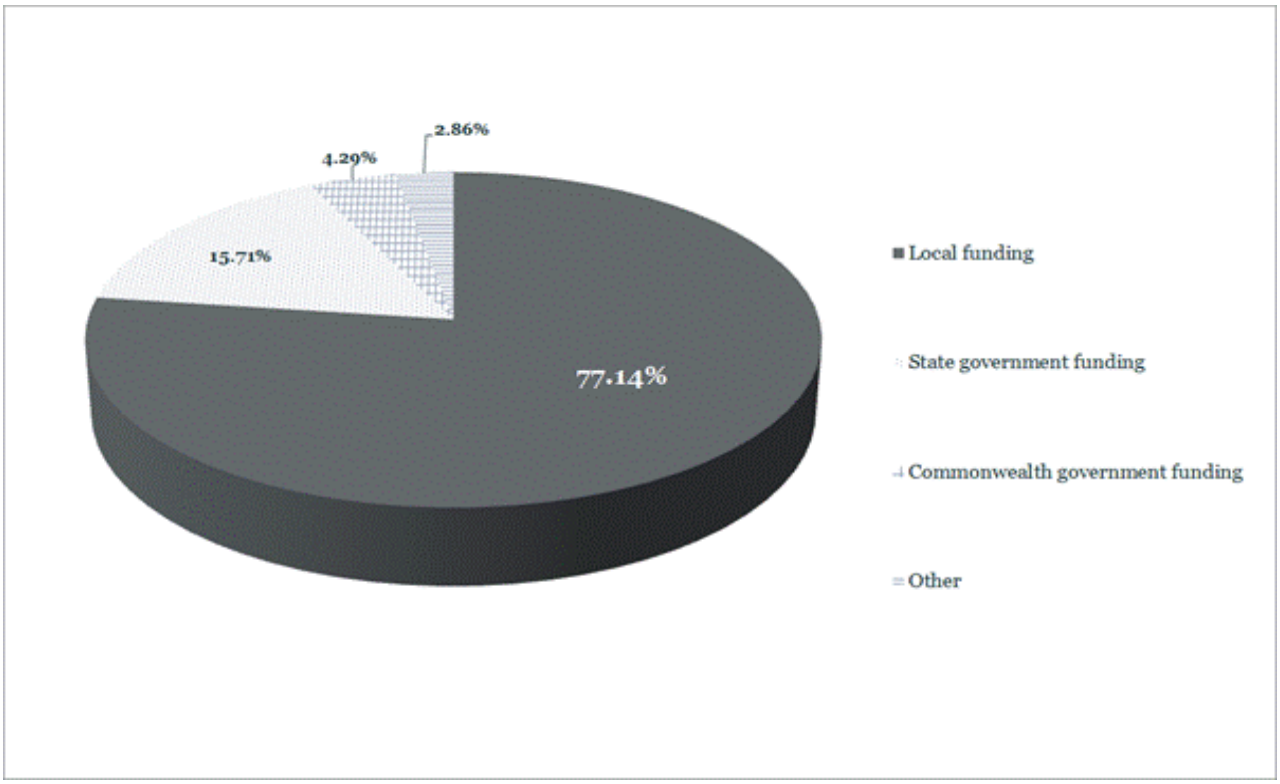

Figure 24. Sources of funding of PWF initiatives by LGAs, based on an Australian survey among 70 LGAs which have PWF projects.

Source: Based on data obtained from the survey (chapter 4, Appendix A)

Reputation risks, associated with PWF project failure or low quality, can be viewed in a broader management perspective, which implies that the company's (in our case -- local government's) vision and leadership, strategy, communications, the quality and scope of services all directly influence the image of the company and how it expresses itself to the outside world (Larkin 2002). Arguably, in the case of PWF provision, reputation risk associated with PWF project failure cannot be effectively transferred to the private contractor. In the event of project underperformance or failure, local authorities rather than private contractors are likely to be held responsible. Illustrative is the case described by the City of Launceston official in a 2017 interview with Dr Ian McShane. (LGA official, South Australia, 2017). The Launceston City Government declined to host the Tasmania Government/ Telstra PPP network on their local PWF infrastructure because that network was a lower specification than the city's network, which indicates that the Launceston authorities took issues of service quality and reputation seriously. As McShane (2019) points out, city governments often specifically indicate proprietorship over the networks, through generalised promotion and, most directly, through network SSID names (e.g. Adelaide*Free*).

Finally, an important theoretical incentive for turning to private provision of goods and services is the belief that private contracting typically yields greater cost efficiency, since the private sector has stronger incentives (associated with private ownership) to lower costs than the public sector. However, the private sector's incentive to reduce costs may lead to a decline in quality. The simple trade-off between quality and cost as a representation of the government's choice between providing goods and services in-house and contracting them out, as theorised by Laffont & Tirole (1993), is contested by Hart, Shleifer & Vishny (1997). These authors argue that the quality of goods and services produced by the private sector can be either higher or lower than that of the public sector, due to the ability of the private sector to innovate, compete with other private suppliers, and invest in quality improvement.

Reflecting on the recent events surrounding the failure of private contractors in quarantine hotels (related to the COVID-19 quarantine measures), Holden (2020) points that private contracting can lead to the long-standing trade-off between costs and quality putting the latter at risk in case of incomplete contracts. Based on Hart, Shleifer & Vishny (1997), Holden argues that since it is not possible to include all the details and contingencies in public-private arrangements (hence the term "incomplete" contracts), the private sector will try to exploit contract gaps where possible to reduce costs at the expense of quality. In the case of PWF, the low transparency and veil of confidentiality of contracts prevents local authorities from conducting a comprehensive comparative analysis of what quality and scope of PWF is reasonable in relation to a certain price. It also introduces the problem of information asymmetry, as discussed in Chapter 4, where lack of information sharing within the local government

sector inhibits sound decision-making on cost and contract terms. This, coupled with the fact that local governments often lack operational control or at least informed oversight of the PWF, jeopardizes the quality of the PWF infrastructure, while, due to the lack of a highly competitive and transparent market (see chapter 5 of the thesis), low price is also unlikely to be achieved.

This section has taken a critical look at the provision of Wi-Fi infrastructure in the private sector. The criticism in this section does not imply that local governments should avoid contracting PWF services and adhere to internal provision, as some LGAs may simply not have capabilities to do this. However, the PPP framework or contracting out (whatever terms we use) must be implemented from an empowered position, with stronger local government involvement and operational control over the PWF infrastructure, or at least informed oversight of it. At the same time, accountability and transparency need to be strengthened and decisions should be made based on the circumstances of a particular situation, as consistent with the principles of EE.

8.5 Factors Impeding LGA PWF Control

As noted in 7.2 above, there are three types of impediments to LGA control over PWF provision:

- internal (institutional and organisational);
- contextual (external and economic);
- ideological or paradigmatic.

Each is described in more detail in the following sub-sections.

8.5.1 Institutional and Organisational Impediments

While operating in a more favourable external environment compared to the US (Guttentag 2018), which is characterised by legislative restriction or explicit opposition to PWF projects from telcos, Australian LGAs have nevertheless often preferred a PPP model of PWF provision.

This model typically presumes minimal control over the functioning and configuring of the network by the LGA; however, evidence suggests that PPP contracts omit LGA access to PWF metadata (City of Adelaide official 2016). The motivations for LGA outsourcing preferences related to organisational factors include finance and the comparatively low prioritisation of PWF initiatives by LGAs officers who do not consider it a core project (McShane & Grechyn 2019). Managing PWF projects does not fit the cultural framework of local government service provision for some; and this raises controversial

managerial issues, such as deciding on the areas of PWF provision and the technical characteristics of the wireless infrastructure. Interviews and comments gathered as part of the national PWF survey revealed that the spatial and technical design of PWF infrastructure, and calibration of the network performance, were left to the discretion of the contractor within the allocated funding. (LGA official in Victoria, 2018; LGA official in SA, 2019).

Since Mandviwalla et al. (2008, p.78) first described local governments as 'not best practice leaders on project management and technology implementation', little appears to have changed in Australia in a context of LGA PWF provision. Financial constraints on LGAs can be a limiting factor. The Australian local government sector accounts for only 3.5 per cent of Australia's total taxation revenue, with property rates as the only tax base. At an aggregate level, LGAs are nearly 90 per cent self-funded (Australian Productivity Commission 2017). Besides taxation revenue, which accounted for 37% of the aggregate local government sector's revenue from 2010 to 2011, other sources of financial inflows include grants and subsidies (10%), sales of goods and services (25%) and interest (4%), while 24% of funds were raised from alternative sources (ABS 2012).

The structure of local expenditures depends on population density and locational characteristics (e.g., urban/ rural). Local governments in densely populated urban areas use a significantly lesser share of their taxable incomes for the maintenance of local infrastructure (ALGA 2017). This can be explained by the funding characteristics of transport systems. In many cases, urban systems are serviced by the private sector or funded from the state budget. Conversely, local governments in sparsely populated rural areas have greater responsibility for construction and maintenance of local infrastructure on their own, especially rural roads, which can absorb a significant share of rural shire budgets (Grant & Drew 2017).

In addition to the burden of building and maintaining local infrastructure, rural and small regional LGAs are more reliant on external funding sources (ALGA 2017). Being financially constrained, rural LGAs may have difficulty turning their attention to innovative projects, which could potentially enrich local social and cultural life and create additional public value. As one LGA officer in Western Australia reported '[we are] a rural shire and we don't see public Wi-Fi as a priority' (LGA officer, WA 2017). However, small LGAs in depressed regions have an opportunity to turn PWF infrastructure into a local trademark if it has sufficient quality, and thus help revitalise tourism and the local economy (Austrade 2019; McShane, Wilson & Meredyth 2016).

Major city centres can also greatly benefit from a high-quality PWF as it fosters their image as an innovative, digital and tourist-friendly destination. This was the case with the City of Adelaide, which, as discussed in Chapter 4, has vigorously (and with some justification) promoted its digital innovation credentials. However, as a city official revealed, although the council would like more control over PWF provisioning, it lacked institutional capacity. (LGA official, 2019). The issue, then, is not limited to regional and rural centres, or less digitally-engaged cities.

8.5.2 External and Economic Limitations

In Australia, the policy environment is, in general, quite supportive for launching PWF initiatives by LGAs, particularly when compared with the situation in the US. As noted briefly in the previous section, US wireless initiatives by municipalities met with fierce opposition from the telecommunication sector (Guttentag 2018; Gillet, 2005). These resulted in legislative prohibitions for municipal involvement in PWF provision in some US states. The comparatively relaxed attitude of Australian telcos to municipal wireless initiatives can be partially explained by the late start of widespread PWF initiatives in Australia (circa 2011–2013), compared with the earlier US expansion (circa 2003–2005). By the time PWF initiatives gained momentum in Australia, there was almost a decade of evidence available that municipal PWF did not cause serious competitive threats to the large-scale telecommunication networks. However, telcos identified their own incentives to invest in Wi-Fi infrastructures as growing pressure on the cellular telecommunications networks made the risk of the mobile band congestion apparent. So, telcos invested in Wi-Fi networks (e.g., Telstra established its own Wi-Fi network 'TelstraAir') aiming to partially offload data from their congested cellular network to the Wi-Fi infrastructure which operates in a completely different wave spectrum (Lambert, McQuire & Papastergiadis 2013; Kastrenakes 2020).

Asymmetry of information on the market of PWF service provision also hinders informed decision-making on the model of PWF provision by LGA officers, which adds to the significant variance in prices for PWF deployment and maintenance of PWF (as shown in Chapter 4).

Finally, there is a risk associated with the lack of the control by LGA over PWF provision posed by the abrupt ending of a PWF project even though the LGA is willing to continue it. This is a significant limitation for those LGAs who rely on external providers. For example, the contractor of a PWF service may not be willing to extend the contract for PWF provision with the LGA. Further, increased service prices may cause the LGA to terminate the PWF service as occurred in a rural area of NSW

with a population of 4,700 people. The LGA had outsourced the service to a local ISP with no ownership rights or PWF infrastructure control. As the respondent noted:

> We previously had free Wi-Fi. The provisioning company dissolved, and council did not have the resources to maintain the service. (LGA officer, NSW 2017).

8.5.3 Paradigmatic Limitations

Paradigmatic limitations relate to social and political conventions of how public administration is undertaken. Moore (1995) calls this the 'authorising environment', and it concerns perceived legitimacy and support for LGA provision of telecommunication infrastructures. The fact that PWF is free for end users has introduced additional complexity to public (dis)approval of PWF in some instances. This can raise taxpayer concerns as well as questions related to long term PWF sustainability. Moreover, the assumption that the local municipal council should be paying for public Internet, which can be accessed by mobile broadband, is contestable. As an officer from a New South Wales LGA, with a population of more than 37,000 noted, 'There is a thought here at Council as to why should we be paying for peoples' access to the internet'. (LGA official, NSW 2018).

Paradigmatic limitations occur formally through legislative prescriptions, but also informally through political preferences, media and research. For example, Park and Lee (2010, p. 425) find it ironic that local governments have increased investments in the provision of PWF in an 'era of deregulation and privatisation of public utilities'. This attitude toward government participation in telecommunications exemplifies the paradigm of privatisation that effects LGA PWF initiatives. Deregulation and privatisation find their ideological roots in Adam Smith's laissez-faire principle (Bozeman 2007). However, in Australia, it became particularly evident from the early 1990s with the part-privatisation of the national public telecommunications monopoly provider, Telstra, as part of wider market liberalisation of the industry, along as with disinvestment in and privatisation of other sectors.

The Smithian postulate of an 'invisible hand' of the market, and government non-intrusion as the best strategy to achieve optimal economic results, gave rise to classical and neoclassical economic schools proclaiming the advantages of the free market and privately-owned firms over government regulation and state enterprises (Landreth & Colander 2002). The drive for increased business efficiency and productivity was the core motivation for transferring telcos from state to private ownership (Bortolotti et al., 2001). However, the system of privately-owned telcos proved to be ineffective in ensuring equal

access to quality communication service provision in Australia (Coutts 2015) and led to the introduction of the state-owned NBN company (McLaren 2018).

As noted, paradigmatic limitations are often based on political attitudes and expectations and may have no relation to practical outcomes. For example, some authors observe that 'local governments are not effective venues for redressing most deep social or economic cleavages' (Oliver et al. 2012, p.10). However, investment in PWF does not typically imply overly ambitious social or economic goals. Investing in PWF serves rather humble yet important purposes as described further in this chapter, and allows the LGA to experiment in the digital communication sphere. Further, as noted, investment in PWF does not entail significant LGA entrepreneurial risk. If community groups can successfully deploy PWF networks, and technology enthusiasts meet the challenge of metadata retention requirements, what elements of PWF remain risky or insurmountable? Local governments can contract out ISP deployment, consultancy and staff training, and hence, acquire full in-house operational control over the PWF provision.

8.6 Dealing with Barriers

8.6.1 Overcoming Institutional and Organisational Impediments

Resource limitations and limited staff expertise are among the principal institutional impediments for choosing the model of PWF provision with more LGA control. Based on data obtained from the survey (chapter 4), in most cases (77.14%) LGAs rely on self-funding their PWF initiative (see Figure 24 in the previous section).

The organisational capacity of the LGA unit in charge of PWF provision rests on three types of resources: human (staff with sufficient capabilities), material (physical elements of PWF infrastructure) and non-material (data generated within PWF network and know-how accumulated by council staff related to leveraging of PWF infrastructure in urban management). Of these, human resources are of primary importance.

In some cases, regardless of the source of funding, the PWF projects have been launched as 'pilot projects', which can mitigate reputational risks associated with poor performance or abrupt termination of the project (McShane & Grechyn 2019). This positioning could reflect the fact that the funding for those projects was limited to a specific period with no clear prospect of further funding. Yet, the long-

standing success of the project becomes uncertain when in two or three years allocated funding comes to an end. The irony of the situation is that by the end of the 'test period', many LGAs do not have any clear perspective whether the project is a success or failure since they have not performed any kind of evaluation of the PWF project— including technical performance monitoring (McShane & Grechyn 2019). Significantly, in a second survey of PWF providers (see Figure 25), approximately two- thirds of LGAs confirmed they did not undertake *any* evaluation of PWF investment.

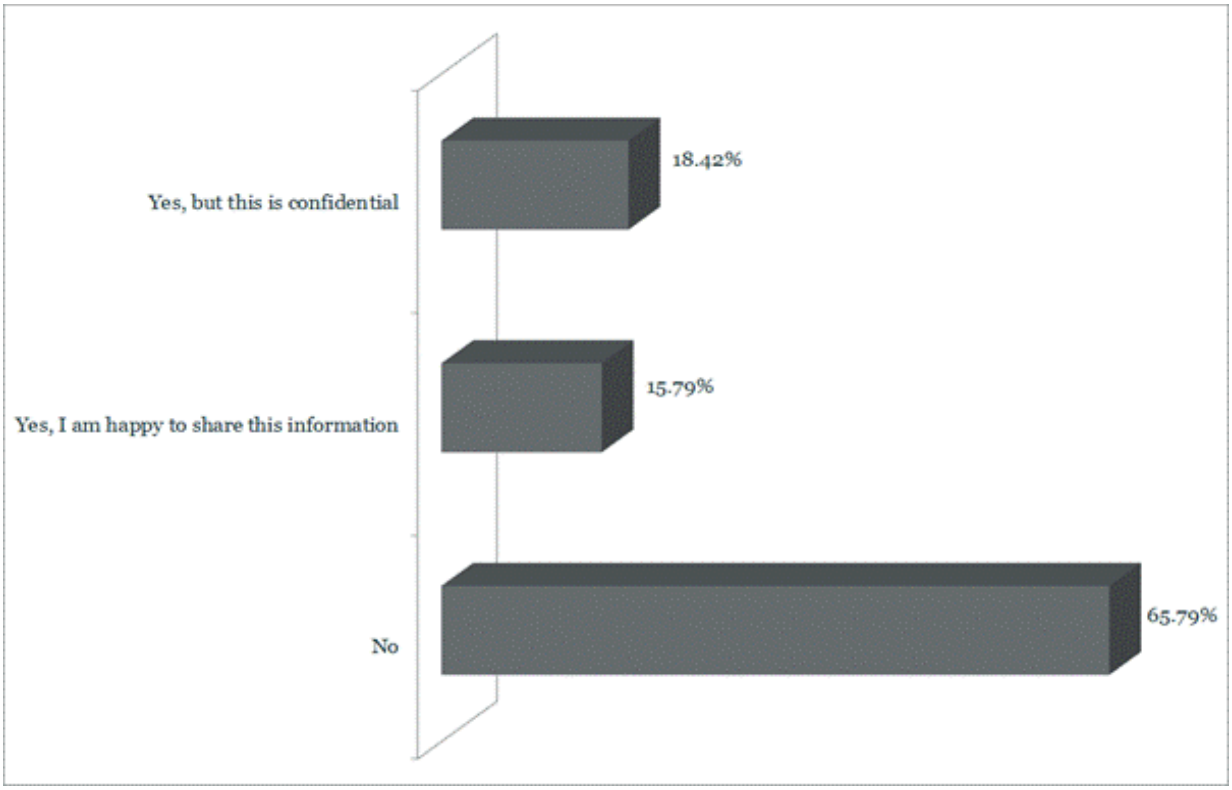

Figure 25. Answers to the question 'Have you performed evaluation of any kind of investment in PWF' by LGA officers

Source: Based on data obtained from the survey of 70 LGA PWF providers

Problems in accessing PWF network data when LGA has no operational control over PWF provision contributes to the inability or demotivation of LGA to undertake the evaluation. However, during the planning stage of the PWF provision model, LGA can increase their control over PWF provision and infrastructures. There are various options, depending on LGA's capacity, which are considered below

If 77.14% of LGAs found ways to self-fund the PWF project over the initial years of operation, it is not unreasonable to suggest that, given a clear vision of the project and its relevance to the LGA strategic plan, additional funds could be attained to secure PWF infrastructure as a valuable LGA asset.

For example, additional support and resources for the project can come from financial optimisation or cooperation with local businesses and volunteers, as exemplified by the deployment and maintenance of the PWF in Goulburn NSW (McShane, Wilson & Meredyth 2016). Many governments already have useful infrastructures such as electricity poles and wires, buildings and other structures, or elements of fibre networks, which can be efficiently used in PWF provision and significantly decrease deployment and long-term operational costs.

Nevertheless, only 29.03% of LGAs in Australia view PWF as a core service (see Figure 26). Despite the growing trend of investing in PWF infrastructure by Australian LGAs in recent years, there is some tension between the growing interest in investing in PWF by LGAs and its provisional status.

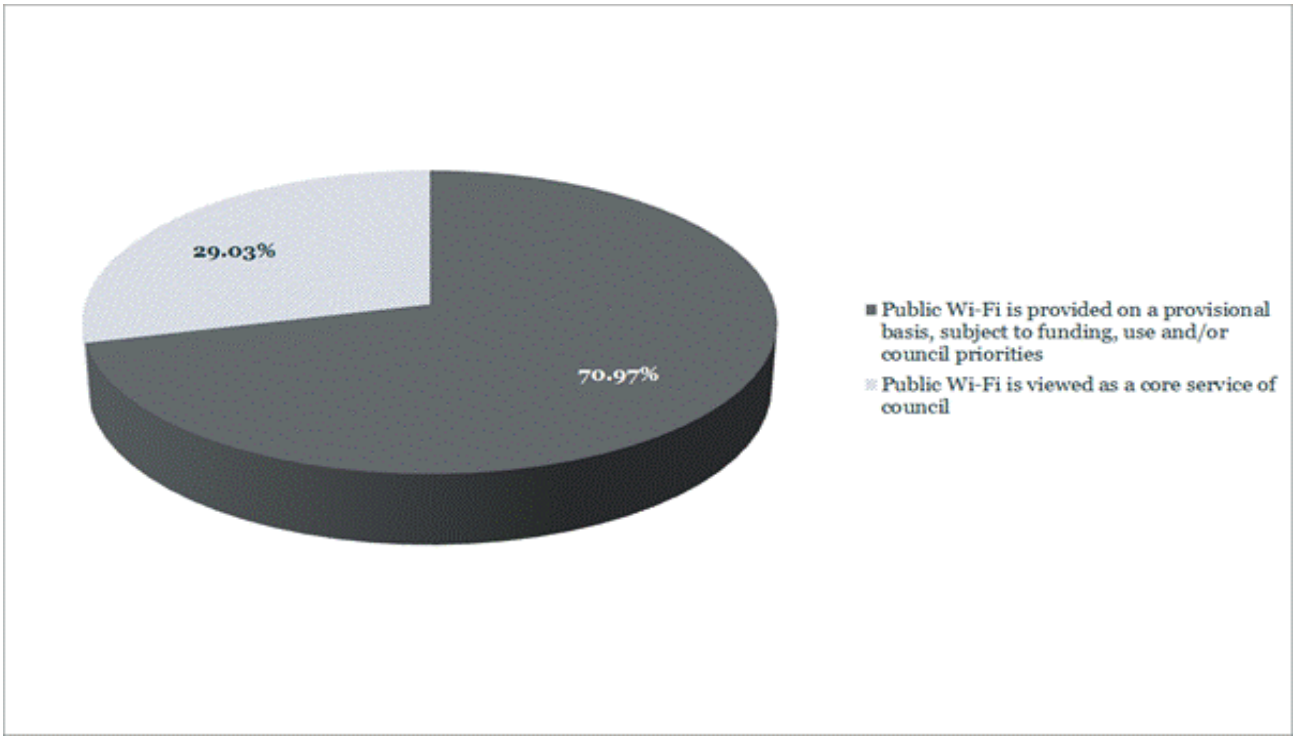

Figure 26. PWF in Australia as a core versus casual project
Source: Survey of Australian LGAs

Another important point is increasing LGA's institutional capacity by investing in training in-house IT personnel. As a possible option for later taking over operational control while contracting out PWF provision, the contractor can be hired for deploying and configuring the network. Then the contractor would provide coaching and necessary software for LGA staff member(s) who would take over the operational control of the PWF infrastructure. Meanwhile, the local government sector has not focussed on IT competencies in training (McShane & Grechyn 2019; Zivkovic & Kats 2013).

In summary, LGAs' adaptability to advances in technology would help to address the changing demands of local communities. Adaptive measures include a commitment to continuous education courses and professional training for staff; calibrating the technical characteristics of the PWF network; and an openness to new ways of leveraging PWF infrastructure, which can result in higher public value, such as the use of public Wi-Fi metadata or new income streams, by leasing a share of PWF capacity to telcos.

Finally, each local government in Australia is unique because they differ in terms of economic development, size, demographics, population density and other factors. When deciding on the model of PWF provision, the individual characteristics of the locality, as well as the capacity of the local government body, must be included.

8.6.2 Ways to Overcome External (Economic) Impediments

The external (economic) impediments are beyond the sphere of the direct control of the LGA. However, LGAs can overcome or reduce them by increasing their institutional capacity; for example, through sharing experience and building cooperative networks. The SWIFT (South Western Integrated Fibre Technology) a Canadian consortium of local municipally owned and operated community networks, is a good example (Pant & Odame 2017).

As described in the previous section, there are ample possibilities for expanding the institutional capacity of LGA officers, including their control over PWF infrastructure. For example, although Australia has one of the highest levels of Internet connection prices in the world (Grechyn & McShane 2016), LGA control over PWF provision could provide a last resort for free Internet connection if commercial broadband becomes unaffordable. Theoretically, the area covered with PWF of sufficient quality could restrain internet providers from an uncontrolled price increase. The extent to which PWF could affect commercial pricing depends on the degree of the price increase for commercial broadband and the cross elasticity of demand for PWF service and commercial broadband service— an issue for future research.

Another impediment is provider risk. It is usually assumed that outsourcing PWF infrastructure to a PPP can transfer risk from the public to the private sector (Flinders 2005). However, in practice the opposite can occur if the external provider withdraws the service or the operator fails, which, as noted

in section 4.2 occurred in NSW. Inhouse LGA PWF ownership and control can mitigate these risks in the long term.

Further, rollout of the NBN provides additional opportunities for LGAs, particularly in areas where backhaul network infrastructure is insufficient. LGA can build on the advantages of NBN through the mediation of the contractor. Nevertheless, as noted previously, it is advisable to include suitable training of LGA IT staff in the contract so they can assume operational control after the deployment of the PWF network is complete. Moreover, the LGA could directly negotiate with the NBN to rent their network capacity, including access to backhaul, since the inclusion of intermediaries in the process of service delivery often leads to increases in the final price (Hurt 2007).

Finally, sharing information among LGAs, refraining from including the confidentiality condition in any contractual agreement on PWF provision, good practices for monitoring and evaluation, made publicly available, will also enhance general accountability, transparency and improve the environment for prospective LGA investments in digital infrastructures.

8.6.3 Ways to Overcome Paradigmatic Impediments

It is important to understand that the mainstream socio-political consensus on what is the expected role of LGA in infrastructure provision is not fixed in stone. The trend towards privatisation and the smaller role of government in infrastructure provision, which has unfolded since the late 1980s continues. However, rollout of the NBN exemplifies more active involvement of the government in delivering communication infrastructures to local communities (McLaren 2018).

Dunleavy et al. (2006) discuss new processes in public administration including digital governance, and argue that these address the drawbacks of NPM by reintegrating fragmented services through networking and by adopting a value-based approach to governance using modern information and communication technologies. The new paradigmatic frameworks of NPG and digital governance justify a more active involvement of LGAs in the provision of PWF.

The new paradigm can be summarised as follows. In the era of digitisation and gradual expansion of local governments in terms of their functions, capability and responsibilities, it is time to replace the outdated and limiting concept of the three Rs ‘roads, rates and rubbish’ with one which better reflects

the nature of modern challenges which arise for LGAs and the ways to meet these challenges. Speaking figuratively, it is timely to replace the three Rs with the three Ds:

1. Delivery of quality public services
2. Data-driven and digital urban governance
3. (Re-)design of urban spaces make them more comfortable and liveable, including the design of public infrastructures.

8.7 Conclusion

This chapter analysed the motivations for LGAs to increase control over PWF provision and infrastructure, the impediments, and how they may be overcome. While the motivations for LGAs to increase control over PWF may vary, they are all structured around the notion that without operational control over PWF provision, LGAs cannot guarantee the sustainability of the PWF project in the long term. Further, greater control over PWF infrastructure by LGAs is necessary for achieving long-term strategic goals, such as fostering digital inclusion and facilitating innovation.

In many cases without operational control, LGAs cannot effectively retain the network information necessary for usage monitoring, performance parameter calibration and more advanced practices, such as usage of PWF metadata in urban analytics, and integration with other network data, such as that produced by IoT networks. The LGA must have adequate mechanisms to change network parameters of misconfigured PWF networks to meet user expectations since PWF only has value if it provides the capacity for connecting users to the Internet. The ‘on top’ ways of utilisation of PWF infrastructure by the LGA, such as usage of PWF metadata in urban analytics, also depends on the technical performance of PWF because informative metadata can only be retained on a properly configured network.

The factors which prevent LGAs from gaining more control over PWF are institutional and organisational (internal), contextual (external and economic) and paradigmatic (ideological or socio-political). Institutional limitations include access to funding or qualified staff. Contextual impediments include information asymmetry, oligopolised markets and poor backhaul infrastructure. The paradigmatic impediment echoes the complex of prevailing social and political views and beliefs on perceptions concerning the appropriate role of LGA in various economic activities.

This thesis has argued the case for LGAs reassessing their organisational capacity in deciding on the degree of involvement in PWF provision. This includes the implementation of the EE approach to PWF investment management by which the LGA officers provide their own in-house evaluations taking into account the local peculiarities rather than rely on ready-made formula.

Chapter 9: Conclusion

This thesis investigated LGA PWF infrastructure investment in Australia as a nexus where people, technology, policy, regulations and politics, law and paradigms of public administration necessarily engage with each other. Consequently, PWF infrastructure as a subject of research is recognised as having multiple dimensions, including the authorising environment (rationales for PWF provision), models for PWF provision, technical characteristics, possibilities for LGA PWF innovation, and long term sustainability and delivery to the community of the best possible freely accessible wireless infrastructure.

The central contribution of the thesis is that it provides the first systematic survey and analysis of LGA investment in PWF infrastructure. The principal issue arising from the survey results related to the overall lack of PWF evaluation consistent with the values of good public governance. The thesis identified constraints on quantitative analysis associated with a lack of available tools to assess the economic and social effects of public Wi-Fi (such as boosting economic growth or fostering innovation). Sobolevsky et al. (2017) remains the single available attempt to evaluate the effects of PWF on local economic growth. However, impediments to quantitative evaluation of the PWF's economic effects include unavailability of low-aggregated data together with doubts about the validity and generalisability of the results if low-aggregated economic proxy data is obtained.

Nevertheless, although methodologically robust quantitative evaluation of the economic effects of PWF cannot currently be undertaken, this thesis argues that local governments can and should elaborate their criteria for evaluating the investment in PWF infrastructure, taking into account the geographic, economic and demographic characteristics of their jurisdiction. The findings of the thesis serve as a stepping stone and research base for enhancing the role of the local government sector in the provision and in-house evaluation of PWF infrastructure, which can also be a precursor for a higher, more significant and informed role by LGAs in local telecommunications; for example, 5G deployments.

The rollout of 5G networks presents new challenges for the local government sector's engagement with telecommunications. The 5G network requires a significant level of small antenna installations in urban areas, which in principle calls for a strong local government role in the urban planning aspects of this deployment. However, these so-called minimal impact installations are exempt from local

planning laws (Doureihi & Mitchell 2019). This is likely to be an issue LGAs should manage, particularly taking into account the shortage of space suitable for 5G deployments in a dense urban environment (Bajkowski 2019), as well as suspicion of and resistance to this technology in some communities. Regardless of whether they have direct responsibility or not, LGAs will be increasingly engaged with telecommunications as they increasingly become part of the urban fabric.

The rollout of 5G, which can theoretically incorporate a public wireless network capability, does not negate local government investment in public Wi-Fi. This is because 5G is a commercial deployment, while PWF is public investment. Further, and despite the wide uptake and accessibility of Wi-Fi technology, 5G will not be available in remote and rural areas in the short term (ALGA 2019b). The advent of 5G does reinforce the need for LGAs to clarify their rationales and the outcomes of PWF.

To provide the research base for an enhanced role of Australian LGAs in telecommunication infrastructure provision, the thesis identified and explored a range of problems and questions relating to the local government sector's initial foray into this area, in PWF deployment. To underpin the analysis, empirical data on PWF deployment was gathered through a national survey. This data enabled examination of the role of technical parameters of PWF, models of PWF provision, the role of PWF metadata in PWF evaluation and urban analytics, and the macro context of telecommunication prices in Australia.

The thesis used a mixed quantitative-qualitative approach and adopted econometric regression, analysis of survey data, statistical analysis, interviews, case studies, and critical analysis of available literature as methods to explore the research questions. The findings of the thesis serve as a basis for developing policy and technical and operational settings for more effective and sustainable investment in PWF by LGAs.

Summarising the key argument of this thesis, PWF has been approached by LGAs as a service, similar to other municipal services, and a combination of limited understanding of the particular characteristics of digital communications infrastructure, along with a reflexive response to service outsourcing, has led to sub-optimal investment in this area. Drawing on the theory and practice of EE this thesis suggests more operational control by the LGA officers over the PWF infrastructure, with the vision that if the PWF is controlled by the LGA (possibly involving the local community), it unlocks various managerial capabilities and opportunities for experimentation and improvement, such as more effective achievement of the principle of social justice in the field of public access to the Internet. That is, strengthening the oversight over PWF and ensuring that the public wireless infrastructure is of

sufficient quality will not only enhance the ability of local governments to assess and monitor their investment in local broadband, but also will help to meet public expectations of wireless network quality and sustainability. Furthermore, actions in accordance with the principles of EE, such as investing in the competence of IT staff, acquiring the necessary skills to collect and analyze PWF metadata, viewing investments in PWF as a strategic public asset that requires constant monitoring in search of opportunities for improvement will serve to add value to PWF.

9.1. Summary of Findings Related to Research Questions

What is the current state of PWF provision by local authorities in Australia? What is the context in which this development is taking place? Which local authorities deploy PWF and why?

The national survey conducted as part of the thesis provided evidence to support the growing trend of investment in PWF in Australia. More than sixty per cent of LGAs that participated in the national survey provided PWF to their communities, which, generalised at a national level, represents approximately 200 councils.[16] The three most frequent rationales for investing in PWF infrastructure identified in the survey were encouraging tourism, promoting digital inclusion and encouraging or facilitating business activity. PWF deployments are more widespread in the metropolitan and coastal areas than inland and rural regions. As an economic development official of a coastal shire in Victoria commented, 'It's very hard to be a major tourism arrangement and not offer free Wi-Fi'. (LGA official, Victoria, 2018). Regional areas have sparse PWF coverage (as expected with lower population density),) and the networks impose more stringent restrictions (i.e., daily traffic allowance and the maximal duration of the session). These patterns highlight heterogeneity in the level of infrastructure development in the various regions of Australia.

The research identified governance and operational problems in PWF provision, including low transparency and accountability, limited IT competence in the LGA sector, limited evaluation of an investment in PWF, and constraints on LGAs to freely access network metadata and exercise greater operational control of the network. While transparency and accountability in Australian public administration are long-standing issues (Argyrous 2012; Quinlivan et al. 2014; Stafford & Stapleton

[16] The sample of 111 usable answers allows statistical generalisation with a 95% confidence interval within ±8% error. However, the possible participation (non-response) bias must be considered, since the LGAs in metropolitan and coastal areas (more likely PWF providers) were more likely to participate in the survey than LGAs from remote areas (less likely to be PWF providers). The final figure of 200 LGAs, which are PWF providers in Australia is an approximate estimation with an adjustment for the participation bias.

2017), these problems have peculiarities in the case of PWF provision by LGAs. The difficulty of accessing the network metadata can be attributed to regulatory barriers, restricted contractual agreements and uncertainty of LGA officials about the value and uses of PWF metadata. Deprived of access to network metadata, LGAs have less capacity to undertake in-house monitoring and evaluation of their PWF, which, in turn, negatively affects accountability. Further, service contract details are unavailable (none were accessible during this research) due to commercial-in-confidence claims, compounding transparency problems and inhibiting peer learning by sharing information among LGAs. The national survey and subsequent interviews uncovered significant information asymmetry in this area, exposing LGAs and taxpayers to financial risk and sub-optimal network performance.

How do the policy and macroeconomic contexts influence the evaluation of the investment in PWF infrastructure?

The quantitative analysis in chapter 5 showed that broadband prices in Australia are significantly higher compared to most of other OECD countries, even after applying adjustments to purchasing power parity (PPP). Further, Internet access in Australia, on average, is much more expensive than other consumer goods and food compared to other countries (for which the Big Mac index serves as a benchmark). These results of price analysis and the broadband market in Australia, supported by published field research on the PWF as a 'survival infrastructure' for poor and homeless people (Humphry 2014), reinforces the argument for PWF provision to bridge the digital divide and to provide 'last resort' Internet access.

In evaluating PWF investment, it is not only the macroeconomic context which matters, but also the policy context. Bozeman (2007) argues that the approach to public administration known as New Public Management (NPM) took firm root in Australia and New Zealand in the 1990s. The preferred model for service and infrastructure delivery within the NPM approach is contracting out to the private sector. Ideological concepts of 'smaller government' and 'steering, not rowing' often make sense, or at least are convenient for Australian local governments, whose capacities are restricted by a limited fiscal and human resource base. However, the thesis argued that a deliberately small role of LGAs in PWF provision jeopardises the long-term sustainability of the PWF project and stifles LGA capacity to innovate and experiment with PWF infrastructure.

During the last decade or so, NPM has co-existed and competed with the New Public Governance approach (NPG) (Osborne 2010; Torfing & Triantafillou 2013)—sometimes also called 'Public Value Governance' (Grant & Drew 2017)—which emphasises the pivotal role of creating public value while

delivering public services. The idea of creating public value originates from Moore's (1995) work which seeks to modify NPM's sometimes crude market emulation. The NPG approach presumes a more proactive role of the government officials, involvement in community interests and needs, and reflection on what is important in given circumstances. Contributing value to the community (as the creation of public value) is not a guaranteed outcome. In the case of PWF provision, it implies that local government embraces the tensions between economic, social and ethical considerations, and undertakes decisions in the context of local circumstances and needs. There are many options all of which require knowledge and judgement: whether or not to provide PWF infrastructure; whether to invest in enhancing technical competence of IT personnel; whether to undertake greater oversight and control or at least ensure better technical parameters of the wireless network in negotiation with the ISP contractor. LGA officials who pursue the creation of public value should be guided by regulations and policies and reflect on the needs and interests of the local community.

While the creation of public value has become a public sector cliché (Grant & Drew 2017), it has a clear application to PWF provision by LGAs. However, public value creation requires knowledgeable oversight of and possibly direct provision of PWF to generate the best possible community value from the infrastructure. Reinforcing the point that public value 'provides a managerial ethos that is particularly suited to local governments in Australia' (Grant & Drew 2017, pp. 5-6), this principle applies to PWF investment. Indeed, Wi-Fi, being a disruptive technology operating in a relaxed regulatory environment (Lemstra, Hayes & Groenewegen 2010), is well suited for non-market interventions to promote digital inclusion. If the role of local governments is limited to funding the PWF project or contracting out the components of urban infrastructure to the ISP contractor, it discounts the innovative and disruptive possibilities that Wi-Fi can provide. Moreover, limited provisioning also seems contradictory, particularly for the areas lacking telecommunication services, if the task of patching the holes caused by market failure falls back on the mercy of the market through contracting out.

Is the quality of the PWF service important for users?

According to the results of the national survey, encouraging tourism is the primary rationale for PWF provision, identified by almost 70% of survey respondents. Promoting digital inclusion is the second most frequently mentioned rationale. However, what is the role of the technical performance of PWF in facilitating tourism, fostering digital inclusion, and indeed supporting all the other rationales for PWF provision nominated in the survey? PWF technical parameters and the resultant quality of service are significant factors in defining user satisfaction and experience. However, the link between the

technical parameters of PWF wireless connections and user satisfaction remained unclear because of gaps in theoretical and empirical knowledge beyond the scope of this thesis. However, the thesis has argued that scant interest in this seemingly trivial question by LGAs has resulted in many PWF networks having poor technical parameters.

To overcome problems related to lack of LGA PWF data, the research focussed on tourists as the main target group for PWF provision, as identified in the national survey, and sought to determine the significance of PWF quality for that group. Using Wi-Fi speed in Australian hotels as a proxy, the study showed a significant influence of Wi-Fi quality on the level of customer satisfaction reflected in online rankings. The thesis survey found that a one per cent increase in Wi-Fi quality in Australian hotels corresponds to an increase in customer satisfaction by 0.00376 units[17]. This finding is inconsistent with a small amount of research conducted in this area (Mellinas 2017), who found that the quality of hotel Wi-Fi does not impact hotel customers' satisfaction, while this thesis finds the opposite. It is reasonable to assume that this result could apply to tourism in general, in line with the finding by a 2019 Austrade Survey that poor Wi-Fi quality is one of the reasons tourists are dissatisfied when travelling through Australian rural and regional areas (Austrade 2019).

Notably, broadband speed is slower in hotels which either offer free Wi-Fi or are in proximity to PWF networks with more stringent daily usage limitations. This further illustrates a national issue of uneven telecommunications infrastructure and service quality.

Can PWF metadata be accessed and used for urban management purposes?

PWF network metadata were examined from the three perspectives: the regulatory peculiarities of DRO in case of PWF provision, access to PWF metadata by LGAs, and the possibilities which access to PWF metadata offers for urban analytics. In summary, LGAs are not aware of the potential benefits of metadata and are risk averse regarding its collection and use. Regarding the privacy risk of PWF metadata if it is available to the public, chapter 7 demonstrates that it is practically impossible to trace back PWF metadata to the identity of a particular user. Moreover, the benefits available to LGAs are significant because they can assist in bridging the 'Big Data Divide' (Andrejevic 2014) and, thereby, address asymmetrical access to the increasing amount of information collected by governments and commercial monopolies like Facebook or Google. Public PWF metadata can be used to create a 'data sandbox' for data scientists and enthusiasts in local municipal areas. As chapter 7 also showed by

[17] Customer satisfaction lies in the range of 1-5. Then, starting from the average customer satisfaction with Service quality, 3.737, a one per cent increase in the Wi-Fi quality leads to the average increase in customer satisfaction by 0.00376 units or by 0.1 per cent (which is economically small but statistically significant).

analysing metadata from a Launceston LGA in Tasmania using Python 3.7 software, collecting location metadata would have been useful to map activity across the network. However, the data were unavailable in this case, likely due to misconfiguration by the ISP or non-inclusion of the data in the report which the ISP provided to the Launceston LGA. This lack of access to metadata typifies the situation for LGAs because PWF contractors exercise control over the data, and/or LGAs are highly risk-averse in providing access to any datasets they have. The potential benefits of LGA analytics would be increased if PWF metadata from multiple cities (and various locations in those cities) were available, enabling comparison of urban activity patterns.

Does the organisational model through which PWF is provided influence LGA's capacity to sustain and innovate with PWF?

Chapter 8 investigated models of PWF provision and based on findings from research provided in chapters 4, 5, 6 and 7, considered policy suggestions for more effective and sustainable provision of PWF by LGAs in Australia. In summary, it argued that LGA investment in PWF infrastructure could potentially provide long-term benefits in rethinking the role of local governments in digital service provision. However, despite an increasing interest in PWF investment, there is currently a risk that the provision of public wireless projects in Australia will decline due to combined effects of technological change, unsecured funding, and loss of control over the PWF infrastructure by local governments at the end of the contract period.

While the caricature of traditional LGA responsibilities as 'roads, rates and rubbish' (Grant & Drew 2017, p.155) is outdated, if it ever resembled reality, some LGAs are nevertheless reluctant to undertake bolder initiatives in providing local communication infrastructure. However, this thesis argued that a more significant LGA role in the provision of PWF infrastructure is timely and suggests a new LGA paradigm or set of aims described as of 'delivery of public services, digital data-driven governance, and (re-)design of public space'. Concrete measures that could be adopted include investing in the IT capability of staff, acquiring operational control over PWF provision, ensuring adequate technical parameters of wireless networks and experimenting with PWF metadata.

LGAs which cannot provide PWF entirely in-house still have an option to seek outsourcing of contractual conditions that secure LGA PWF operational control. There are also the possibilities for community partnerships, as demonstrated by the case of Goulburn, Victoria (McShane, Wilson & Meredyth 2016) and in the SWIFT consortium in Ontario, Canada (Pant & Odame 2017). Establishing community partnerships can build digital capability throughout the community, and responds to

increasing interest in the co-design of public services (McGann, Blomkamp & Lewis 2018; Van Oost, Verhaegh & Oudshoorn 2009).

For contracted-out services, the scope of work can be limited to deployment and initial physical and operational setting for the PWF infrastructure. Arrangements between in-house and contracted services should reflect the needs of local circumstances and ensure LGAs have access to PWF metadata.

LGAs should pay particular attention to ensuring access to PWF metadata, which is critical for monitoring the performance of PWF and ensuring its sufficient quality, as well as, potentially, for urban management and planning purposes, and, overall, take more "empowered" position in PWF provision.

9.2. Originality and Research Value

The thesis contains several original contributions. First, it provided the first national survey of investment in PWF by LGAs in Australia to investigate the rationale of PWF provision, technical and organisational characteristics of PWF projects, and associated managerial issues. Further, its findings concerning national broadband market pricing contributed to a better understanding of the macro context in which investment in PWF infrastructure occurs. This thesis extends the application of EE to the provision and management of digital communications infrastructure, which has not been done previously.

Second, the research revealed current barriers to providing a methodologically, robust quantitative evaluation of the economic effects of PWF infrastructure investment. The thesis found that more attention to in-house LGA PWF evaluation research is required, driven by the specific needs of each LGA jurisdiction using relevant LGA criteria. This thesis extends the application of EE to the provision and management of digital communications infrastructure, which has not been done previously.

Third, the analysis of the effects of hotel Wi-Fi speed on hotel customers satisfaction confirmed the importance of Wi-Fi technical parameters on the level of user satisfaction. This study also confirmed the uneven distribution of telecommunication infrastructure in Australia.

Fourth, the thesis has provided an argument for the opening of PWF metadata for public access. Even if PWF metadata is not publicly available, the research points to the importance of ensuring the access to PWF metadata for LGA PWF providers to enable technical evaluation of the network as well as the use of PWF metadata in urban analytics.

9.3. Practical Recommendations and Policy Implications

9.3.1 Accountability, Evaluation and Technical Expertise

To reiterate and summarise, the recommended adoption of the EE approach includes evaluation *per se* (as a process of determining the value of the project), and also calls for the more significant role of the local government in PWF provision (see chapter 8 for details). Arguably, advancing the LGA role in PWF provision responds to the long-standing interconnected issues of transparency, accountability, evaluation and technical expertise. More specifically, evaluation, enhancing the level of knowledge, and advancing the role of LGA in PWF provision are processes that complement and reinforce each other. For example, improving the level of expertise together with attaining a more significant role for LGAs in PWF provision results in the LGA's ability to access and analyse PWF metadata for routine monitoring and evaluation of PWF infrastructure.

9.3.2 Investing in PWF by LGAs and Digital Inclusion in National and State Policies

The importance of the PWF infrastructure as a 'last resort' for providing Internet access is highlighted by the finding of the thesis that the relative prices for Internet connection in Australia are considerably higher than in most other OECD countries. Further, 14% of Australian households do not have access to the Internet at home (ABS 2018). However, although there is merit in providing PWF to the local communities and targeting digital inclusion and other rationales, such as tourism promotion or experimentation with PWF metadata, this may have limited impact without ensuring that the PWF has sufficient technical performance and sustainability.

This study provided additional evidence of the uneven geography of allocation of telecommunication infrastructure in Australia due to differences in demography, local resources and economies. This might be partly addressed by horizontal fiscal equalisation policies, a form of financial assistance aimed to help sub-national governments to reduce capacity inequalities (Commonwealth Grants Commission 2010). However, as pointed out by McShane, Wilson and

Meredyth (2014), the scope of fiscal equalisation does not extend to telecommunications. This lack of funding equity seems inconsistent, given the goal of ensuring the equal quality of road networks across the country establishes the criteria for financial redistribution of the tax revenues by the state to the local governments. Ensuring the equal distribution of quality 'digital highways' as telecommunication infrastructure is beyond current financial equalisation policy. Commercial telcos have profit as an incentive, and consequently, target highly-populated areas with a higher return on investment. This means that remote, sparsely populated areas suffer from chronic under-investment in telecommunications.

To ensure that all Australian citizens have access to telecommunication, Telstra — formerly an incumbent public monopoly, and now the largest commercial telco in a deregulated environment — was compensated by the Government for losses incurred by delivering communications to the regional areas via the Universal Service Obligation (USO). However, this system was ineffective in ensuring equal access to quality communication service provision in Australia, particularly in the era of digital communications (Coutts 2015). Moreover, the introduction of the NBN underlines the commercial telcos' failure, as well as that of government policy, to provide broadband of sufficient quality and quantity throughout Australia (McLaren 2018). In a situation of systemic market failure in providing telecommunication to the regions of Australia, the role of LGAs in facilitating digital inclusion through investing in PWF infrastructure is especially important. Of course, supportive national policies, in addition to deployment of the NBN network is essential, since PWF deployment requires the availability of the backhaul communication infrastructure (either wired or satellite). Further, local governments with a limited fiscal base may require funding from state or national governments to establish PWF infrastructure and develop the institutional capacity to maintain it in the long term. One way to do this sustainably, rather than in the form of one-off grants, is by reconsidering the nature of horizontal fiscal equalisation principles to address regional differences in telecommunication infrastructure endowment.

9.3.3 Knowledge-Sharing and Promoting Transparency

The socio-economic factors which often relate to a rural and regional location negatively affect the ability of local governments to attract and retain suitably qualified staff, particularly compared to big cities such as Melbourne (Kliger 2007). Greater openness and knowledge sharing would contribute to mitigating the uneven spread of technical expertise across regional areas. Australian local governments are experienced in establishing cooperative arrangements in some areas, for example, in waste management, but not in telecommunications provision (Aulich et al. 2011). As shown in chapter 8,

Canada's SWIFT broadband consortium provides a good example of pooling local network expertise. Further, chapter 5 shows Canada and Australia are close in terms of GDP per capita ratio, the density of population and telecommunication market patterns. While there is a high level of oligopolisation in telecommunications by telcos in both countries, the Canadian SWIFT consortium attempts to resist telcos who 'use their dominance in infrastructure and content to reduce the scope for end-users to competitively [provide] services and applications' (SCIST 2018, p. 16). Australian LGAs could benefit from investigating the relevance of the Canadian PWF model.

9.4 Limitations of the Study and Avenues for Future Research

The first limitation of the study relates to the national survey response rate and sample representation. The overall response rate of 24% is acceptable for the population of 465 LGAs, but responses from Northern Territory and regional Australia were few and affected the sample distribution.

Second, the survey did not include questions about the average download and upload PWF speeds. The goal was to maximise survey participation without sacrificing the essential questions related to technical infrastructure, so only two questions related to PWF quality (time and traffic caps). The survey design assumed that questions about average broadband speed would be beyond the competence of non-technical respondents. However, this limitation did not significantly influence the research design. Even if data on average speed on PWF networks were available and considered robust, it would not void the proxy of hotel Wi-Fi speed in measuring the role of PWF quality in users' satisfaction, because there is no available data on the level of PWF users' satisfaction.

The other limitation relates to commercial-in-confidence claims which effectively prevented access to PWF provision contracts. Thesis arguments related to the peculiarities of PWF provision contracted by LGAs, such as lack of government access to PWF metadata and the need to establish such access, are based on limited and sometimes anecdotal evidence available from interviews and contacts with LGAs officers. Access to LGA PWF contracts would allow more grounded and substantial judgment, and strike a significant blow for transparency and accountability in this area.

There are several avenues for future investigation that originate from this thesis. While the thesis focussed on the PWF provision mostly from the perspective of LGAs, the PWF users' motives and their satisfaction merits a separate study. The issue of PWF metadata, which is a recurrent topic in this thesis, is worth further consideration, particularly examining the question of public access to metadata and elaborating the practical ways PWF metadata can be used in urban analytics. The ongoing

developments in mobile communications, including the current implementation of the 5G standard, together with increasingly congested commercial radio spectrum, poses critical questions about whether PWF infrastructure can still be a valuable municipal or community asset, or even whether it can serve to facilitate the dynamic efficiency of the telecommunication market. However, this thesis has ultimately argued for the public provision of PWF on a range of grounds, especially digital inclusion, local economic activity, urban management and innovation.

9.5 Final Remarks

After two decades of operation in a field characterised by rapid technological change, public Wi-Fi has proven to be a durable, and indeed increasingly popular, platform. Commercial communication technologies are continuously evolving with the 5G standard currently developed and deployed to complement standard and previous generations of telecommunications, including 4G (LTE).[18] In parallel, the Wi-Fi standard is developing through the evolving technology of wireless transmission and the release of more frequency bands by regulators. In April 2020, the US Federal Communications Commission (FCC) issued a decision to add 6 GHz to Wi-Fi spectrum, which is 'the biggest upgrade of Wi-Fi in 20 years' (Kastrenakes 2020). ACMA is likely to follow suite, approving amendments to Australian telecommunication regulations (Kastrenakes 2020), that will facilitate reduced interference and faster connection speeds.

The 5G and Wi-Fi standards are similar: they are both designed for radio local area networks (RLAN) belonging to the high-frequency spectrum (ACMA 2020). However, they are not effective in terms of penetrating buildings or other obstacles and have a significantly smaller area of coverage compared to the LTE standard. Further, 5G and new Wi-Fi standards allow faster data transmission (ACMA 2020). The necessity to install multiple 5G transmission towers and antennae to enable dense coverage makes deployment of 5G expensive for telcos and is only feasible in densely populated areas. Telcos will not extend 5G into rural or sparsely populated areas any time soon, which further increases the digital divide between metropolitan and regional areas (ALGA 2019b).

Telcos may seek to use LGA PWF infrastructure to augment the 5G licensed spectrum while advancing with their 5G deployments, emulating their practice of effectively offloading data from LTE to public Wi-Fi networks. This provides additional motivation for taking greater control over the PWF infrastructure by LGAs. By providing PWF in-house, local governments are in a stronger position to

[18] Abbreviation for 'Long Term Evolution' the 4G communication standard.

negotiate better conditions for the local community. Offloading to the public sector is a form of cost-shifting, an impost of the type which the local government sector has voiced concerns over in other settings (Commonwealth House of Representatives Standing Committee On Economics, Finance and Public Administration, 2003). LGAs need to be aware of this trend and leverage their position as owners of physical infrastructure required for 5G installations. Conversely, if the LGA contracts out PWF service and does not own or control PWF infrastructure, ISP contractors may negotiate directly with a telco and exclude any effective role for the LGA in managing PWF provision. Whatever model is chosen, PWF represents an opportunity for LGAs to address the digital divide in Australia.

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APPENDIXES

Appendix A. Design of the Survey Disseminated Among Australian LGAs about PWF Provision

PUBLIC WI-FI IN AUSTRALIA

Dear local government officer,

RMIT University is conducting research to better understand the role played by Australian local government authorities (LGAs) in the provision of public Wi-Fi. We hope that you might participate in this research by completing the following survey regardless of whether your LGA currently provides public Wi-Fi. The survey should take less than 10 minutes to complete, and your participation is highly valued. The results of this survey will be aggregated, anonymised and made publicly available. Further detail on the research can be found at www.publicwifiaustralia.com.

Thank you for your contribution,

Mr Viktor Grechyn, Dr Ian McShane and Dr Christopher Wilson

Public Wi-Fi Research Team, RMIT University

This research project has been approved by RMIT's Human Research Ethics Committee (reference CHEAN A 0000015711-09/13). Further details of the project and participant information can be accessed here.

Please write down the name of your Local Government Authority

_____

Please choose your principal area of responsibility in your LGA

- Economic Development and/or Tourism
- Planning
- Administration
- Education, culture and training
- Health and human services
- Finance
- Environment, Land, Water and Planning
- Information Technologies
- Other

Display This Question:
If Please choose your principal area of responsibility in your LGA = ***Other***

Please specify your principal area of responsibility
_____

We define public Wi-Fi as networks provided by a Local Government Authority to the public. This includes networks provided by third parties through a contractual arrangement with the LGA.

As we are interested in distinct, stand-alone, investment by LGAs in public wi-fi, this survey **excludes** wi-fi access provided by local libraries (unless a strategic decision was made to provide access to the public library network outside the building and outside operating hours).

Does your LGA provide public Wi-Fi?

- Yes
- No
- Don’t know

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

How long has the public Wi-Fi service been in operation?

- Less than 1 year
- 1-3 years
- 3- 5 years
- Over 5 years
- Don’t know

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

Where is your public Wi-Fi service available? *(multiple choices possible):*

- Retail precincts/Town centre/CBD
- Parks
- Sports/Arts venues
- Local Government offices and service centres (e.g. Community House)

- Public libraries (ONLY if a strategic decision was made to provide access to the public library network outside the building and outside operating hours)
- LGA offices/facilities
- Other public venues

Display This Question:
If Where is your public Wi-Fi service available? (multiple choices possible): = ***Other public venues***

Please specify where your public Wi-Fi is also available
_____

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

Does the public Wi-Fi have set download limits?

- Under 200 MB (per day or session)
- 201 MB - 500 MB (per day or session)
- 501 MB -1 GB (per day or session)
- More than 1GB

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

Does the public Wi-Fi have set access time limits?

- Less than 30 mins
- 30 mins
- 1 hour
- 2 hours
- 3+ hours

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

Which of the following actions must a consumer take to use your public Wi-Fi service:

- Accept terms and conditions
- Register with an email address, Facebook account or other like information
- None of the above
- Don't know

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = Yes

Which of the following best describes your public Wi-Fi business model?

- Deployment of public Wi-Fi is organised in-house
- Deployment of public Wi-Fi is contracted out
- Don't know

Display This Question:

If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

Why does your LGA provide public Wi-Fi? *(multiple choices possible)*

- Respond to ratepayer/resident demand
- Encourage or facilitate business activity
- Promote digital inclusion
- Encourage tourism
- Encourage innovation
- Because other LGAs are providing public Wi-Fi
- For use in urban management
- Collect information from the community (e.g. for consultation or use planning purposes)
- Connect to the council's web-site
- Other rationales

Display This Question:
If Why does your LGA provide public Wi-Fi? (multiple choices possible) = ***Other rationales***

Please specify additional rationales for provision of public Wi-Fi
_____

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***Yes***

Has council reviewed or evaluated the operation and/or impact of the public Wi-Fi system?

- Yes
- No
- Don't know

Display This Question:
If Has council reviewed or evaluated the operation and/or impact of the public Wi-Fi system? = ***Yes***

Did the evaluation/revision lead to a change in the level of investment in Public WiFi?

- Increased investment (network improvement or expansion)
- Decrease in investment (reduction in network size or capacity)
- Termination of the project
- No change
- Don’t know

Display This Question:
If We define public Wi-Fi as networks provided by a Local Government Authority to the public. This i... = ***No***

What is the probability that your LGA will deploy public Wi-Fi in the next 3 years?

Very low									Very high
1	2	3	4	5	6	7	8	9	10

How high a priority should the provision of public Wi-Fi be for LGAs?

Very low									Very high
1	2	3	4	5	6	7	8	9	10

Does your LGA have a digital strategy?

- Yes
- No
- Don't know

Display This Question:
If Does your LGA have a digital strategy? = ***Yes***

Does your digital strategy address public Wi-Fi provision?

- Yes (1)
- No (2)
- Don't know (3)

Do you have any further comments on the provision of public Wi-Fi? Please provide your email address if you are happy for us to contact you.

_____

Thank you very much for your participation!

End of Block: PUBLIC WI-FI IN AUSTRALIA

Appendix B. Design of the Survey Disseminated Among Australian LGAs about the Evaluation of PWF Provision

PUBLIC WI-FI IN AUSTRALIA: EVALUATION

This survey is part of the Public Wi-Fi in Australia project. The project has been approved by the RMIT Human Research Ethics Committee. For further details on participation and data handling can be found here.

What is the funding source for your public Wi-Fi service?

- Local funding
- State government funding
- Commonwealth government funding
- Other (please write) _____

Which statement best describes public Wi-Fi provided by your LGA?

- Public Wi-Fi is provided on a provisional basis, subject to funding, use and/or council priorities
- Public Wi-Fi is viewed as a core service of the council

Has your local government evaluated public Wi-Fi provision? If yes, what kind of evaluation was undertaken? ***(multiple answers possible)***

- No, we did not evaluate public Wi-Fi provision
- Yes, we evaluated its technical performance (bandwidth, use etc.)
- Yes; we evaluated feedback from the local community
- Yes; we evaluated financial aspects of public Wi-Fi provision
- Yes; we evaluated the impact or outcomes of the public Wi-Fi service (e.g., business activity or tourism)
- Other (please write) _____

In your view, is evaluation of public Wi-Fi important? If so, why?

- Yes, it's important to check on how efficiently public Wi-Fi is implemented, in terms of financial costs and administrative efficiency
- Yes, it's important to evaluate public Wi-Fi effect on local community and/or business environment
- No, cost and time of evaluation process would not pay off
- No, it's difficult or impossible to undertake quantitative evaluation of public Wi-Fi impact on local community and/or business environment
- Your own option (please write) _____

Display This Question:
If Has your local government evaluated public Wi-Fi provision? If yes, what kind of evaluation was u... != ***No, we did not evaluate public Wi-Fi provision***

Have you reported on your public Wi-Fi evaluation to council or residents?

- No
- Yes, I am happy to share this information
- Yes, but this is confidential

Display This Question:
If Have you reported on your public Wi-Fi evaluation to council or residents? = ***Yes, I am happy to share this information***

Please upload a file containing an evaluation of public Wi-Fi provided by your government. If you want to do it later, you can alternatively send it to viktor.grechyn@rmit.edu.au

Do you want us to send you report on the results of the analysis?

- No thanks, I will manage to find it if I need it
- Yes (please write email address to which you would like the survey report sent)

  _____

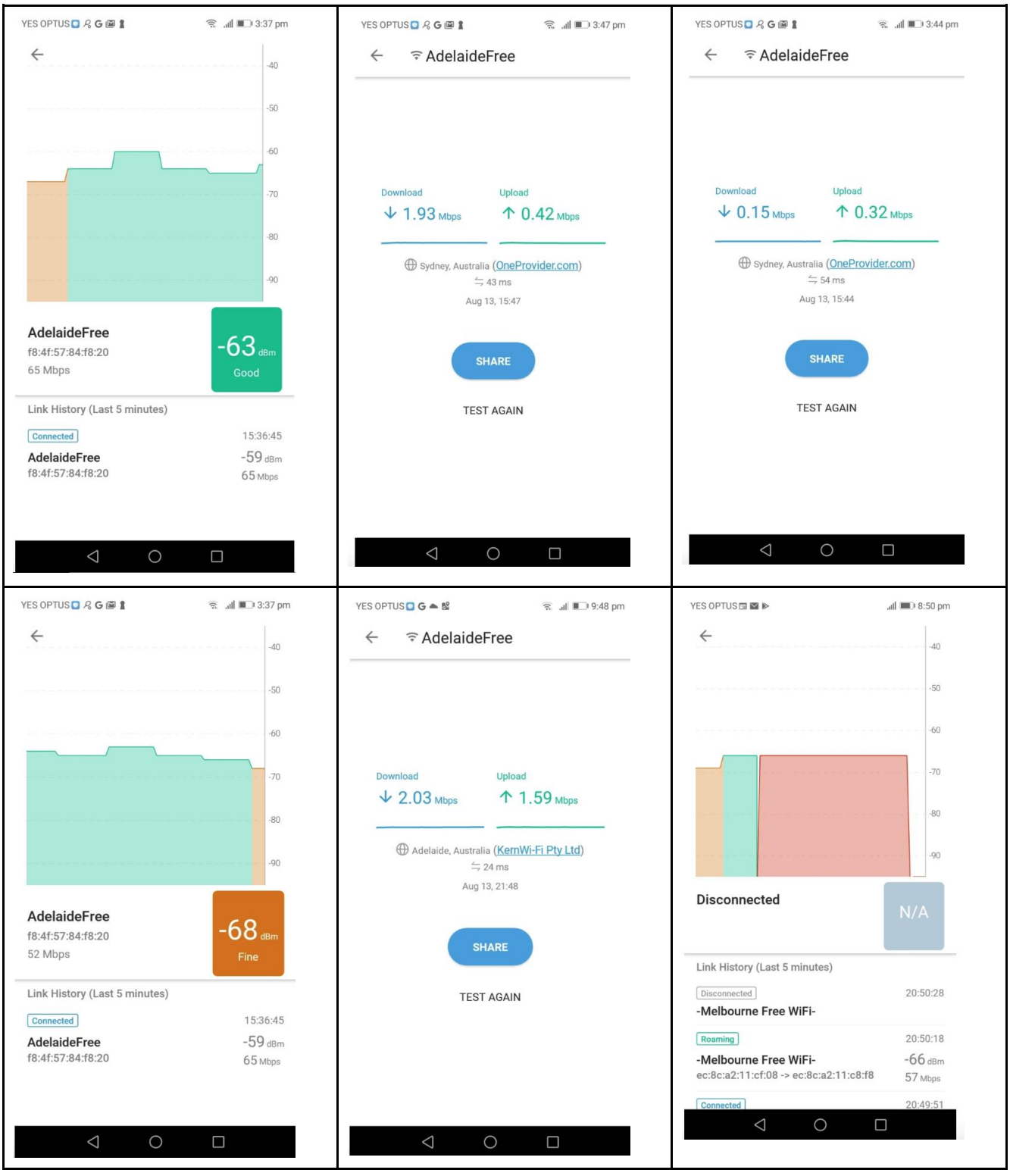
End of Block: PUBLIC WI-FI IN AUSTRALIA: EVALUATION

Appendix C. Structure of the National Online Survey

("other" designates open-ended questions)

Category	Question/Variable	Measurement
Basic information	Name of LGA	Open-ended
	Principal area of responsibility of LGA officer participating in survey	8 types + other
	Provision of PWF	yes–don't know– no
Characteristics of PWF service	Duration of PWF service provision	4 types + don't know
	Locations of PWF provision	Multiple choice: 6 types + other
	PWF download limits	4 types
	PWF access time limits	5 types
	Actions that consumer must take to use PWF	Multiple choice: 3 types + don't know
Decision-making and administration	PWF business model	2 types + don't know
	Funding source for PWF service	Multiple choice: 3 types + other
	PWF as provisional or core service	2 types
	Rationales of PWF provision	Multiple choice: 9 types + other
	Probability of deployment PWF in the next 3 years (for non-providers)	100 point scale: very low ↔ very high
	Priority of PWF provision	100 point scale: very low ↔ very high
	Existence of digital strategy in LGA	yes–don't know– no
	Addressing PWF provision in digital strategy	yes–don't know– no
Evaluation of PWF and its role in administrative process	(Non)performing evaluation of PWF and type of evaluation, if performed	5 types + other
	Impact of evaluation on level of investment if PWF	4 types + don't know
	Reporting on results of PWF evaluation to public	3 types
	Importance of PWF evaluation as a part of administrative process	Multiple choice: 4 types + other
Ending block	Further comments on the provision of PWF	Open-ended
	Upload PWF evaluation report or other documents	Uploading file

Appendix D. Interface of Mobile Application "WiFiMan" Which Was Used for Testing PWF Networks in Adelaide and Melbourne



Appendix E. Dataset and Stata DO-File (Chapter 5)

Published: 2019-11-25

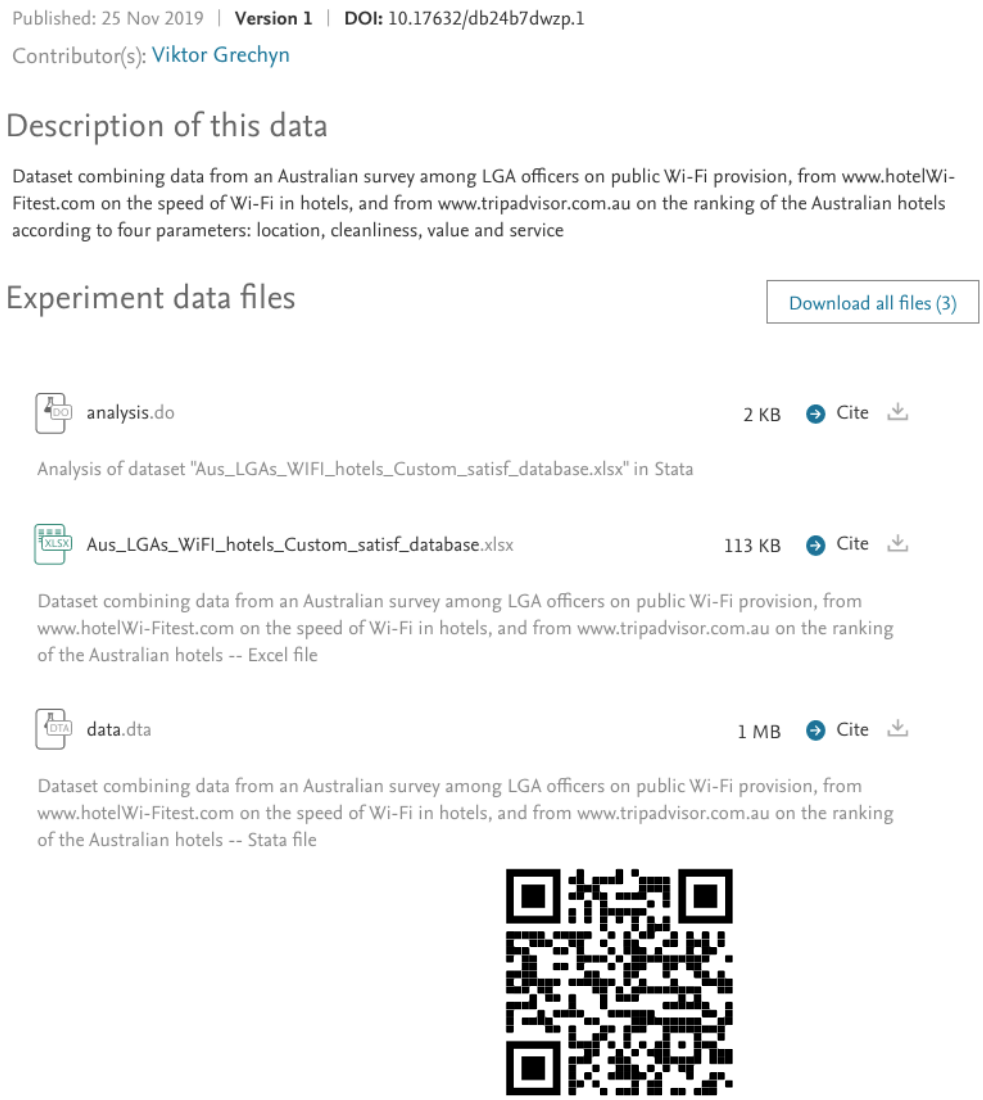
DOI: 10.17632/db24b7dwzp.1

Grechyn, Viktor (2019), “Public Wi-Fi provision by LGAs in Australia, Wi-Fi in Australian hotels and the level of satisfaction of the hotels' customers”, Mendeley Data, v1

Dataset: Public Wi-Fi provision by LGAs in Australia, Wi-Fi in Australian hotels and the level of satisfaction of the hotels' customers

File: Aus_LGAs_WiFI_hotels_Custom_satisf_database

DOI: http://dx.doi.org/10.17632/db24b7dwzp.1#file-55f325ef-4651-411b-9d32-0188e48a98f1



Appendix F. Analysis of Launceston PWF Metadata in Python 3.7.0 (Chapter 6)

```
# import of the necessary libraries
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

# read file
f = 'City of Launceston Wi-Fi Usage June 14 2014 onwards.xlsx'
df = pd.read_excel(f)
print(df.shape)

# all sessions Figure 21. Distribution of sessions by login hour
hist, bins = np.histogram(df['Hour'], bins = list(range(24)))
width = np.diff(bins)
center = (bins[:-1] + bins[1:]) / 2
fig, ax = plt.subplots(figsize=(8,3))
ax.bar(center, hist, align='center', width=width)
ax.set_xticks(bins)
fig.suptitle('Distribution of sessions by login hour', fontsize=16)
fig.savefig('session_by_hour_all.png')

#Counting the number of unique MAC addresses
print(len(df.[‘MAC’].unique()))


# sessions by date type Figure 22. Distribution of sessions by login hour and day type

df_weekend = df[df['Day name'].isin(['Sat', 'Sun'])]
df_weekdays = df[~df['Day name'].isin(['Sat', 'Sun'])]
print(df_weekend.shape)
print(df_weekdays.shape)

hist, bins = np.histogram(df_weekdays['Hour'], bins = list(range(24)))
hist2, bins2 = np.histogram(df_weekend['Hour'], bins = list(range(24)))
width = np.diff(bins)
center = (bins[:-1] + bins[1:]) / 2
fig, axs = plt.subplots(1, 2, sharey=True, figsize=(8,3))
axs[0].bar(center, hist, align='center', width=width)
axs[1].bar(center, hist2, align='center', width=width)
axs[0].set_xticks(list(range(1,23,2)))
axs[1].set_xticks(list(range(1,23,2)))
axs[0].set_yticks(list(range(0,20000,2500)))
axs[1].set_yticks(list(range(0,20000,2500)))
axs[0].set_title('Weekday')
axs[1].set_title('Weekend')
```

```
fig.subplots_adjust(top=0.8)
fig.suptitle('Distribution of sessions by login hour and day type', fontsize=16)
fig.savefig('session_by_hour_day_type.png')


# Drawing scatter plot of the distribution of MAC addresses by number or sessions Figure 23
mac_sessions = pd.crosstab(index=df[“MAC”], # Make a crosstab
                                        columns = “sessions”        #Name the count column

print(mac_sessions[“sessions”].sort_values(ascending=False).head(10))

mac_sessions = pd.crosstab(index=mac_sessions[“sessions”],      # Make a crosstab
                                        columns = “count”        # Name the count column
mac_sessions = mac_sessions.reset_index()
mac.sessions.info()
ax1 = mac_sessions.plot.scatter(x=’sessions’, y = count, xlim = (0, 100), ylim = (0, 1000))
mac_sessions[‘cummul’]=mac_sessions[‘count’].cumsum()  #Count the number of MAC
                                          #addresses with correspondent number of sessions
mac_sessions[‘cumul_share’]=mac_sessions.cummul/mac_sessions[‘count’].sum()
mac_sessions[‘normalize’]=mac_sessions[‘cummul’]/mac_sessions[‘count’].sum()
```

Appendix G. Structure of Launceston PWF Metadata and Examples of Values of the Logs

Names of logs and examples of values

Logged in	GMT+10	Month	Week	Day	Day name
6/14/2014 1:08	Sat 14/06/14 11:08	201406	24	14	Sat

Hour	Logged out	Last updated at	Agent	Online	Reason	Login
11	6/14/2014 1:45	6/14/2014 1:08	Mobile Safari 6.4	36	Idle-Timeout	LCC Free Access 41103

Download	Upload	Traffic Total (MB)	Pkts down	Pkts up	MAC
73832	9636	0.08	86	76	51:0B:78:11:3B:A7

Explaining the logs of metadata

NAME OF THE METADATA VARIABLE	DESCRIPTION
Logged in	Time and date when the user of PWF service logged in.
Logged out	Time and date when the user of PWF service logged out.
GMT+10	Time and date when the user of PWF service logged in plus day of the week.
Month	Year and month of the log.
Week	The number of the week in the year when the log was made.
Day	The day of the month when the log was made.
Last updated	The time and date of the last activity of the user in the system.

Login	PWF session login; consists of the words "LCC Free Access" and 5 digits which are assigned randomly for every new PWF session (for example, "LCC Free Access 41103").
MAC	Globally unique identifier of the mobile device connected to PWF, for example: "a4:c3:61:53:31:76".
Agent	The name of the software (Internet browser) used by the mobile device connected to the PWF network; for example, "Mobile Safari 7.1".
Online	The duration of staying connected to the PWF network (in minutes).
Reason	Reason for the disconnection of PWF sessions. The set of the possible reasons include (*where the meaning is not self-evident from the name of the reason, the explanation is provided*): Admin-Reset (reset of the session by the administrator), Idle-Timeout, IP-Reclaimed (assigning a new dynamic IP address to the session), MAC-Mismatch (interruption of the session because the MAC address of the device which attempts to connect to PWF is in the "blacklist" and is not allowed to connect PWF network), Quota-Exceeded (the Wi-Fi session traffic allowance has been exceeded), Session-Hijack (identified authorized attempt to receive access to sensitive information), and Session-Timeout.
Download	The volume of traffic downloaded during the session, in KB
Upload	The volume of traffic uploaded during the session, in KB
Traffic Total	Aggregate (download and upload) traffic, in MB
Pkts down	A number of downloaded packets during the session (*a packet is data organized in a block for its transmission*).
Pkts up	A number of uploaded packets during the session

Appendix H. Ethics approval letter

RMIT UNIVERSITY

Design and Social Context College Human Ethics Advisory Network (CHEAN)
Sub-committee of the RMIT Human Research Ethics Committee (HREC)

Notice of Approval

Date:	**9 November 2016**
Project number:	**CHEAN A 0000015711-09/13**
Project title:	**Public WiFi in Australia**
Risk classification:	**Low Risk**
Investigator:	**Dr Ian McShane, Professor Denise Meredyth, Prof Denise Meredyth, Prof Jason Potts, Dr Mark Gregory, Dr Chris Wilson, Prof Margaret Jackson, Prof Catherine Middleton, Mr Viktor Grechyn**
Approved:	**From: 9 November 2016** **To: 31 December 2018**

I am pleased to advise that your amendment request has been granted ethics approval by the Design and Social Context College Human Ethics Advisory Network, as a sub-committee of the RMIT Human Research Ethics Committee (HREC). The CHEAN approves the addition of Mr Viktor Grechyn to the research team, and the removal of Dr Prateek Goorha.

Terms of approval:

1. **Responsibilities of investigator**
   It is the responsibility of the above investigator/s to ensure that all other investigators and staff on a project are aware of the terms of approval and to ensure that the project is conducted as approved by the CHEAN. Approval is only valid whilst the investigator/s holds a position at RMIT University.
2. **Amendments**
   Approval must be sought from the CHEAN to amend any aspect of a project including approved documents. To apply for an amendment please use the 'Request for Amendment Form' that is available on the RMIT website. Amendments must not be implemented without first gaining approval from CHEAN.
3. **Adverse events**
   You should notify HREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
4. **Participant Information and Consent Form (PICF)**
   The PICF and any other material used to recruit and inform participants of the project must include the RMIT university logo. The PICF must contain a complaints clause including the project number.
5. **Annual reports**
   Continued approval of this project is dependent on the submission of an annual report. This form can be located online on the human research ethics web page on the RMIT website.
6. **Final report**
   A final report must be provided at the conclusion of the project. CHEAN must be notified if the project is discontinued before the expected date of completion.
7. **Monitoring**
   Projects may be subject to an audit or any other form of monitoring by HREC at any time.
8. **Retention and storage of data**
   The investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

Please quote the project number and project title in any future correspondence.

On behalf of the DSC College Human Ethics Advisory Network, I wish you well in your research.

Dr David Blades
Research Governance and Compliance Advisor
RMIT University
E: david.blades@rmit.edu.au