How is Digital Infrastructure Adopted and Assimilated?
The IPv6 Story

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknoledgements), nor material which to a substantial extent has been submitted for the award of any degree or diploma of a university or other institution of higher learning.

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ABSTRACT

The adoption of Internet Protocol version 6 (IPv6) is vital for addressing the depletion of Internet Protocol version 4 (IPv4) addresses and the growth of the Internet. Despite the criticality of the shortage of IPv4 addresses, organisations around the world have been slow to adopt IPv6. While some researchers have examined organisational IPv6 adoption and assimilation, the literature is dominated by technical studies. In addition, there is little research on the broader issue of the adoption of digital infrastructure, including IPv6. The goal of this study is to better understand the organisational adoption and assimilation of digital infrastructure, by studying the IPv6 adoption experience.

This study focused on identifying the determinants and barriers of organisational IPv6 adoption and assimilation, and on providing an in-depth understanding of the impact of organisational resources, institutional forces and network externalities across varying stages of organisational adoption and assimilation. To achieve these research aims, a thorough literature review and multiple case studies were used. Semi-structured in-depth interviews were conducted with 22 informants from sixteen organisations in New Zealand. These organisations were from different industries, of different sizes and were at different stages of IPv6 adoption.

The data collected during the interviews was used to develop through visual maps for each case, and to surface themes across cases. The within-case analysis identified twelve determinants and eleven barriers of organisational IPv6 adoption, which were then categorised into institutional, organisational and network-specific factors. The data was then used to develop a multi-level model of digital infrastructure adoption, and a stage model of digital infrastructure adoption and assimilation.

This study contributes theoretically to our understanding of digital infrastructure adoption and assimilation by explaining how factors internal and external to organisations influence their adoption decisions. By consolidating the experiences of the sixteen organisations, the study also provides useful suggestions to practitioners on how they should managing their adoption of IPv6 and other types of digital infrastructure. Finally, this study concludes by describing its limitations and by providing suggestions for future research on this crucial topic.

Chapter 1: Introduction

The current system for assigning unique addresses to devices connected to the Internet (Internet Protocol version 4 or IPv4) is 32-bits in length (e.g., 194.101.1.1) and can support up to 4.3 billion addresses (Edelman, 2009). Although this is a large number, the continuous growth of the Internet is causing these IPv4 addresses to deplete quickly. The growing number of Internet-enabled devices (e.g. mobile phones, tablets) and the requirement for always-on connectivity and multiple IP addresses (Infoblox, 2013) makes 4.3 billion addresses just not enough. Mueller (2008, p. 2) stressed the IPv4 depletion problem by stating:

> *The problem of address scarcity is as severe for the Internet economy as the oil shocks and gasoline shortage of the 1970s were to the industrial economy. Address shortages could act as a brake on the growth of the Internet.*

As a remedy to the IPv4 depletion problem, IPv6 was introduced in 1995 by the Internet Engineering Task Force (IETF) (Hovav & Popoviciu, 2009). IPv6's 128-bit length offers 340 trillion, trillion, trillion IP addresses (Cicileo et al., 2009) and supports the continued growth of the Internet. In addition to larger address space, IPv6 also provides benefits such as enhanced security and mobile device management, which is critical to communications over the Internet (Bernard & Thayer, 2011). Other advantages that IPv6 has over IPv4 include better quality of service, improved scalability, and simpler headers. Thus, the organisational adoption of IPv6 is critical for the growth of the Internet.

The biggest driver for businesses to adopt IPv6 is the need for business continuity (Horley, 2014). Other drivers for adopting IPv6 are the growth of the Internet applications market, which requires more addresses, and the sophistication of web-based services, that need a more capable and efficient network infrastructure (Tassey et al. (2009).

A related issue is the growing commercial interest in the 'Internet of Things' (IoT). IoT foresees a world where all physical objects, such as appliances, will have sensors and will be connected to the Internet. However, it is difficult for IoT to exist in an IPv4 environment because of the limited number of IP addresses. Thus, the adoption of IPv6 is vital for the advancement of IoT.

1.1 The Research Problem

Despite the importance of IPv6, the adoption of IPv6 globally has been extremely slow and limited (Horley, 2014; OECD, 2014). One reason for this could be the complexity of IPv6 adoption, including the risk of losing Internet access during the transition (Infoblox, 2013). Adopting IPv6 is a complex issue because networking protocols like it are a type of digital infrastructure (Hovav & Schuff, 2005), underlying an organisation's entire portfolio of information systems. Upgrading or replacing any type of digital infrastructure, such as platforms, enterprise systems and IT capabilities (Hanseth & Lyytinen, 2010), is more difficult than upgrading or replacing individual applications or devices because they have fewer dependencies. For instance, it is relatively easier to upgrade an organisation's email system than the Internet protocol used to transfer its network traffic.

There is a lack of research on the adoption of Internet standards (Hovav et al., 2004) such as IPv6. The existing IPv6 literatures are dominated by technical IPv6 studies (Colitti et al., 2010; Nikkel, 2007) compared to organisational IPv6 adoption studies. The existing non-technical IPv6 studies mostly focus on a country-wide IPv6 adoption effort (AGIMO, 2009; Hovav et al., 2011; Hovav & Kim, 2006; Mason & Mahindra, 2011; White et al., 2010) rather than focusing on organisational IPv6 adoption. In addition, prior IPv6 studies have focused on IPv6 adoption (AGIMO, 2009; Hovav et al., 2004; Networks, 2011) but have neglected the assimilation of IPv6. IPv6 adoption is defined in this study as the period when organisations start planning and ensuring their network applications and equipment support IPv6. In contrast, IPv6 assimilation occurs when IPv6 is deployed across all of the network infrastructure and services in an organisation.

IPv6 is a type of digital infrastructure. Organisations rely on their digital infrastructure to operate effectively (Png et al., 2001). Compared to traditional IT applications, digital infrastructure has a more complex design as it consists of other infrastructures, platforms, applications and IT capabilities (Hanseth & Lyytinen, 2010). Digital infrastructure is never built from scratch as it is built on what already exists, and changing it is a very challenging task (Nilsson et al., 2002). Despite the complexity and importance of digital infrastructure, there is a lack of research in the area of information systems (IS) (Tilson et al., 2010a). The majority of prior digital infrastructure studies have also focused only on the characteristics and features of the digital infrastructure (Hanseth & Lyytinen, 2010), neglecting the area of organisational adoption and assimilation of digital infrastructure. There are few studies on the assimilation of digital infrastructure to draw from therefore, even though it is important for organisations to assimilate digital infrastructure in order to fully experience its benefits. As noted by Gallivan (2001), it is vital for an organisation to assimilate the innovation across the entire organisation and not just stop at the adoption of the innovation. Like all technologies, the adoption of IPv6 in an organisation occurs in stages as the new technology is first introduced, implemented and deployed, and finally assimilated.

Prior literature has stated that external factors such as governmental pressure (Dell et al., 2008) and vendor support (Hovav et al., 2004) are important for IPv6 adoption. However, only a few studies have examined the role of institutional factors in organisational digital infrastructure adoption. For example, Currie (2012) studied the impact of institutional forces on the adoption of electronic records by patients in England. However, she focused only on the impact of institutional forces on adoption, not all of the stages of adoption and assimilation. The study also focused collectively on individuals and organisations, rather than the organisational adoption and assimilation process. It is important to understand the effects of external forces that could motivate or hinder change (Currie, 2009).

In addition, organisations that intend to adopt IPv6 need to have adequate organisational resources. IPv6 literatures have stated that various organisational resources are vital for IPv6 adoption (Grossetete et al., 2008; Hovav et al., 2004; OECD, 2014); however, there is a lack of studies that compile all the necessary organisational resources that are important for organisations' IPv6 adoption and assimilation. There is also a need to investigate the impact of adequate organisational resources and lack of organisational resources on organisational IPv6 adoption and assimilation.

Digital infrastructure adoption is non-linear and path dependent as it is influenced by the network effects of the people involved and the network of technologies involved (Hanseth & Lyytinen, 2010). Hence, it is important to investigate the role of the network of actors that are involved either directly or indirectly in organisations' adoption and assimilation of IPv6. Although the importance of network externalities was mentioned by Hovav et al. (2004), there is still limited information on the role and impact of networks on organisational IPv6 adoption and assimilation.

This section has explained the research problem, and the next section discusses the significance and motivation of the research.

1.2 Significance and Motivation of the Research

This section presents the motivation behind the research and its significance based on the research problem discussed in Section 1.1. As the research problem indicates, there is a lack of studies on organisational IPv6 adoption and assimilation. Most available IPv6 literatures are technical studies and the non-technical IPv6 studies that exist are focused on the country-wide IPv6 adoption effort. Also, previous IPv6 literatures have emphasised IPv6 adoption but overlooked the assimilation of IPv6. Therefore, the motivation of this study is to investigate and research the adoption and assimilation of IPv6 in organisations. Since IPv6 is a type of digital infrastructure, prior literatures on digital infrastructure and its adoption and assimilation need to be studied. Studying IPv6 from a digital infrastructure perspective can provide a better understanding of the adoption and assimilation process.

Section 1.1 also stated that there is a need to study the impact of external factors on the adoption and assimilation of IPv6. This study argues that institutional forces are important for the adoption and assimilation of IPv6. The impact of institutional forces can be examined through the lens of institutional theory. Institutional theory posits that organisations that are part of the same environment should advocate similar practices and become isomorphic with each other (Kostova, 2002) as this isomorphism leads to legitimacy that is vital for organisations' survival (Gosain, 2004). Currie (2009) stressed that external factors (institutional forces) can be barriers and drivers of change. Hence, this study investigates the impact of institutional forces on the adoption and assimilation of IPv6 in organisations.

The lack of studies on the impact of organisational resources on IPv6 adoption and assimilation in organisations has been mentioned in Section 1.1. Since prior IPv6 literatures have listed various important organisational resources for IPv6 adoption, this study classifies these organisational resources into three categories: human resources, technological resources and relationship resources. This study is motivated to understand the influence of organisational resources on the adoption and assimilation of IPv6 by organisations.

As mentioned in Section 1.1, there is a need to examine the role and impact of networks on organisational IPv6 adoption and assimilation. Hovav et al. (2004) highlighted the role of network externalities because the increasing number of organisations that adopt IPv6 creates positive network externalities that reduce risks from the lack of central governance. Thus, this research investigates the role and impact of networks on organisational IPv6 adoption and assimilation.

In summary, this study's objectives are to identify the external and internal determinants and barriers to the adoption and assimilation of IPv6 by organisations. Some factors that have been suggested include government support (Che & Lewis, 2010) and the presence or absence of trained staff (Mason & Mahindra, 2011). Institutional theory (DiMaggio & Powell, 1983) is used to classify the various external factors that influence organisations' adoption and assimilation of IPv6, including coercive, mimetic or normative forces. In addition, the impact of various types of organisational resources, such as human resources, technological resources and relationships, on the adoption and assimilation of IPv6 are examined. The influence of different types of networks (such as professional, supplier and customer) and network externalities on the adoption and assimilation of IPv6 are also be examined.

A generic or *"one-size-fits-all"* plan is not practical for organisations seeking to adopt IPv6, because each organisation has a different level of dependency on its networks, different levels of resource availability, different strategic visions and different management philosophies (Infoblox, 2013). Hence, this research examines how organisations from various industries and of different sizes have adopted IPv6 so as to compare their experiences. This study includes organisations (at the time of the data collection) are at varying stages of the adoption process, so as to clarify the process of new digital infrastructure adoption and assimilation.

Section 1.1 stated the research problem while Section 1.2 has discussed the significance and motivation of the research. The next section, Section 1.3, presents the aims and research questions.

1.3 Aims and Research Questions

Based on the research problems (Section 1.1) as well as the significance and motivation of the research (Section 1.2), two research questions were formulated. This study asks the following research questions:

1. What are the determinants of IPv6 adoption and assimilation in organisations?

a) How do institutional factors impact the different stages of the adoption and assimilation of IPv6?

2. What are the barriers of IPv6 adoption and assimilation in organisations?

By identifying the determinants and barriers of IPv6 adoption and assimilation in organisations, the process of organisations' IPv6 adoption and assimilation can be clarified. These determinants and barriers are classified into organisational resources, institutional forces and network externalities. Determinants drive organisations to adopt and assimilate IPv6 while barriers hinder organisations from adopting and assimilating IPv6.

The impact of organisational resources, network externalities and institutional factors across different stages of adoption and assimilation of IPv6 is investigated to provide a clearer picture of the adoption and assimilation stages. Hence, the influence of three institutional forces (coercive, mimetic and normative), three organisational resources (human, technological and relationship) and network externalities on the process of IPv6 adoption and assimilation are clarified through the study. This section has presented the aims and research questions. The next section (Section 1.4) provides the theoretical foundations of this study.

1.4 Theoretical Foundations

As mentioned in Sections 1.1, 1.2 and 1.3, the factors that are crucial for organisational IPv6 adoption and assimilation can be categorised into three domains: institutional forces, organisational resources and network externalities.

This study stresses that external factors or institutional forces are important for the adoption and assimilation of IPv6 in organisations. In order to understand the influence of institutional forces, institutional theory is used in this study. Since digital infrastructure adoption is more complex that technology adoption, it will be useful to understand the impact of institutional forces on the adoption and assimilation of digital infrastructure in the case of IPv6. As Iannacci (2010) indicated, there is a lack of studies on the influence of institutional perspective on digital infrastructure and the studies that exist focus on the technological perspective rather than the institutional perspective. The impact of three institutional forces (coercive, mimetic and normative) on the different stages of IPv6 adoption and assimilation are studied.

This study also highlights that organisational resources are vital for organisations' IPv6 adoption and assimilation process. Thus, IPv6 literatures are reviewed to identify essential organisational resources that are important for organisations' IPv6 adoption and assimilation. These organisational resources are categorised into human resources, technological resources and relationship resources.

This research also emphasises the role and impact of networks on the adoption and assimilation of IPv6. Therefore, the literature on network externalities is studied to identify and understand the role of networks in organisational IPv6 adoption and assimilation. Key factors such as institutional forces, organisational resources and network externalities that may drive or hinder organisational IPv6 adoption and assimilation at the various stages were identified. This section has presented the theoretical foundations of this study. The next section, Section 1.5, provides the research methodology of this study.

1.5 Research Methodology

This section presents the research methodology of this study. In order to support and extend the literature studies, data was collected through the post-positivist case study method. Since this study adopts a post-positivist epistemology, both the literature review and views and experiences of participants are important. Semi-structured in-depth interviews were conducted with 22 informants from 16 organisations. As Yin (2009) stated, interviews are one of the most important sources of case studies. These 16 organisations were from different industries, of different sizes and were in different stages of IPv6 adoption. These organisations consisted of four tertiary institutions, four telecommunications companies, four IT vendors, two government agencies, one food retailer and one air transport organisation. Data collected from the interviews was transcribed through Nvivo, and analysed through thematic analysis. A within-case analysis was conducted for each case study which included details of organisational IPv6 adoption and assimilation experiences and the perspectives of participants and organisations. Then, thematic analysis was conducted as a cross-case analysis. Section 1.5 provides the study's research methodology and the next section, Section 1.6, presents the structure of the thesis.

1.6 Structure of the Thesis

This thesis is organised into seven chapters. Chapter 1 establishes the research problems, significance of the topic and the rationale for undertaking this study. Chapter 1 also presents the aims and research questions in addition to the theoretical foundations and research methodology of this study.

Chapter 2 reviews relevant research on digital infrastructure, digital infrastructure adoption and assimilation, and IPv6 adoption and assimilation. Chapter 2 also discusses the evolution from IPv4 to IPv6, benefits and costs of IPv6 adoption and assimilation, and the IPv6 adoption and assimilation process.

Chapter 3 examine literatures on institutional theory, organisational resources and network externalities in terms of their implications for organisational IPv6 adoption and assimilation. Chapter 3 also provides a table summarising theories applied by other organisations that have adopted and/or assimilated organisational IT, and how this study differs from prior literatures.

Chapter 4 describes and justifies this study's research methodology. This study adopts a post-positivist case study methodology to answer its research questions. Chapter 4 discusses the way research sites were chosen, the way data was collected and the way data was analysed.

Chapter 5 reports on the IPv6 adoption experiences of each of the 16 organisations that participated in this study. The findings are presented in two ways – organisational vignettes and descriptive analyses.

Chapter 6 builds on the within-case analysis presented in Chapter 5 and presents a cross case analysis of the study.

Chapter 7 concludes the study by providing a summary of the study and discussing the findings, as well as whether the research questions have been answered. This chapter also highlights the theoretical and practical contribution of this research, its limitations and suggestions for future work in this field.

Chapter 2: Context of Study - Digital Infrastructure

This study aims to identify the determinants of and barriers to the adoption and assimilation of IPv6. Since IPv6 is a type of digital infrastructure, this chapter reviews the literatures on digital infrastructure generally and IPv6 specifically. Section 2.1 provides an overview of current research on digital infrastructure, while Section 2.2 discusses the adoption and assimilation of digital infrastructure. Section 2.3 examines prior research on the adoption and assimilation of the IPv6 protocol.

2.1 Digital Infrastructure

Infrastructure is metaphorically seen as a substrate: something that other things run on or operate, such as railroad tracks on which railcars run (Star & Ruhleder, 1996). With growing industrialisation and urbanisation, physical infrastructure (e.g., roads, railway lines, electrical grids and water delivery systems) has become necessary to support economic activity (Tilson et al., 2010a). Within organisations, the concept of corporate infrastructure first appeared in the 1980s as large corporate information systems began to be installed and used. Corporate infrastructure plans stressed the standardisation of systems and data throughout each organisation as a method of accommodating the centralised IS department and resources while also distributing systems and applications across the various business units and departments (Ciborra & Hanseth, 1998).

As information technology has become increasingly ubiquitous, the concept of ‘digital infrastructure’ has come into vogue. Digital infrastructure can be defined in many ways (Table 1) and is the backbone for operating various IT applications such as email, video conferencing and instant messaging (Png et al., 2001). Other similar terms include ‘e-infrastructure’, ‘information infrastructure’, ‘IT infrastructure’, ‘digital infrastructure’, ‘cyber infrastructure’, ‘integrated infrastructure’, ‘IT platform’ and ‘corporate infrastructure’. In this study, the term ‘digital infrastructure’ is used.

Table 1 Definitions of Digital Infrastructure

Reference	**Definitions of Digital Infrastructure**
(Hanseth & Lyytinen, 2010, p. 4)	*"a shared, open (and unbounded), heterogeneous and evolving socio-technical system (which we call installed base) consisting of a set of IT capabilities and their users, operations and design and shaped by neighbouring infrastructure, existing IT capabilities, user and designer learning, cognitive inertia, etc."*
(Tilson et al., 2010b, p. 748)	*"basic information technologies and organizational structures, along with the related services and facilities necessary for an enterprise or industry to function"*
(Hanseth & Lundberg, 1999, p. 4)	*"shared resources for a community; the different components of the infrastructure are integrated through standard interfaces; they are open in the sense that there is no strict limit for who can use them and for which purpose or function; and they are heterogeneous, consisting of different kinds of components – human as well as technological"*
(Karasti et al., 2010, p. 381)	*"constellations of software technologies and systems usually associated with the Internet, e.g., 'information infrastructure' and 'cyberinfrastructure'. Typical metaphors for infrastructure consist of ensembles of things (e.g. pipes, wires, and servers) that connect or transport people, fluids, signals, and such while staying in the background and being taken for granted in addition to being transparent to their users and becoming visible only in case of breakdown"*

Compared to IT capabilities, applications and platforms, digital infrastructure has the most complex design (Hanseth and Lyytinen (2010). Digital infrastructure is recursively composed of other infrastructures, platforms, applications and IT capabilities (Hanseth & Lyytinen, 2010). Digital infrastructure can be regarded as networks installed into much bigger and more complex structures (Nilsson et al., 2002). The Internet is an example of a digital infrastructure (Hanseth & Lyytinen, 2010) and the Internet Protocol (IP) is the essence of the Internet as it presents services that are relied on by all other services (Hanseth et al., 1996).

An example of the importance of digital infrastructure is the role of telecommunications. Businesses rely on telecommunications to operate effectively as telecommunications provide them with voice and data connectivity across different locations over large distances, but this is only possible with the underlying digital infrastructure transporting voice and data (Png et al., 2001).

Digital infrastructure has become a significant part of the environment because of three key changes over the last two decades (Edwards et al., 2009):

1) Information handling and processing has moved away from stand-alone (individual) computers and local networks to more distributed grid or cloud networks, connected through the Internet;
2) Digital convergence ("atoms-to-bits") of audio, video, image and text requires data processing and editing;
3) The World Wide Web (WWW) has become a sine qua non of global commerce, government, and social interaction.

Despite this, digital infrastructure has been surprisingly under-studied in the information systems (IS) field. A content analysis of articles published in *Information Systems Research (ISR)* in its first 20 years found that only 2% of the articles discussed infrastructural issues and out of those articles, only five (1% of the total) had infrastructural issues as the main focus (Tilson et al., 2010b). Tilson et al. (2010a) similarly analysed 260 *MIS Quarterly* articles and highlighted that despite heavy reliance on computing infrastructure and broadband networks, little attention has been paid to digital infrastructure by the IS field, especially in the areas of infrastructure evolution and digital convergence. Two benefits of studying digital infrastructure, mentioned by Bygstad (2010), are the switch from researching a single application to a large socio-technical network, and gaining a fresh outlook on how digital infrastructure is developed.

Digital infrastructure is similar to traditional infrastructure, such as public utilities; for example, it is transparent to end users, it is built on an installed base, it supports users' work invisibly, but transparently reveals its functions when it breaks down to support staff (Ribes & Finholt, 2009). Infrastructure (traditional and digital) can be characterised using the following nine dimensions proposed by Star (1999):

i. Embeddedness: it is embedded into other structures, social arrangements and technologies;
ii. Transparency: its usage is transparent as it does not need to be reinvented or assembled each time or for each task, and it supports those tasks invisibly;
iii. Reach or scope: it may be temporal or spatial – infrastructure has reach beyond a single event or a one-site practice;
iv. Learned as part of membership: newcomers encounter infrastructure as a subject to learn as part of a community's membership;
v. Links with conventions of practice: infrastructure shapes and is shaped by the conventions of a community of practice;
vi. Embodiment of standards: infrastructure is modified by scope and often by conflicting conventions, and becomes transparent by attaching itself to other infrastructures and tools in a standardised manner;
vii. Built on an installed base: infrastructure does not grow 'de novo'; it wrestles with the inertia of an installed base and inherits strengths and limitations from that base;
viii. Becomes visible upon breakdown: infrastructure becomes visible when it breaks; for example, everyone becomes aware of the email server when it stops working.
ix. Is fixed in modular increments, not all at once or globally: infrastructure is big, layered and complex and it is not possible to change it from above. The

changes will take time and negotiation with other aspects of the involved system.

However, digital infrastructure is different from traditional infrastructure in that it is a heterogeneous collection of technologies, platforms, components, and IT capabilities that support different applications over large geographical distances (Racherla & Mandviwalla, 2013). Among the above characteristics, which have been discussed in many studies on digital infrastructure, one of the most important characteristics is that digital infrastructure is built on an installed base. Digital infrastructure is never built from scratch; instead, it is built on what already exists and as the installed base grows, changing it becomes more and more challenging (Nilsson et al., 2002). In addition, digital infrastructure's recursive nature, as well as its scalability, flexibility and the varying substance of the material (data) being 'transported', make it generative (Tilson et al., 2010b). Digital infrastructure is generative for the following reasons (Tilson et al., 2010b):

1. It allow the creation of new infrastructure businesses which were previously not supported by the older physical infrastructure, such as electricity and water; Two self-reinforcing mechanisms that result from digital infrastructure adoption are: (i) the innovation mechanism which creates new services; and (ii) the service mechanism which results in more users and profits (Bygstad, 2010);
2. It is scalable because it offers cost-effective and simple replacement or upgrading of devices, which enhances performance and growth and lowers costs compared to older infrastructure;
3. Its flexible nature has increased its reach and scope to a level unattainable by traditional infrastructure.

2.2 Digital Infrastructure Adoption and Assimilation

As mentioned in the previous section, digital infrastructure is never built from scratch; it usually fits into the existing structure and the growth of the installed base means that changing it is difficult and costly. Nilsson et al. (2002) argued that the properties of digital infrastructure are fundamentally different from traditional information systems as the former is connected into large and complex networks and systems based on standardised communication protocols and formats for information and data exchange.

New digital infrastructure has to be adopted and existing infrastructure upgraded because digital infrastructure provides a platform for new applications and strategies (Ciborra et al., 2000). For example, an updated digital infrastructure is crucial for the success of a country's e-government strategy which will enable users to have easy and reliable electronic access, and inadequate digital infrastructure is seen as a key barrier to e-government adoption (Ebrahim & Irani, 2005). Ebrahim and Irani (2005) also found that unreliable digital infrastructure in the government will decrease the performance of e-government.

The adoption of digital infrastructure starts with the planning of the organisation's implementation. The organisation starts by ensuring that all applications, devices and services are able to support the new digital infrastructure. The organisation may choose to adopt the new digital infrastructural component in a test-bed, in which case the new infrastructure will only be used in a small portion of the organisation's networks before it is deployed across the entire organisation. Assimilation is the extent to which the use of the technology diffuses across organisational projects or work processes and becomes embedded in the activities of those projects and processes (Gallivan, 2001; Purvis et al., 2001).

Since digital infrastructure lies "underneath" applications, its adoption and assimilation process is transparent to end-users. However, this does not imply that infrastructure adoption is simpler; instead, the complex nature of digital infrastructure makes the adoption and assimilation process difficult and complicated. The adoption of digital infrastructure differs greatly from the adoption of individual applications and devices, because digital infrastructure is "*recursively composed of other infrastructures, platforms, applications and IT capabilities and controlled by emergent, distributed and episodic forms of control*" (Hanseth & Lyytinen, 2010, p. 1). Since digital infrastructure consists of other infrastructures, platforms, applications and IT capabilities, the adoption process can affect these components. The other infrastructures, platforms, applications and IT capabilities are dependencies of the new piece of digital infrastructure that is being introduced. If a certain component of digital infrastructure is upgraded or replaced with a new one, the other infrastructural components, IS platforms, applications and IT capabilities need to be able to support it. If they are unable to do so, they or the new component will need to be replaced or upgraded. In addition, the adoption of new or updated digital infrastructural components will have an impact on the operations of other infrastructural components, platforms, applications and IT capabilities. There could be broader negative repercussions if the adoption of digital infrastructure is problematic, such as an inability to access organisational websites.

The adoption of digital infrastructure has to happen gradually as it is deeply embedded in each organisation's practices, and its size and complexity do not allow it to be changed directly (Hanseth & Lundberg, 1999). The adoption of digital infrastructure normally occurs in an incremental manner through partly planned and unplanned processes (Sahay et al., 2009). In addition, cultural differences affect organisational decisions to adopt specific types of digital infrastructure. For example, the level of uncertainty avoidance, which refers to the magnitude with which people from a culture feel unprotected by uncertainty or unknown situations, matters: organisations from countries with lower levels of uncertainty avoidance are more prepared to adopt digital infrastructure compared to people from countries with higher levels of uncertainty avoidance (Png et al., 2001).

Since digital infrastructure is an organisation's technological platform, the adoption of digital infrastructure affects all of the organisation's functions. Nielsen and Aanestad (2006) discussed how various types of digital infrastructure are designed and operated to achieve particular needs, which are largely related to control. Digital infrastructure technologies are large and open sociotechnical networks comprising heterogeneous actors, and these actors have different perspectives of, and only partial control over, the digital infrastructure (Nielsen & Aanestad, 2006). There can only be partial control over the adoption and assimilation of digital infrastructure because it has its own acceleration rates and slow-downs when it hit delays, unintended consequences, sudden oppositions and imperfect attempts to align stakeholders (Ciborra et al., 2000). According to Nilsson et al. (2002), the size and complexity of digital infrastructure design and usage, along with its long lifespan, makes any high degree of control over it almost impossible. The complexity means that overly ambitious digital infrastructure projects mostly do not meet expectations (Hepsø et al., 2009). Nielsen and Aanestad (2006) stressed that control over digital infrastructure, especially when a change is being implemented, is not easy to obtain. While controlling technology itself is challenging, controlling digital infrastructure is more so, as it consists of various technologies, devices and services.

One of the challenges from the digital infrastructure literature is the role of decision-makers in influencing adoption decisions. An example can be seen in health, where decision-makers in organisations tend to invest only in areas where they see tangible and direct financial benefits; for example, technologies with a quick return on investment (ROIs) such as magnetic resonance imaging (MRI), compared to digital infrastructure such as electronic patient records (EPR) (Poon et al., 2006). It is also important that digital infrastructure adoption be approached from a different perspective than as a traditional information systems implementation. For example, the development and implementation of an EPR system in the Norwegian and Swedish healthcare systems using a traditional information systems implementation perspective caused many hospitals to struggle to integrate these complex and rigid systems with their existing systems (Nilsson et al., 2002). The returns from infrastructure adoption take much longer to be realised than those from IT applications or services as they are far more costly. Digital infrastructure should ideally be completely assimilated by an organisation across its entire network if its benefits are to be fully realised.

As with all technologies, digital infrastructure evolves over time; for instance, Internet Protocol version 6 (IPv6) was introduced to overcome the limitations or Internet Protocol version 4 (IPv4), and cloud computing evolved from grid computing (Messerschmidt and Hinz (2013) . The latter change marks a shift from an infrastructure delivering storage and computing resources (i.e., grid) to a more economical infrastructure that delivers abstract resources and services (i.e., cloud) (Messerschmidt & Hinz, 2013).

As mentioned in the previous section, one of the key features of digital infrastructures is that they are built on an installed base (existing components of digital infrastructure). Thus, the evolution of digital infrastructure is enabled and confined by the installed base, and added components should be integrated and compatible with the existing base (Hanseth & Lyytinen, 2010).

Compared to adoption, less research has been done on the assimilation of digital infrastructure, even though the assimilation of digital infrastructure is as important as its adoption. The assimilation of digital infrastructure is vital for an organisation in order to obtain the full range of benefits from it. According to Gallivan (2001, p. 59), "*it is not* *technology use or user adoption per se that matters as the outcome of interest, but rather how extensively the innovation is used and how deeply the firm's use of the technology alters processes, structures, and organizational culture*". Gallivan (2001) argued that assimilation has two dimensions: (i) breadth of use, which is the number of adopters within the organisation, and (ii) depth of use, which is how widely the technology is used and its impact within the organisation.

According to Hanseth and Lyytinen (2010), the majority of digital infrastructure research focuses on its characteristics and features, a smaller portion examines strategies for designing standards and infrastructures, and only a few studies look at design strategies for infrastructure development. Tilson et al. (2010a) found that the IS area has taken "for granted" digital infrastructure research and stated that IS researchers should start digital infrastructure studies by reviewing interconnections between known-about current IS research categories and the then-current logical and physical infrastructures. This, according to Tilson et al. (2010a), would be a platform to develop diverse infrastructure characteristics classifications and design connections among disparate initial findings by including a role for these characteristics. Tilson et al. (2010b, p. 756) also stressed the need for:

> *(1) deeper theoretical work on the notion of infrastructures, (2) new theoretical lenses to understand the paradoxical nature of change and control in digital infrastructures, and (3) better understanding of the ways in which infrastructural change shapes IT governance, IS development, and promotes new effects across all levels of analysis*.

Previous studies on technology adoption and/or assimilation have studied the impact of institutional factors and/or assimilation (Liang et al., 2007; Shi et al., 2008; Westphal et al., 1997). However, the same cannot be said about studies of digital infrastructure. The only available literature on the effect of institutional forces on digital infrastructure is

Currie (2012) study on the impact of three institutional isomorphic changes on the roll-out of electronic records to patients across England. The three forces reported in the study focused on individuals and organisations as a collective in England. There was less emphasis on each organisation's adoption and assimilation process in terms of the factors that influenced them to adopt or assimilate digital infrastructures. It will also be beneficial to understand how these institutional forces changed across different stages of the adoption and assimilation process. In the need to gain or maintain legitimacy, organisations may adopt and/or assimilate digital infrastructure. Institutional forces may have the ability to influence the organisation to be a leader or a follower in the adoption and assimilation of digital infrastructure.

The next section examines the literature on the adoption and assimilation of IPv6 and organises what is known about the field using the concepts from research on digital infrastructure.

2.3 IPv6 Adoption and Assimilation

2.3.1 Evolution from IPv4 to IPv6

The Internet is a loosely-organised, interconnected network (Bradner, 1996) that has driven education, industrial and other areas of productivity in recent decades. However, the depletion of available Internet addresses will hinder and limit the growth of the Internet. Roughly two billion people globally use the Internet for web browsing, email correspondence, multimedia content and services accessibility, playing online games, social networking applications usage and other usage (Miorandi et al., 2012).

The rapid growth in the number of Internet-connected devices (smartphones, tablets, laptops, and others) has led to an imminent shortage of IPv4 addresses: since every device connected to the Internet requires an IP address, IPv4 addresses are rapidly being used up. IPv6 was developed to replace IPv4 and can lead to improvements such as simplified configurations, improved quality of service, and built-in security (Weiser, 2001). IPv4 consists of 32-bit addresses and it is restricted to approximately 4 billion addresses which are a non-renewable resource similar to oil (Networks, 2011). IPv6 addresses are 128-bits long which allows more than 340 undecillion addresses (Networks, 2011). IPv6 offers a huge number of IP addresses, an opportunity to remove Network Address Translation[1] (NAT) devices which have been used to expand address capacity, and better network architectures by simplifying address assignment, improving support for header options and extensions and providing faster, more efficient configuration options for communication devices (Tassey et al., 2009).

NAT was instituted in the 1990s to remedy the exhaustion of IPv4 addresses before IPv6 products were developed. This feature led users to overlook the complexity that NAT introduced, its trade-offs, and its effects on applications and connectivity (Grossetete et al., 2008). According to Egevang and Francis (1994, p. 9), NAT is inappropriate as a long-term or even a short-term solution because it has negative characteristics such as:

> *require[ing] a sparse end-to-end traffic matrix [or else], the NAT tables will be large, thus giving lower performance; increase[ing] the probability of mis-addressing; … break[ing] certain applications, hid[ing] the identity of hosts, [which] … may benefit privacy, [but] … is generally a negative effect*

Other methods used to prolong the usage of IPv4 are Classless Inter-Domain Routing (CIDR) and Dynamic Host Configuration Protocol (DHCP). CIDR aggregates IP addresses while DHCP is more of a configuration aid to assign temporary IPv4 addresses to devices (White et al., 2010). These methods provide address conservation

[1] Network Address Translation allows a single device, such as a router, to act as an agent between the Internet (or 'public network') and a local (or 'private') network. This means that only a single, unique IP address is required to represent an entire group of computers on a local network.

but the address conservation will decrease as more always-on broadband connectivity is required (Eslambolchi, 2013).

Although it will be almost impossible for additional Internet-enabled devices to be connected to the Internet once IPv4 addresses have completely been used up, the migration to IPv6 is still in the initial phase (OECD, 2014). According to the Google IPv6 Traffic graph (one of the barometers of global IPv6 deployment), the availability of IPv6 connectivity among Google users as of 31 January 2015 is 4.66% (Google, 2015). The figure is increasing every year but is still fairly small despite the criticality of deploying IPv6.

Grossetete et al. (2008) maintained that the evolution of the Internet has caused various challenges such as IPv4 address depletion, enhanced operating systems and applications, future generation infrastructures and the requirement for always-on connection for expanding types of devices. The boom in the growth of mobile devices and the network demands of such devices has encouraged Internet Service Providers (ISPs) to adopt IPv6 and avoid NAT, which is costly, weakens performance, and cause applications to be broken (Infoblox, 2013). Organisations that do not intend to adopt IPv6 might be forced to buy IPv4 addresses from organisations that do not need them anymore. For example, when Borders bookshop went through bankruptcy, its 65,536 IPv4 addresses were sold for $786,000, about $12 for each address (Infoblox, 2013). Infoblox (2013) also highlighted that APNIC, which allocates IPv4 addresses in Asia, has depleted its holdings, and only provides emergency allocation of IPv4 address blocks[2] to qualified organisations.

IPv4 and IPv6 are examples of digital infrastructure. Hovav and Schuff (2005) stated that IPv6 is an infrastructure technology with its underlying technologies benefits from

[2] IP addresses are broken up into blocks of numbers, for instance, 168.20.57.0 through to 168.20.57.255.

its features. According to (Star & Ruhleder, 1996), the nine properties of infrastructure have been applied to IPv4/IPv6 to stress that it is a digital infrastructure and has the properties of one. These properties are as follows:

1. Embeddedness: IPv4/IPv6 is embedded into the Internet and is assigned to each device that connects to the Internet.
2. Transparency: IPv6 is transparent to end-users (Hovav & Popoviciu, 2009). They are unaware of how IP addresses are assigned to devices, and how the protocol carries traffic.
3. Reach/Scope: IPv4/IPv6 has reached beyond a one-site practice. The Internet runs on IPv4/IPv6 addresses. All Internet-enabled devices requires an IP address and millions of devices are connected to the Internet.
4. Learned as part of membership: Network engineers or network technicians who manage networks need to know IP configurations and assignments. They would have been managing IPv4 addresses for some time and will have to learn how to manage IPv6 when it is adopted.
5. Links with conventions of practice: IPv4/IPv6 has links to the conventions of practice in various ways. For instance, different organisations are assigned with different numbers of IP addresses and the way they are managed depends on the size of the organisation or the intensity of its IT usage. If it is an IT focused organisation, it might require more IP addresses for its huge number of Internet-enabled devices.
6. Embodiment of standards: Each time an Internet-enabled device connects to the Internet, it is assigned with an IP address automatically. When that device disconnects from the Internet, that IP address is assigned to the next device that connects to the Internet.

7. Built on an installed base: IPv4/IPv6 is not a stand-alone technology. It is assigned to devices. It battles with the 'inertia of the installed base'. If the internet-enabled device supports IPv4/IPv6 properly, IPv4/IPv6 can be used on the device. It also inherits the strength and limitations from that device.
8. Becomes visible upon breakdown: Normally, IPv4/IPv6 is generally invisible, but if there is a problem related to IPv4/IPv6, for instance, two computers are assigned the same static IP address, there are ways to fix the problem.
9. Is fixed in modular increments, not all at once or globally: Since IPv4/IPv6 adoption is a complex process, it will not happen at one go. It will be done in stages or phases.

2.3.2 Benefits and costs of IPv6 adoption and assimilation

IPv6 adoption can potentially reshape and redefine markets (Grossetete et al. (2008). One of the biggest benefits of IPv6 adoption is the Internet of Things (IoT). The economic and social impact of IoT has been speculated to be even greater than the industrial revolution (Ahlinder & Eriksson, 2011). Tan and Wang (2010, pp. V5-376) defined IoT as *"things hav[ing] identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environment, and user contexts"*. IoT is specified by Miorandi et al. (2012) as the worldwide Internet connectivity of smart devices; the set of supporting devices such as RFIDs, sensor/actuators, machine-to-machine communication devices and others; and the accumulation of applications and services that benefits new business and market opportunities.

Mattern and Floerkemeier (2010) stressed the need for IPv6 addresses for IoT:

If, in a future Internet of Things, everyday objects are to be addressed and controlled via the Internet, then we should ideally not be resorting to special communications protocols as it is currently the case with RFID. Instead, things should behave just like normal Internet nodes. In other words, they should have an IP address and use the Internet Protocol (IP) for communicating with other smart objects and network nodes. And due to the large number of addresses required, they should use the new IPv6 with 128-bit address.

Fiveash (2014) emphasised that IPv6 adoption will be the key for IoT, although it is quite a challenge to achieve in an IPv4 environment. IoT6 (2014) stated that IPv6 is vital for IoT and vice versa, and highlighted that IPv6 is the communication key for IoT. According to Jara et al. (2013, p. 98), IPv6 is crucial for IoT because it provides *"scalability, flexibility, tested, extended, ubiquitous, open, and end-to-end connectivity"*. In other words, IPv6 offers the best connectivity for IoT.

Two main factors contribute to the adoption of IPv6: a) the need for additional address space, and b) the emergence of new applications and devices which require more addresses and an efficient network infrastructure (Tassey et al., 2009). IPv6 is a component of an organisation's digital infrastructure that will support the development and use of innovations that utilise the features of IPv6 (Hovav & Schuff, 2005). The adoption and assimilation of IPv6 will provide a platform for new services and technologies while increasing the number of users utilising the services and technologies, which will increase profits. Organisations that delay IPv6 adoption, on the other hand, may find it difficult to connect to other organisations who have shifted to IPv6, and their aging infrastructure could lead to increases in support costs and risk when integrating new IPv6 applications and services (Networks, 2011). IPv6 adoption is also important to provide next generation network services, which are crucial for the advancement of an organisation's operations in the net-centric and global business world (White et al., 2010).

The integration of IPv6 in an organisation's existing digital infrastructure will happen on a service-by-service basis where a cost-effective approach will be undertaken (i.e., a huge amount of device management) (Grossetete et al., 2008). In other words, the integration of IPv6 into the current IPv4 digital infrastructure will occur in a cost-effective manner in which services and devices will be upgraded to IPv6 step by step or in stages so that costs will be managed. The upgrades or replacement of devices and services to support IPv6 might also occur through the organisation's refresh cycle which happens every three to five years.

2.3.3 The IPv6 adoption and assimilation stages

The adoption of IPv6 is an evolutionary process where existing IPv4 networks and their associated services migrate to IPv6. Thus, it is essential to differentiate between the adoption and assimilation of IPv6 because both stages require different types of effort. Not all organisations that adopt an innovation will assimilate the innovation because they might not see a reason to assimilate the innovation or might not have the resources to do so. Hence, understanding the factors that impact both processes might push organisations to fully assimilate the innovation. As mentioned in the previous section, adoption occurs when an organisation starts planning to deploy new digital infrastructure, and assimilation refers to the time period when an organisation diffuses the new digital infrastructure across all of its IT equipment and services. In the IPv6 context, adoption refers to the initiation of the decision-making process around whether IPv6 should be deployed, and, once the decision has been made to adopt it, the planning and implementation of the project to replace and/or upgrade the necessary hardware and software. Once IPv6 has been adopted, assimilation is the process of fully deploying the protocol across the organisation's networks, applications and other services. This may entail the entire organisation’s digital infrastructure and its connection with its peers having dual-stack IPv4/IPv6 or IPv6 only. Organisational members will use IPv6 for their day-to-day operations.

IPv6 adoption starts through test beds or pilot projects, as testing IPv6 in an environment closed to outside interference is necessary to avoid disrupting services to users and for identifying security risks (Cisco, 2008). In addition, pilot projects and test beds also help to foster IPv6 expertise and confidence (Zhang, 2012). The practitioner literature has identified multiple activities that occur at the stages of adoption, as detailed below:

- *IPv6 Initiation and Adoption Stage*:

  This stage includes the process of identifying barriers, determinants and benefits of adopting IPv6 in organisations. Budgets are allocated for the IPv6 project. IT asset inventories are done to ensure they are IPv6 capable. Hardware and/or software are replaced or updated to ensure they have IPv6 capability. IPv6 adoption planning focuses on the protocol integration and co-existence with IPv4. Operational and governance policies are reviewed to integrate IPv6 into the business and organisational structures to ensure successful assimilation of IPv6. Organisational members such as senior level management, IT management and IT staff are provided with IPv6 knowledge or awareness. In this stage, senior level management understand the importance of IPv6, the business implications of not adopting IPv6, the timelines of the IPv6 adoption project, and the cost of IPv6 adoption. IT management should understand the networks, applications and services affected by IPv6 adoption, and come up with a set of activities for the adoption of IPv6 solutions and services. IT staff should undergo IPv6 training or certification courses where they will be trained in the IPv6 technology basics, the mechanisms of IPv6 adoption, and guidelines for IPv6-enabled networks and solutions operations and maintenance. A test bed (pilot test environment) for IPv6 adoption is established at this stage to test it at a smaller scale before assimilating it throughout the organisation.

- *IPv6 Assimilation Stage*:

  This stage involves a full roll-out of IPv6 across the organisation. The solutions architected in the previous stage are implemented in this stage and IPv6 is enabled across the organisation. The assimilation of IPv6 covers the entire IT infrastructure equipment and software upgrade to IPv6, the establishment of IPv6 connectivity between the organisation with its peers, and IPv6-enabling of various services spread across the organisation. At this point, organisational members are required to fully utilise IPv6, and IPv6 is employed in daily work processes. The usage of IPv6 in a more comprehensive and integrated manner to support organisational work is expected to increase organisational efficiency and effectiveness.

The literature on IPv6 adoption has identified the following barriers to the adoption and assimilation of IPv6:

- *Lack of IPv6 skills and experiences*: Most organisations do not have the required IPv6 skills and experiences to adopt and assimilate IPv6 (Dell, 2010). There is a lack of IPv6 subject matter experts (SME) (Grossetete et al., 2008). A lack of IPv6 trained staff may hinder organisations from adopting and fully assimilating IPv6. In contrast, organisations that have the knowledge of IPv6 can boost their adoption process (Hovav & Schuff, 2005) .

- *Perception that IPv6 is immature* (Dell et al., 2008): The perception that IPv6 is still immature causes organisations not to adopt or delay the adoption of the IPv6 process. This perceived immaturity leads to a perception that it is a high-risk technology choice (Bons & Weigand, 2011).

- *Avoidance of being an early adopter* (Dell et al., 2008): As mentioned by Dell et al. (2008), the biggest barrier to organisations' IPv6 adoption is the reluctance of being an early adopter. Organisations try not to be the early adopter as they prefer to learn from other organisation's experiences and avoid unexpected risks.

- *Adoption costs*: One of the most cited adoption barriers is the direct cost of IPv6 adoption, along with the additional training costs and the sunk costs in existing IPv4 infrastructure (Hovav & Popoviciu, 2009). Any IPv6 investments would be considered as cost that is not justifiable (Grossetete et al., 2008).

- *Lack of IPv6 "killer" applications*: The lack of killer applications is also seen as a barrier to the adoption and assimilation of IPv6. Although service providers and enterprises have found cost-effective ways to use IPv6 such as content delivery or facilities maintenance, there is no killer applications for IPv6 (Grossetete et al., 2008).

- *Lack of a business champion*: Some organisations do not think IPv6 has a strong business champion in comparison to other technologies which results in inadequate information available for potential adopters (Hovav & Popoviciu, 2009).
- *Cultural differences*: Cultural differences was mentioned as a challenge in the adoption of digital infrastructure and it could be applied to the context of IPv6. Organisations from certain organisations or countries might try to avoid from uncertainty and therefore, avoid or delay the adoption IPv6.
- *Size and complexity*: The size of the organisation as well as the complexity of IPv6 are barriers of IPv6 adoption. Leavitt (2011) and Bons and Weigand (2011) have indicated that the complexity of IPv6 is a barrier to IPv6 adoption. Large organisations might find it difficult to adopt IPv6 because of the huge number of applications and amount of equipment that they have to replace to upgrade or adopt IPv6. Small organisations might not have the funding required to adopt IPv6 or

might have adequate IPv4 addresses. Although Hovav et al. (2011) found that organisation size does not have a significant impact on IPv6 adoption, Gallaher and Rowe (2006) stressed that organisation size is a barrier to organisations IPv6 adoption.

- *Role of decision makers*: Decision makers or senior level management may not find it necessary to adopt IPv6 and may not give IPv6 priority in the organisation.
- *Workaround technologies exist*: Workaround technologies such as NAT, Dynamic Host Configuration Protocol (DHCP) and Classless Inter-Domain Routing (CIDR)[3] are technologies developed to counter the shortage of IPv4 addresses and become a barrier towards the adoption and assimilation of IPv6 (White et al., 2010).

These factors support the adoption and assimilation of IPv6:

- *Organisational-wide effort*: As IPv6 adoption requires an organisational-wide effort, central organisational direction plays an important role in the IPv6 adoption process (Grossetete et al., 2008). The adoption process requires close coordination and management (Ladid, 2006).

- *Government support*: Governments can support the adoption of digital infrastructure through their ownership of a large number of IT assets and equipment (Che & Lewis, 2010). Government mandates to adopt a new standard reduce the level of risk and uncertainty about the future of that standard, allowing the standard to become dominant (in that country or region), which in return ensures a market for related products (Bons & Weigand, 2011). For example, the transition from analogue to digital mobile telephony, as well as digital television, has been a success through a mandate by various governments. Governments in countries such as Korea, China, Japan, Taiwan, and the USA, have mandated, initiated or promoted

[3] NAT links many Internet-enabled devices through a translation device using a single IPv4 address, DHCP assigns temporary IPv4 addresses to nodes, and CIDR aggregates IP addresses.

IPv6 adoption, resulting in successful adoption. This indicates the efficacy of the government "push" approach (Dell et al., 2008). Hovav et al. (2004) concluded in their research that a government's involvement and sponsorship can hugely impact the assimilation of Internet standards (IPv6).

- *Backward compatibility*: If IPv6 applications and devices can work with their IPv4 counterparts until IPv4 is phased out, firms will be more likely to adopt IPv6 as this will lower the risk of adoption (Hovav et al., 2004). Compatibility is crucial in the Internet environment because interoperability is necessary (Hovav et al., 2004).
- *Network externalities*: The presence of positive network externalities creates an environment amenable to IPv6 adoption (Hovav et al., 2004). Positive network externalities exist when a user's utility for a product or service increases with an increase in users of identical or compatible products or services (Lai et al., 2007). Widespread adoption of IPv6 will lower the barriers of IPv6 adoption for other organisations in the same community/industry as it will make it easier to interact with them.

IPv6 migration should be done gradually across the network to ensure minimal disruption to existing networks (Mason & Mahindra, 2011). A phased approach will help mitigate the various timelines that confine an organisation's integration plans (Grossetete et al., 2008). Planning IPv6 adoption is crucial because the adoption process could have various issues and huge investment may be required (Che & Lewis, 2010). Che and Lewis (2010) also added that the planning of the new architecture may require a great amount of effort and those who are involved in the adoption must have a good IPv6 understanding.

2.4 Summary of Chapter 2

This chapter has reviewed literatures on digital infrastructure, digital infrastructure adoption and assimilation, and IPv6 adoption and assimilation. Most prior research on IPv6 has focused on technical aspects of IPv6 (Colitti et al., 2010; Nikkel, 2007) rather than the organisational adoption aspects of IPv6. The majority of the non-technical IPv6 studies that are available are focused on a country-wide IPv6 adoption effort (AGIMO, 2009; Hovav et al., 2011; Hovav & Kim, 2006; Mason & Mahindra, 2011; White et al., 2010) rather than on organisational IPv6 adoption. Also, IPv6 studies tend to look at only the IPv6 adoption phase (AGIMO, 2009; Hovav et al., 2004; Networks, 2011) and do not consider the assimilation of IPv6. The available studies on IPv6 also neglect organisations in varying stages of IPv6 adoption and assimilation. Organisations in varying stages of IPv6 adoption and assimilation might experience different barriers and determinants of IPv6. Hence, this study provides insights into organisational IPv6 adoption and assimilation rather than a country-wide effort. This study emphasises that the IPv6 assimilation stage is equally as important as the IPv6 adoption stage. This study includes organisations in varying stages of IPv6 to understand its barriers and determinants. In addition, this study includes organisations from different industries and sizes. As the literature has indicated, organisations' size might have or might not have an influence on IPv6 adoption and assimilation. Thus, this study looks into this aspect as well by selecting organisations of different sizes.

The factors discussed in this chapter can be categorised into three domains: institutional forces, organisational resources, and network externalities. For instance, IPv6 skills and resources and adoption costs are organisational resources necessary for successful organisational IPv6 adoption, and government support is an example of an institutional factor. Network externalities are also found to be important for IPv6 adoption. In order to understand the adoption and assimilation of digital infrastructure such as IPv6, the external factors that impact the adoption and assimilation process need to be studied. These factors can influence the organisation's decision to adopt, not to adopt, to assimilate and/or not to assimilate the digital infrastructure. It is also beneficial to learn how the external factors change in importance over time or stages. This will guide the organisation's digital infrastructure adoption and assimilation process and provide a foundation for the organisation to plan and make decisions on the adoption. Since institutional factors are relevant for IPv6 adoption and assimilation, the next chapter discusses institutional theory. In addition, organisational resources (e.g., IPv6 capable equipment, IPv6 skills, etc.) are also crucial for the adoption and assimilation of digital infrastructure such as IPv6 and these are discussed in detail in the next chapter. The impact of network externalities on the IPv6 adoption and assimilation is also described in the next chapter.

Chapter 3: Conceptual Development

This chapter describes the factors influencing the adoption and assimilation of digital infrastructure in organisations. This study stresses that external forces, organisational resources and network externalities are vital for the adoption and assimilation of digital infrastructure. To understand the impact of external forces, institutional theory has been studied and applied in this research.

This chapter is organised in the following way: Section 3.1 covers institutional theory, Section 3.2 discusses the role of organisational resources, Section 3.3 describe the role of network externalities, and Section 3.3 describes the theories used in prior studies of IT adoption and assimilation.

3.1 Institutional Theory

This study argues that external factors are critical in the adoption and assimilation of digital infrastructure, and that the impact of these external factors changes across the stages of IPv6 adoption and assimilation. Some of the external factors that prior research on IPv6 adoption has studied include governmental pressure (Dell et al., 2008) and vendor support (Hovav et al., 2004). These different sources of compulsion on organisations can be usefully examined through the lens of institutional theory. The basic belief of institutional theory is that organisations that are part of the same environment should uphold similar practices and become 'isomorphic' with each other (Kostova, 2002). Isomorphism leads to legitimacy which is crucial for an organisation's survival (Gosain, 2004).

DiMaggio and Powell (1983) explained that structural and behavioural changes in organisations are caused less by issues such as productivity and rivalry than by the structuration of organisational fields (i.e., the need to attain organisational legitimacy). Furusten (2013) highlighted that organisations are intertwined with what occurs around them. In other words, organisations are affected by their environment and the organisations in that environment. Three institutional isomorphic change mechanisms were identified by DiMaggio and Powell (1983): 1) coercive isomorphism, arising out of political influences and legitimacy problems; 2) mimetic isomorphism, caused by the reaction towards uncertainty; and 3) normative isomorphism, which is related to professionalization. Currie (2012, p. 237) defined professionalism as *"the collective struggle of members of an occupation to define the conditions and methods of their work, to control 'the production of producers' and to establish a cognitive base and legitimation for their occupational autonomy"*. Scott (2008) stressed that each one of the isomorphic forces provides distinct justification for claiming legitimacy through official, moral or cultural authorisation.

For more than three decades, institutional isomorphism has contributed greatly to studies of institutional theory (Currie, 2012). Not only are institutional forces *"symbolic"*, they are also appealing because they create *"cognitive schema, normative guidance, and rules that constrain and empower social behavior"* (Scott, 2008, p. 429). It is often questioned whether the institutional environment is really crucial to organisations. Furusten (2013) maintained that organisations are unable to discount their institutional environment; that is, if they do not obey the requests of the actors and products in their environment, they will lose the legitimacy required to operate, which will lead to their customers and suppliers leaving them.

3.2.1 Use of institutional theory in IT adoption research

Institutional theory has been extensively used in the field of management and has started appearing in information systems (IS) studies (Liang et al., 2007). For instance, Gosain (2004) studied enterprise information systems both as carriers and objects of institutional forces. Hu et al. (2007) examined the presence of coercive, normative and mimetic forces in improving organisational information systems security. Currie (2009) suggested that institutional theory provides a strong theoretical foundation for the investigation of IT adoption and assimilation across organisations and markets. Since digital infrastructure adoption and assimilation is more complex than the adoption and assimilation of non-infrastructure IT, it will be useful to understand how external forces influence the digital infrastructure adoption and assimilation process. However, the influence of institutional factors on digital infrastructure has been less studied and the research that does exist (Iannacci (2010, p. 35):

> *has taken a technological slant at the expense of the institutional perspective, to the point that it has looked at their development from a narrow technological perspective to emphasise the irreversibility of the (technical) installed base and the role of technology as an ally*

A related stream of literature that has drawn on institutional theory is the study of innovation. Institutional theorists have emphasised that the role of the external environment and social norms is to elevate the assimilation of technology within organisations through isomorphic pressures (Mazza & Pedersen, 2008). Damanpour (1991) also mentioned that the interaction with external entities is crucial during the initial as well as the later phases of the innovation life cycle. Currie (2012) used the isomorphic change concept to study innovation in health. Liang et al. (2007) study examined the influence of social, technical and political institutional pressure on the assimilation of enterprise systems. Hirt and Swanson (2001) stressed the importance of external entities (consultants, vendors and industry conferences) in the post-adoption of Enterprise Resource Planning (ERP). Isomorphic pressures such as coercive, mimetic or normative forces can drive organisations to adopt an innovation (Tschoegl, 2010). Aguila-Obra and Padilla-Meléndez (2006) stated that the external factors related to Internet adoption are *"pressure from competitors, customers or suppliers; the role of* *government (incentives); partners' alliances; technological infrastructure; technology consultants; image of Internet technology and users expectations"*.

In short, numerous researchers have acknowledged that institutional factors are vital to the adoption and/or assimilation of technology (Damanpour, 1991; Hirt & Swanson, 2001; Liang et al., 2007; Mazza & Pedersen, 2008). In addition, research on IT-enabled change often neglects the change process, which means that it is a norm to research *"the role of technology"* without taking into account *"the policy and professional agendas (e.g. coercive, regulative, normative, cultural and mimetic forces)"* (Currie (2009, p. 72).

3.2.2 Explaining IPv6 adoption with institutional theory

Institutional theory seeks to explain the process of institutional isomorphic change that exists in organisations. The three isomorphic forces described above are explained below in the context of IPv6 adoption:

1. *Coercive isomorphism* is a consequence of formal and informal pressure applied on organisations by other organisations that they rely on, and by cultural expectations in the society that the organisations function within (DiMaggio & Powell, 1983). DiMaggio and Powell (1983, p. 150) argued that these pressures could also be described *"as force, as persuasion, or as invitations to join in collusion"*. In the IPv6 scenario, the three external coercive pressures that influence IPv6 adoption are:
    a. <u>Global depletion of IPv4 addresses</u>: This is the main reason for organisations to adopt IPv6. Bluecat (2011) emphasized that the depletion of IPv4 addresses indicates that organisations are no longer able to ignore IPv6. Since the last IPv4 address block was assigned, Internet Corporation for Assigned Names and Numbers (ICANN) has

been pushing for IPv6 adoption (Delahunty, 2011). This indicates the role that IPv4 depletion plays in the adoption of IPv6 by organisations.

b. IPv6 mandate by government: Governments play a crucial role in IPv6 adoption by setting policies to stimulate IPv6 development; identifying and facilitating technology and market solutions; and building out infrastructure to simplify private sector adoption (Cisco, 2010). Government agencies can improve the quality of their public services through elevated security, mobility, and information access and collaboration features available after adopting IPv6 (Talcove, 2007). Several governments around the world have pointed out that the deployment of IPv6 is critical to the growth and continuity of government services and are raising awareness through test beds, incentives and/or mandates and procurement measures (ISOC, 2009). Governments are concerned with organisations that are reluctant to adopt IPv6 or are misinformed because there could be implications for a country's security and economic vitality (Cisco, 2010). ISOC (2009) noted that the two ways that governments can ensure that the stability and viability of the Internet are not compromised is firstly, by emphasizing the significance of IPv6 to ensure the continuity of business and national economy and secondly, by leading by example. Government-mandated and government-sponsored IPv6 adoptions have provided clear guidance that a change is necessary (Grossetete et al., 2008). Hardware and software vendors will also be pressured with governmental IPv6 mandates to ensure that they provide IPv6 support that improves performance and scalability, and is uniform across platforms (Grossetete et al., 2008).

c. Desire to remain competitive: Another factor driving organisations' IPv6 adoption is the need to have a competitive edge. In today's globalised world, connectivity with the global marketplace is vital for organisations and if the services provided by organisations do not have IPv6 support, they could lose potential customers and business partners (Hovav & Popoviciu, 2009).

2. *Mimetic isomorphism* is caused by environmental uncertainty. As DiMaggio and Powell (1983, p. 151) argue, *"uncertainty is also a powerful force that encourages imitation"*. Aldrich and Pfeffer (1976) mentioned that short-term advantages can be achieved by organisations that adopt innovations that have been successfully adopted by other organisations. When organisations do not possess the knowledge and skills required to adopt IPv6, they model themselves after other organisations that have successfully implemented the technology. Lack of knowledge and skills has been identified as a barrier towards IPv6 adoption in organisations (Dell, 2010). According to Hovav and Schuff (2005), organisations regarded as innovators are most likely to be early adopters and are characterised as being more "venturesome". Literatures that have discussed the issues of early and late IPv6 adopters indicate that late adopters try to model their adoption based on organisations that have adopted IPv6 (Hovav et al., 2004; Hovav & Schuff, 2005). Grossetete et al. (2008) suggested that organisations should leverage what they learn from other organisations to streamline the integration process and increase their chances of success.

3. *Normative isomorphism* arises from professionalisation. DiMaggio and Powell (1983, p. 152) defined professionalisation as *"a collective struggle of members of an occupation to define the conditions and methods of their work, to control the production of producers and to establish a cognitive base and legitimization*

for their occupational autonomy". DiMaggio and Powell (1983) also highlighted that despite the difference of professionals from different organisations, they still have certain similarities and exchange of information between them contributes to acknowledged hierarchy status which becomes a matrix for information flows and personnel movement across organisations. Many IPv6 campaigns and seminars have been held globally to raise awareness and promote IPv6 adoption, and many organisations have sent their representatives to these events to obtain a better understanding of IPv6 adoption. The socialisation of these representatives through their participation in these events creates normative pressure to adopt IPv6. Scott (1987) indicated that normative pressure from accrediting agencies provides an additional incentive to conform. The Global IPv6 Forum (http://www.ipv6forum.com/) has various IPv6 certification and skills programmes to encourage organisations to adopt IPv6, and has chapters in most of the countries around the globe. For example, the New Zealand IPv6 Taskforce promotes IPv6 adoption and assists with regional training and education programmes as well as implementation planning (http://www.ipv6.org.nz/). Gosain (2004, p. 163) claimed that *"normative isomorphism derives from professionalization: formal education and the growth and elaboration of professional networks legitimate and rapidly diffuse new models. Organizations belonging to such professional networks tend to adapt."* In other words, normative pressure as a result of professionalisation causes organisations to assimilate new technology and these professionals will adapt better to the technology.

Institutional theory hypothesises that organisations seek social success through legitimacy accumulation, which makes organisations more homogenous (DiMaggio & Powell, 1983; Nicholas, 2012). This study believes that the three isomorphic forces (coercive, mimetic and normative) discussed above will pressure organisations to adopt and assimilate digital infrastructure components, such as IPv6, to gain legitimacy. Organisations will want to ensure that they meet the expectations or rules set by the government, professional associations and social groups. Legitimacy in this context refers to *"a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions"* (Suchman, 1995, p. 574). As stressed by Heino and Tuominen (2008), the inability to react towards institutional forces could endanger organisations' legitimacy. Therefore, organisations will adopt and/or assimilate the particular digital infrastructure component to make sure that their position in the environment is not at risk and they are not left behind. Hovav et al. (2011) highlighted that the adoption of IPv6 depends on the protocol's usefulness to the organisation and also the importance of the environment. Their study found that IPv6 adoption in South Korea was influenced by government strategy, which generated user demand and normative pressure. The model developed by the authors includes the influence of environmental conditions such as switching costs, resource concentration and power, government sponsorship and normative pressure on IPv6 adoption decisions. Hovav et al. (2011) collected data through a survey which provided confirmation that the role of institutional forces in the adoption of digital infrastructure such as IPv6 should not be taken for granted and should be investigated further. This study therefore extends Hovav et al. (2011) study by using a case study approach to obtain an in-depth understanding of the effect of all three isomorphic forces on the organisational IPv6 adoption and assimilation.

It is important to note that institutional theory is a useful lens for analysing external factors that can be both catalysts for change, as well as barriers to change (Currie, 2009).

In summary, there is a need to investigate the impact of institutional forces (coercive, mimetic and normative) on digital infrastructure (such as IPv6) adoption and assimilation in the field. Data collected from the field is useful to confirm the presence of these forces and to understand how these forces have influenced the adoption and assimilation process. It is also vital to see how these forces across stages of the digital infrastructure adoption and assimilation.

The importance of organisational resources in the adoption and assimilation of IPv6 will be discussed in the next section (3.2).

3.2 Organisational Resources

Besides institutional factors, organisational resources also play an important role in the adoption and assimilation of digital infrastructure. If organisations do not possess the adequate required resources to adopt IPv6, they will not be inclined to adopt it. Fichman (2004) model of IT platform adoption examines four perspectives as determinants. One of the determinants – the bandwagon perspective – is similar to the institutional forces discussed in the previous section, while the other three – the technology-strategy perspective, organisational learning perspective and adaptation perspective – are akin to organisational resources.

In the context of IPv6 adoption and assimilation, the resources that are relevant based on prior studies are IPv6 skills and knowledge (human), hardware and software that supports IPv6 (technology), and top management and vendor support (relationships). These resources are required for successful IPv6 adoption and assimilation in organisations. These resources are discussed below:

1. <u>Human resources</u>, such as IPv6 skills and knowledge: In order for organisations to adopt and assimilate IPv6, they need to have staff with the required skills and knowledge. AGIMO (2009) stressed that the lack of IPv6 skills in the

marketplace might cause the Australian government to be unable to employ qualified IPv6 skilled staff with the technical ability to implement IPv6. Grossetete et al. (2008) highlighted that the lack of IPv6 expertise, knowledge and practical experiences is one of the challenges of IPv6 adoption cited by early adopters. Dell (2010) mentioned that most organisations lack IPv6 skills and experiences. In Mason and Mahindra (2011) study, IPv6 skill building plays a key role in the adoption of IPv6.

2. <u>Technological resources</u>, such as IPv6 hardware and software support: Organisations that plan to adopt and assimilate IPv6 should also have IPv6 capable hardware and software. Networks (2011) emphasised that one of the challenges of organisations' IPv6 adoption is that their hardware and software are not IPv6 capable. AGIMO (2009) maintained that hardware, operating systems, applications and ICT gateways should be upgraded to IPv6 in order for the organisation to move to the state of IPv6 readiness. Ahlinder and Eriksson (2011) regarded it worthwhile for organisations to invest in getting IPv6-enabled software and hardware because the world is progressing towards IPv6. The Internet of Things also presents an opportunity or a reason for organisations to ensure their equipment is IPv6 capable.

3. <u>Relationship resources</u>, such as top management and vendor support: Top management and vendor support are also essential for organisations who intend to successfully adopt and assimilate IPv6. Mason and Mahindra (2011) stressed that the role of top level management is important in organisations' IPv6 adoption as they need to know the importance of IPv6 and the business impact of non-adoption while setting timelines and providing the necessary investment

to develop IPv6 products. Leavitt (2011) noted that most vendor equipment now provides IPv6 support. Hovav and Schuff (2005) believed that vendors can profit from incorporating IPv6 into their devices and should design the devices to enhance IPv6 features.

Organisations that plan to adopt and assimilate IPv6, or are adopting and assimilating IPv6, need to have adequate organisational resources that will support the IPv6 adoption and assimilation. Various organisational resources have been highlighted as important for IPv6 adoption by prior research (Grossetete et al., 2008; Hovav et al., 2004; OECD, 2014) and these resources have been presented in this section. However, there are few studies that have compiled the necessary organisational resources that are necessary for organisations' IPv6 adoption and assimilation. This study has categorised organisational resources essential for IPv6 adoption and assimilation into three categories: human resources, technological resources, and relationship resources. There is a need to understand experiences of organisations in terms of whether relevant organisational resources support its IPv6 adoption and assimilation, or whether the lack of organisational resources hinders its IPv6 adoption and assimilation. The data collection will be used to understand the impact of the three categories of organisational resources mentioned above on organisations' IPv6 adoption and assimilation.

The relative importance of these resources vis-à-vis the influence of institutional forces in the adoption and assimilation process of digital infrastructure components, such as IPv6, were examined in the field through the case study findings. The next section presents the impact of network externalities on IPv6 adoption.

3.3 Network Externalities

Networks have rarely featured in studies on the adoption and diffusion of digital infrastructure, which is surprising considering digital infrastructure's role as a platform technology on which applications or services can be built. Network forms of organisation include joint ventures, strategic alliances, business groups, franchises, and outsourcing agreements (Podolny & Page, 1998).

A network's value increases based on the number of locations it serves (the network effect) and the number of its users (the production scale effect). Network externalities are the by-products that appear as networks grow (Lai et al., 2007). Positive network externalities exist when a user's utility for a product or service increases with an increase in users of identical or compatible products or services while negative network externalities exist when a user's utility decreases with an increase in other agents who consume the same products or services (Lai et al., 2007). Network externalities can also be direct and indirect. Direct network externalities can be seen when the benefits derived from network technologies are dependent on the number of users or network size while indirect (or complementary) network externalities are market mediated effects arising from the linkage of a utility of a customer and the number of other complementary products (Lai et al., 2007).

An organization's core technology connects it to its environment, as the environment is the source of inputs and the recipients of outputs, as well as the primary source of technical knowledge, work techniques and tools employed by the organisation (Scott & Meyer, 1994). Thus, technologies are network-dependent by their very nature, and technology adoption is often based on an evaluation of the benefits of adopting an innovation based on the number of current and potential adopters (Hovav et al., 2004). Studies that use analytical models based on network effects and externalities have been carried out on the adoption and diffusion of technologies (Kauffman et al., 2000). For example, Saloner and Shepard (1995) found that network effects played a role in the adoption of Automated Teller Machines (ATMs), since banks with many branches adopted ATMs earlier compared to banks with fewer branches. Lai et al. (2007)

revealed that e-business adoption was influenced by network externalities, with organisations adopting it when their peers and partners had done so.

However, there are not many studies available on the effects of networks on the adoption and diffusion of digital infrastructure. The only relevant study encountered that discusses the impact of network effects on digital infrastructure is that of Zhu et al. (2006) which examined the role that network effects play in open-standard IOS adoption decisions. This is surprising because, compared to other technologies, infrastructure technologies are more reliant on networks because of their role as platforms for other services and applications.

The dynamics of digital infrastructure adoption is nonlinear and path-dependent as the process is influenced by the network effects of the people involved and the network of technologies involved (Hanseth & Lyytinen, 2010). This highlights the importance of understanding the network of actors who are involved in the adoption and diffusion of digital infrastructure either actively or passively. For instance, networks influence the creation of complementary services, enhancing their viability.

In addition, the logic of digital infrastructures has implications when choosing the most appropriate structure through which know-how about infrastructure adoption is transferred, which is crucial for facilitating adoption and diffusion.

In the context of IPv6 adoption, network externalities play a vital role. According to Hovav et al. (2004), network externalities are crucial when studying the adoption of IPv6 because of the need for interoperability. It is important that a large number of organisations adopt IPv6 in order to create positive network externalities that in return can reduce adoption risk resulting from central governance absence (Hovav et al., 2004).

According to Zhu et al. (2006)'s study on the network effects of IOS adoption, direct network effects refer to the increase of adopters based on the sharing of information by individual adopters with a larger number of partners and indirect network effects refer to the increase of compatible software and hardware as the digital infrastructure diffuses. In the context of IPv6, direct network effects could occur when an individual organisation adopts IPv6 and shares the information with its network partners while indirect network effects happen when there is an increase of hardware and software that support IPv6. A number of vendors (e.g., Microsoft and Apple) have included IPv6 support in many of their products while a number of service providers (e.g., Comcast, Verizon Wireless) have made substantial efforts to extend IPv6 services through their access networks (OECD, 2014) which shows indirect network effects based on the effort to accelerate the adoption and diffusion of IPv6.

Network externalities consist of partner influence (i.e., the influence of suppliers, customers and others) and peer influence (i.e., the influence of organisations that are in the same industry) (Lai et al., 2007; Zhu et al., 2006).

Katz and Shapiro (1986) stated that any technology that requires specific training is subject to network externalities. As the previous chapter stated, staff need to be trained to be able to adopt IPv6. Through network externalities, organisations will be motivated to adopt IPv6. The association and influence of partners and peers can motivate organisations to train their technical staff to be able to configure and support IPv6 in their organisation. Hovav et al. (2004) mentioned that an organization's decision to upgrade to IPv6 will also depend on the existing infrastructure of other related organisations such as competitors, customers and vendors. This shows the influence of networks in the IPv6 adoption decision. Organisations might be motivated to adopt IPv6 because of the demands of their customers. The influence of organisations' networks will be further examined through the data collection.

The next section (3.5) indicates theories used by other organisational IT adoption and assimilation studies. This will assist in emphasising the uniqueness and importance of this study.

3.5 Theories Applied by other Organisational IT Adoption and Assimilation Studies

Table 2 summarises the theories used in studies of organisational IT adoption and assimilation. The theory or theories used by various IT adoption and assimilation studies, such as IPv6, 3G, RFID, grid computing, EDI, green IS & IT, open source platforms, website, enterprise systems and other IT in organisations, are summarised in the table. Some of the studies are technology specific studies, while others are meta-analyses or literature reviews on IT adoption and/or assimilation in organisations.

Table 2 Theories used by Different Technology Adoptions/Assimilations

Paper	**Technology**	**Theories Used**	**Relevance of the Theories**
(Hovav et al., 2004)	IPv6 adoption	Diffusion of Innovation (DOI)	Seeks to understand and explain how innovations are spread within an organisational context.
(Tsai et al., 2010)	RFID adoption	Diffusion of Innovation (DOI)	DOI applied to investigate the effects of innovation, organisation, and supply chain integration on RFID adoption intention.
(Messerschmidt & Hinz, 2013)	Grid computing adoption	Institutional Theory and Organisational Capability Theory	Institutional and organisational capability theory suggests an adoption model that accounts for inter- and intra-organizational influences. These factors are important predictors of the technology adoption process.
(Liu et al., 2008)	IT adoption (critical review of 211 papers)	Innovation Diffusion Theory (IDT), Technology Acceptance Model (TAM) and Theory of Planned	34 theories used by various IT adoption papers. 84 papers used TAM as their foundation because of its simplicity and validity; 28

		Behaviours (TPB)	papers used IDT because it can be used to examine organisational and individual adoption, and 19 papers used TPB. 15 other theories or models (from other disciplines: economics, psychology, sociology & institutional theories) were adopted three times or more to examine IT adoption. The theoretical foundation of organisation adoption is richer than individual adoption. There is no dominant theory in organisational adoption but IDT is leading,
(Hameed et al., 2012)	IT innovation adoption in organizations	Diffusion of Innovation (DOI), Technology Acceptance Model (TAM), Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB)	The authors analysed a number of studies. DOI was more extensively used in the studies that performed organizational analysis while TAM, TRA and TPB were utilized mainly for individual level analysis. The TOE framework has been comprehensively approved for organizational level studies of IT innovation adoption.
(Kuan & Chau, 2001)	Adoption of Electronic Data Interchange (EDI) – 575 small firms in Hong Kong	Technology-Organization-Environment (TOE) Framework	The authors found that TOE is a useful approach for examining factors affecting the EDI adoption decision. For small businesses, direct benefits are perceived to be higher by adopter firms than by non-adopter firms, indirect benefits are perceived differently by either adopter firms or non-adopter firms, contrary to the findings on large business.
(Jeyaraj et al., 2006)	51 studies on organisational IT adoption	Innovation Diffusion Theory (IDT), Diffusion/Implementation	Using these theories, the authors examined IT (EDI, telecommunication

	between 1992 and 2003	Model, Tri-Core Model	technologies, DBMS, smart-card payment systems & computer-aided payment systems) adoption at different levels of the organisation such as functional units and entire organizations. These theories deal with the decision to adopt, the intention to adopt, the intention to use, and adoption and diffusion.
(Lai & Guynes, 1997)	Surveyed Business Week 1000 companies to determine whether organizational strategies, structure or context facilitate the adoption decision of integrated services digital networks (ISDN)	Innovation Diffusion Theory (IDT) and Critical Mass Theory	IDT and critical mass theories provide different perspectives, yet complement each other in understanding the adoption behaviour of communication technologies such as ISDN and EDI.
(Dedrick & West, 2004)	Open Source Platform adoption	Grounded theory with guidance of Technology-Organization-Environment (TOE) Framework	The authors found that the willingness and ability of organisations to adopt LINUX depends on a range of factors consistent with some of the key predictions of diffusion of innovation theory such as compatibility with current technologies and skills, organisational resources and tasks, and the availability of external technological resources.
(Chen et al., 2011)	Green IS & IT adoption	Institutional theory	The research contributed to the literature of institutional theory by examining the interaction between institutional forces. The study provided empirical support for the

			complementary effects between mimetic and coercive pressures in driving the adoption of IS & IT-based product stewardship by organisations.
(Zhang & Dhaliwal, 2009)	Organisation technology adoption for operations and supply chain management	Resource-Based View (RBV) theory and Institutional theory	This study identified internal organisational resource factors and institutional factors from supply chain environments that play a key role in firms' adoption of technologies for supply chain operations. It simultaneously highlighted the importance of sustaining higher levels of managerial IT knowledge and understanding partners' technology adoption actions and interrelationships as being key variables.
(Pan & Jang, 2008)	Enterprise Resource Planning (ERP) adoption by 99 firms in Taiwan's communication industry	Technology-Organization-Environment (TOE) Framework	The primary focus of the study was to determine which factors in the TOE framework were responsible for the adoption of ERP. The model posits eight adoption predictors within the three contexts of the TOE framework: technology – IT infrastructure, technology readiness; organization – size, perceived barriers; and environment – production and operations improvement, enhancement of products and services, competitive pressure and regulatory policy.
(Chau & Tam, 1997)	Open Systems adoption	Technology-Organization-Environment (TOE) Framework	The TOE framework provides a useful starting point to look into innovation adoptions and provides an opportunity to

			evaluate the importance of different factors which affect the propensity to adopt open systems. Care must be taken when applying this framework to study the links between the contexts and adoption decision discussed in the framework.
(Beatty et al., 2001)	Corporate website adoption	Innovation Diffusion Theory (IDT)	The authors' findings are consistent with IDT where the early reasons for adoption were based on benefits, compatibility of the technology and organizational support.
(Fichman, 1992)	Information Technology diffusion – critical review of 18 empirical studies published during the period 1981-1991	Innovation Diffusion Theory (IDT)	Diffusion theory provides a useful perspective on one of the most persistent and challenging topics in the IT field, especially on how to improve technology assessment and implementation.
(Cooper & Zmud, 1990)	Material Requirements Planning (MRP) implementation & diffusion approach	IT implementation process model (process approach)	The process approach focuses on the dynamics of IT implementation, examining the behaviour of stakeholders over time.
(Williams et al., 2011)	IS/IT adoption and diffusion (systematic review)	Unified Theory of Acceptance and Use of Technology (UTAUT)	UTAUT provides a useful tool to evaluate the potential success of new technology initiation and assists in identifying factors that are likely to influence technology adoption. This review highlighted under-employed approaches.
(Oliveira & Martins, 2011)	IT adoption models at firm level (literature review)	Diffusion of Innovation (DOI) and Technology-Organization-Environment (TOE) Framework	The authors found that most empirical studies were derived from the DOI theory and the TOE framework. The TOE framework includes the

			environment context which is not available through DOI theory. It provides explanation for intra-firm innovation adoption and it is considered as a more complete model. The TOE framework has a strong theoretical foundation which is consistent with empirical support and the potential of IS adoption application. It was combined with DOI theory, institutional theory and other model to obtain different factors.
(Basoglu et al., 2007)	Organisational adoption of Enterprise Resource Planning (ERP)	Technology Acceptance Model (TAM)	The authors' goal was to build a framework to understand the organisational adoption of ERP systems, taking into consideration previous technology adoption models like TAM, ERP failure factors, opinions of local experts and past research while constructing the model. They also aimed to prove that not only the use but also end users' satisfaction influence organisational studies.
(Aguila-Obra & Padilla-Meléndez, 2006)	Internet technology adoption in organisations	Technology-Organization-Environment (TOE) Framework	The authors showed that technological resources and managerial capabilities are the main organisational factors to explain the Internet technology adoption process.
(Russell & Hoag, 2004)	Social and organisational influences on IT supply chain innovations adoption	Diffusion of Innovations (DOI)	The authors used DOI was used to understand and analyse IT innovation implementation challenges. Results showed that several social and organisational factors do affect implementation success such as users' perspective of the

			innovation, the firm's culture, the type of communication channels used to diffuse knowledge of the innovation and various leadership factors.
(Ramdani et al., 2009)	Enterprise systems (ES) adoption by SMEs	Technology-Organization-Environment (TOE) Framework	The authors used TOE used to develop a model to predict which SMEs are more likely to become adopters of ES. Findings showed that SMEs are more influenced by technological and organisational factors than environmental factors in their adoption of ES.
(Riemenschneider et al., 2003)	IT adoption decisions in small business	Theory of Planned Behaviour (TPB) and Technology Acceptance Model (TAM)	Results showed that a collected model of underlying categories of cognitions from TPB and TAM provide a better fit than either TAM or TPB alone.
(Wang et al., 2010)	Determinants of RFID adoption in the manufacturing industry	Technology-Organization-Environment (TOE) Framework	Key findings included the fact that the implementation of RFID by a firm depends on its technological, organisational and environmental contexts.

Table 2 lists the theories that have been most commonly-used in studies of organisational IT adoption and/or assimilation. These theories are Diffusion of Innovation (DOI) or Innovation Diffusion Theory (IDT), Technology Acceptance Model (TAM) and Technology-Organization-Environment (TOE) Framework. Other theories that have been used are Institutional Theory, Organizational Capability Theory, Theory of Planned Behaviour (TPB), Theory of Reasoned Action (TRA), Resource-Based View (RBV) theory, and Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT was originally suggested and approved as a unified theoretical foundation to aid research on the adoption and diffusion of IS/IT. It was created based on the (Williams et al., 2011, p. 1):

> *review, mapping and integration of eight dominant theories and models, viz: the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Motivational Model (MM), the Theory of Planned Behaviour (TPB), a combined Theory of Planned Behavior/Technology Acceptance Model (C-TPB-TAM), the Model of PC Utilization (MPCU), the Innovation Diffusion Theory (IDT) and the Social Cognitive Theory (SCT)*

Table 2 shows the there are no available studies on the influence of institutional forces, network externalities and organisational resources on digital infrastructure adoption and the assimilation. Most of the theories mentioned in Table 2 are focused specifically on technology acceptance or diffusion which is not the main focus of this research. This research moves beyond the sole study of technology. It stresses that external forces, network externalities and organisational resources determine the adoption and assimilation of digital infrastructure such as IPv6. The TOE framework used in organisational studies of technology is also unsuitable for this study as it emphasizes on the impact of technology, organisation and environment on the adoption of a new technology. UTAUT is also inappropriate for the study of the IPv6 adoption and assimilation phenomena because it is primarily used for understanding users' acceptance of a technology which is again, not the focus of this study.

This study focuses on the whole process of digital infrastructure adoption and assimilation with the identification of crucial factors such as institutional forces, network externalities and organisational resources across the stages. The literature review conducted in previous sections shows that the external forces impacting the adoption and assimilation of IPv6 are integrated into the existing institutional factors (coercive, mimetic and normative). Therefore, applying institutional theory to this study is more appropriate than using the TOE framework.

As with all technologies, IPv6 adoption occurs in stages, from the initial decision to trial the new protocol in a specific location or function to ultimately assimilating it across the entires organisation. At each stage, a group decision-making process occurs, so as to incorporate and consider the range of views in an organisation, as argued by Premkumar et al. (1997). Based on this perspective, this study uses a phased approach to study the adoption and assimilation of IPv6. The phased approach ensures that organisations' IPv6 adoption occurs without the risk of endangering their network infrastructure or incurring unneccesary costs (Infoblox, 2013).

According to Gallivan (2001), Cooper and Zmud's (1990) six-stage model is useful for illustrating technology adoption in organisations. Gallivan (2001) also stressed that the model explains the factors and events that influence various stages of technology adoption. The six stages of the Cooper and Zmud (1990) model (initiation, adoption, adaptation, acceptance, routinization and infusion) are combined into two stages in Section 2.3.3, Chapter 2. The first stage is Initiation and Adoption, and the second stage is Assimilation.

In summary, a stage approach is useful for understanding IPv6 adoption and assimilation, as it reflects organisational practices. The case studies were conducted so as to capture the factors (institutional forces, network externalities and organisational resources) that influence the different stages of IPv6 adoption and assimilation.

3.6 Summary of Chapter 3

In conclusion, this study studies the various stages of organisational IPv6 adoption and assimilation to understand the influences of institutional forces, organisational resources and network externalities across stages of the process. Chapter 2 discussed the adoption and assimilation of digital infrastructure, especially in the context of IPv6. Chapter 3 stressed the influence of institutional forces, organisational resources and network externalities on the IPv6 adoption and assimilation process. The next chapter describes the research method used by this study in the collection of data to support the findings of the literatures.

Chapter 4: Research Methodology

This chapter describes and justifies the research methodology adopted by this study. This study uses the post-positivist case study methodology to answer its research questions. The chapter begins with a description of qualitative research and the reasons why it is appropriate here, followed by justification for the use of a post-positivist paradigm. Next, the details of the methodology are presented: how the research sites were chosen, and how the data was collected and analysed.

4.1 Qualitative Research

Researchers collect data using quantitative or qualitative methods or a mix of both methods, based on their philosophical paradigm and the state of the topic that they are studying. If the topic they are studying is relatively new, they may not have adequate participants for a quantitative survey. Thus, they may choose to conduct a qualitative interview to collect data. Quantitative research is deductive in nature where the researcher creates a theoretical framework to generate hypotheses or theoretical propositions. In contrast, qualitative research is more inductive in nature where in-depth observations of the phenomena are made to generate relevant concepts, propositions and theory. In qualitative research, data is gathered through observations, interviews and documents which are then systematically analysed through various techniques (Kaplan & Maxwell, 2005).

The qualitative approach was chosen for this study because the adoption and assimilation of IPv6 in organisations is an under-studied phenomenon (Hovav et al., 2004) and requires more in-depth analysis. Miles and Huberman (1994, p. 1) stated that, "*Qualitative data are a source of well-grounded, rich descriptions and explanations of processes in identifiable local contexts.*"

The adoption and assimilation of digital infrastructure in organisations is rather complicated as it is a central component of an organisation's network. Digital infrastructure is the core of an organisation's processes, and it connects groups and individuals. It is deeply embedded into the organisation's operations and it takes time to change. The change might have implications for organisational policies and its day-to-day operations. Therefore, studying digital infrastructure adoption and assimilation can assist organisations in the process.

One of the gaps in digital infrastructure research is understanding the stages of digital infrastructure adoption and assimilation. The adoption and assimilation of digital infrastructure such as IPv6 is done in phases. In order to fully assimilate IPv6 across the organisation, it first has to be introduced to the organisation, then adopted and finally, assimilated. However, there are factors or forces that are determinants or obstacles towards the adoption and assimilation of digital infrastructure. To understand these forces, it is critical to understand the adoption and assimilation process. Therefore, it is vital to have an insight into the process of digital infrastructure adoption and assimilation.

Rich data obtained by qualitative research methods such as interviews is necessary to understand the perspectives and behaviours of people involved in their organisation's adoption and assimilation of the IPv6 process. Interviews can provide clarity on the institutional forces, organisational resources and network externalities that this study aims to understand. Participants were able to elaborate in detail the barriers and determinants of their organisation's IPv6 adoption and assimilation.

Since the adoption of digital infrastructure in organisations is understudied, a quantitative approach such as survey, which is more of a hands-off approach, is inappropriate or inadequate to understand this phenomenon.

Drawing on the work of Creswell (2012), qualitative research was also selected because of its consistency with this study's post-positivist research paradigm, that will be explained more in the next section. Prior studies in this field have used a variety of approaches, as shown in Table 3. In comparison to earlier studies, this study uses qualitative methods to answer its research questions, which emphasise the process and multi-level context of infrastructure adoption and assimilation. Hovav et al. (2004) undertook a study on IPv6; however, this was a study focused largely on a review of the literature relating to IPv6.

Table 3 Research Methods used in Prior Studies on Digital Infrastructure Adoption and Assimilation

Papers	**Type of Digital Infrastructure**	**Methods Used**
Hovav et al. (2004)	IPv6	Theoretical Framework based on Literature Review
Zinszer et al. (2013)	Health Information Technology (HIT)	Qualitative Case Study
Poon et al. (2006)	Health Information Technology (HIT)	Multi-site Qualitative Case study
Sahay et al. (2009)	Health e-Infrastructures	Qualitative Case Study – Observation, Documentations and Interviews
DesRoches et al. (2013)	Electronic Health Records	Quantitative Survey
Greenhalgh et al. (2010)	Electronic Health Records	Multilevel Case Study – Interview and Observation
Lorence et al. (2002)	Electronic Patient Record (EPR)	Quantitative Survey
Tam and Ho (2007)	Micropayment Infrastructure - Mondex	Quantitative Survey
Chong and Ooi (2008)	RosettaNet Standards	Quantitative Survey
Barjak et al. (2009)	e-Infrastructure	Qualitative Case Study
Barjak et al. (2010)	e-Infrastructure	Quantitative Survey
Bygstad (2010)	Corporate IT Infrastructure	Critical Realist Case Study
Pipek and Wulf (2009)	Groupware Infrastructure	Qualitative Case Study

Ribes and Finholt (2009)	Cyberinfrastructure	Qualitative Case Study – Documentation & Interview
Shang et al. (2005)	Internet Electronic Data Interchange (EDI)	Multiple Case Study (Qualitative)
Nielsen and Aanestad (2006)	Content Service Platform for Mobile Phones	Qualitative Case Study – Interviews
Png et al. (2001)	Private Leased Circuits, ISDN, X.25 and Frame Relay	Quantitative Survey
Racherla and Mandviwalla (2013)	Wireless Initiative	Qualitative Case Study
Zhu et al. (2006)	Open-Standard Electronic Inter-organisational Systems (IOS)	Quantitative Survey
Messerschmidt and Hinz (2013)	Grid Computing	Quantitative Survey
Trigueros-Preciado et al. (2013)	Cloud Computing	Qualitative (Focus Group Meetings) and Quantitative Survey
Morgan and Conboy (2013)	Cloud Computing	Qualitative Case Study
Shareef (2013)	Cloud Computing	Qualitative Case Study Interview
Low et al. (2011)	Cloud Computing	Quantitative Survey

4.2 Qualitative Post-Positivist Research

Epistemologically, research can take a positivist, interpretive or critical stance (Orlikowski & Baroudi, 1991). Positivist research is the most common among the three types of epistemologies (Liu & Myers, 2011). Positivist research takes place on the basis that there is an existing relationship with the phenomena and it largely seeks to test theory in the hopes of achieving a better understanding of the phenomena (Orlikowski & Baroudi, 1991). Generally, most positivist research uses quantitative methods, such as Gefen and Straub (2005) study of the usage of PLS-graph on factorial validity. However, qualitative methods have also been used for positivist research. Dubé and Paré (2003) provided an overview of the practices, trends and recommendations to enhance the rigor of IS positivist case research. Shanks (2002) similarly provided guidelines to conduct positivist case study research in IS.

Interpretive research, on the other hand, assumes that people create and associate their own subjective and intersubjective interpretations when they are interacting with others around them and researchers aim to understand this phenomena through the assessment of their participants (Orlikowski & Baroudi, 1991). Critical researchers are more critical towards the status quo and regard the beliefs of individuals to be deep-seated, structural contradictions within social systems. The researchers' aim, therefore, is to transform these alienating and restrictive social conditions (Orlikowski & Baroudi, 1991).

This research adopts a post-positivist research epistemology. According to Creswell (2009, p. 7), post-positivist research depicts the thinking after positivism while challenging the conventional complete "truth of knowledge". Creswell (2009) also stated that post-positivists perceive that we cannot be definitive in our view of knowledge when researching human behaviour and actions. Clark (1998, p. 1245) highlighted that *"post-positivism does not reject the truths present in methodologies focusing on the experiences or meanings of individuals, as encompassed by the phenomenological, grounded theory and other interpretive methodologies"*. Numerous characteristics of positivist research are shared by post-positivist research such as the ontological assumption that reality is objective and is determined by prior theories (Creswell, 2012). The post-positivist researcher's perception, however, is not seen as being entirely disconnected from the inquiry (Clark, 1998). In other words, post-positivist research acknowledges that the understanding of objective reality depends on the researcher's observation of reality.

Post-positivist epistemology is demonstrated in this study in numerous ways. Firstly, the researcher performed a thorough literature review from prior studies. The literature guided the data collection process (from the preparations of the questions to gaining knowledge during the interviews with participants). Nevertheless, the researcher was not just restricted to the literature. The researcher also relied on the views and experiences of the participants to obtain accurate findings. Therefore, the researcher sought the experiences and perspectives of the informants in the study of digital infrastructure adoption and assimilation.

Methodologically, post-positivist researchers normally use qualitative data collection and analysis to provide in-depth explanations of the phenomena (Creswell, 2012). Post-positivist research has a less ambitious aim compared to positivist research in the hopes of getting closer to the truth from its participants (Clark, 1998). The basic beliefs of positivism and post-positivism are presented in Table 4. Ontologically, positivist research believes in naïve realism while post-positivist research believes in critical realism. Epistemologically, positivist researchers trust that findings are true while post-positivist researchers think that findings are probably true. Methodologically, positivist research is more quantitative in nature (although there are exceptions to this) but post-positivist research may include qualitative research. Positivist research is more restricted and limited if compared to post-positivist research. Post-positivist research holds prior knowledge with high regard but also prioritises participants' inputs.

Table 4 Basic Beliefs of Positivism and Post-Positivism (adapted from Guba and Lincoln [1994])

Item	**Positivism**	**Post-Positivism**
Ontology	Naïve realism – “real” reality but apprehendable	Critical realism – “real” reality but only imperfectly and probabilistically apprehendable
Epistemology	Dualist/objectivist; findings true	Modified dualist/objectivist; critical tradition/community; findings probably true
Methodology	Experimental/manipulative; verification of hypotheses chiefly quantitative methods	Modified experimental/manipulative; critical multiplism; falsification of hypotheses; may include qualitative methods

The literature review identified institutional factors, organisational resources and network externalities as vital forces influencing the adoption and assimilation of IPv6. This study takes a post-positivist stance because it takes into account the literature studies as well as the understanding of the phenomenon from the data collected from the participants,. Data obtained from the participants provided the researcher with a greater understanding and knowledge of IPv6 adoption and assimilation. The researcher also gained a deeper insight into the factors that influence the IPv6 adoption and assimilation.

4.3 Case Study Method

Case studies are one of the most commonly used qualitative research methods in information systems (IS) research and are suitable for studying the development, implementation and usage within organisations (Darke et al., 1998). Case studies are suitable for studying new IS phenomena when the focus has changed from the technical aspect to organisational issues (Benbasat et al., 1987). For example, IPv6 has been studied technically for many years; however, there have not been many studies on the organisational adoption of IPv6. Case studies also allow IS researchers to have access to real-life IT experiences; to study the complex and ubiquitous interactions among organisations, technologies and people; to investigate new ways of reasoning the opportunities, challenges and issues that confront IT specialists and managers; and to explore and generate hypotheses while providing explanations and testing of the proposed hypotheses (Dubé & Paré, 2003). Case studies are appropriate for answering "how" and "why" questions (Yin, 2009).

The case study method was used in this thesis to understand the determinants and barriers of organisations' IPv6 adoption and assimilation and the impact of institutional factors, network externalities and organisational resources across different stages of the IPv6 adoption and assimilation process. Since the purpose of this research is to study organisational IPv6 adoption and assimilation, case studies were appropriate because they were seen as suitable for understanding the interactions between IT-related innovations and organisational contexts (Darke et al., 1998). Due to the lack of studies on the adoption and assimilation of IPv6, in-depth case studies were necessary to understand the perspectives and experiences of individuals from organisations.

Also, this study aims to understand the institutional forces, network externalities and organisational resources that influence the adoption and assimilation process. It was felt that this could only be achieved if there was a close interaction with participants through in-depth case studies. The survey method was not seen as suitable in this study because there are not many organisations, especially in New Zealand, that have adopted or assimilated IPv6. Therefore, there would not have been adequate participants for a survey. Survey was also seen as unfitting when seeking to understand the factors that created a barrier and/or determinant of the adoption and assimilation process experienced by organisations. As Yin (2009) maintained, there is a distinctive need to select the case study method in order to understand complex social phenomena. Digital infrastructure adoption and assimilation is a complex social phenomena because digital infrastructure is the backbone for IT applications and technologies. Updating it is not straightforward. Any problems that occur during the adoption and assimilation of digital infrastructure is likely to delay or disrupt IT applications and services within organisations.

A multiple case study design was selected for this study as it allows the researcher to investigate the phenomenon in diverse settings (Darke et al., 1998). This design is preferable when the focus of the research is description, theory building or theory testing (Benbasat et al., 1987). The findings from a multiple case studies are considered more compelling and cause the study to be considered more robust when compared to a single case study (Yin, 2009). Since this study is a post-positivist research and the inputs of participants are as important as the findings from the literature review, the multiple case study method was considered appropriate to strengthen the findings. Yin (2009) stressed that the conclusion derived from two case studies is more concrete than the conclusion driven by one case study.

One of the reasons why multiple case studies were chosen for this study was to investigate organisations that are at varying stages of IPv6 adoption (non-adoption, planning, adoption and assimilation). A comparison of organisations at various stages of IPv6 adoption can be achieved when a multiple case study approach is used. Benbasat et al. (1987) highlighted that multiple case study design permits the usage of cross-case analysis and theory extension. In most organisations, only a few employees are aware of or involved with IPv6. Thus, only a few participants could be interviewed from each organisation, and multiple organisations were examined to obtain a deeper understanding of the phenomenon. The study by Paré (2002) showed how multiple case studies contribute by strengthening the understanding of clinical information systems implementation.

4.4 Research Sites

The study is based in New Zealand because of the growing need for New Zealand to adopt IPv6. Since New Zealand is an export-driven economy, it is crucial that New Zealand organisations communicate with their customers, and having IPv6 capability can ensure these organisations can connect to their trading partners (Hedquist, 2013). Major export partners, such as China and India, have run out of IPv4 addresses and are developing IPv6-based Internet applications which will not be visible to organisations in New Zealand if they do not possess IPv6 capabilities (Force, 2012). To ensure New Zealand does not lose touch with the global Internet, it needs to ensure it adopts IPv6 as soon as possible.

The NZ IPv6 Task Force currently advises all organisations to start their IPv6 adoption planning to avoid a big business risk (Force, 2012), and major New Zealand firms have been sharing their IPv6 adoption experiences with their peers (Ahmed, 2012). These firms include Beca, one of the largest employee-owned engineering and professional consultancy services companies in Asia-Pacific, and Trademe, the largest online auction website in New Zealand.

Data was collected from 16 New Zealand organisations. These 16 organisations were from a variety of industries and of different sizes, and were selected to understand their experiences and perspectives of IPv6 adoption and assimilation. Initially, the researcher aimed to collect longitudinal process data from organisations so as to study how organisations progress from one stage to the next. However, this was not possible as the researcher could not recruit an organisation that would allow the researcher to collect longitudinal data. Therefore, the researcher shifted to an altenative strategy of studying multiple organisations at varying stages of IPv6 adoption and assimilation to understand their experiences at the current stage, as well as their previous experiences as they moved across stages. This enabled data to be collected about the factors that influenced organisations at each stage, but was less useful for explaining the mechanisms that affected them as they moved across stages.

Organisations at varying stages of IPv6 adoption were selected for this study. Non-adopters of IPv6 were selected to understand their reasons for not adopting IPv6 and what may motivate them to adopt IPv6 in the future. IPv6 adopters and assimilators were also involved in the study to understand their motivation for adopting IPv6 and the obstacles they faced. Participants from organisations that were currently in the planning stage of their IPv6 adoption programme were also interviewed to understand their perspectives and experiences of IPv6 adoption planning. Section 4.6 explains how the organisations were recruited.

4.5 Data Collection Methods

Data was collected for this study through interviews, one of the most important sources of information for case studies (Yin (2009). The most commonly used interview method for qualitative research is the semi-structured in-depth interview (DiCicco-Bloom & Crabtree, 2006), and it was used in this research. As Bryman and Bell (2007) explained, for a semi-structured interview, "*the researcher has a list of questions on fairly specific topics to be covered, often referred to as interview guide, but the interviewee has a great deal of leeway in how to reply*". In other words, the interviewer prepares a set of questions with the flexibility of asking other related questions and also the flexibility for the interviewee to reply without any restrictions.

Open-ended questions were also prepared and asked during the interview to obtain greater insights and reduce bias. The two characteristics of open-ended interviewing according to Kaplan and Maxwell (2005) are firstly, to derive the participant's views and experiences rather than merely obtaining data which is just a choice among a pre-established response category. The second characteristic is not to restrict the interview to a rigid interview format or set of questions but to elaborate on what is being asked if the interviewee does not understand the question and follow up on unanticipated and most likely valuable information.

Table 5 below shows the interview guide used to conduct the interviews. The research questions assisted in formulating the interview questions. The interview guide covered questions on users' perspectives and experiences of IPv6 adoption and assimilation while addressing the research questions. The interviews focused on understanding the drivers and obstacles of IPv6 adoption and assimilation in organisations, and determining the impact of organisational resources and institutional forces on different stages of the adoption and assimilation of IPv6.

Table 5 Interview Guide

The following questions were developed to guide the interviews:
1. Describe your role, experiences, and current responsibilities. 2. How long have you been working with this organisation? 3. Describe your department: the number of staff, background, hierarchy, IT support structure and intensity of IT use (number of devices, storage etc.). 4. Has your organisation adopted IPv6? If so, at what stage of the adoption process is it? 5. What is your role in your organisation's IPv6 adoption project (technical/administrative/decision maker/user)? 6. If you have not adopted IPv6, what is your current strategy (e.g., NAT) and how long do you intend to use this current strategy? 7. Describe your organisation's decision-making process behind adopting IPv6. What were the factors influencing the decision to adopt IPv6? 8. Has the depletion of IPv4 addresses influenced your organisation's decision to adopt IPv6? 9. Have there been any deviations from your organisation's IPv6 adoption plan? Why? 10. Which approach has your organisation used or will use when adopting IPv6 (e.g., dual-stack)? How will IPv6 be spread to the entire organisation? 11. Can you describe the stages of the project? What were some of the key events? Did anything unexpected occur? Why did it happen? 12. In your opinion, how will IPv6 affect your organisation (operations/IT support/etc.)? What benefits will be realised? 13. What has been the impact of the government's IPv6 adoption campaign? Did it influence your organisation's decision to adopt IPv6? 14. Do you think the changes in other components of your organisation's IT infrastructure has driven your organisation to adopt IPv6? 15. What barriers, if any, has your organisation encountered during IPv6 adoption planning/implementation? 16. Do you face any cost constraints for IPv6 implementation? 17. What do you think is/will be the biggest cost of your organisation's IPv6 adoption project: hardware, software or human resources? 18. Has your organisation found it difficult to recruit staff with the knowledge and

experience to implement IPv6?

19. How involved is the senior level management in your organisation's IPv6 adoption?
20. Have you attended IPv6 information or education events with other organisations? How has that helped you in understanding IPv6 adoption?
21. Have the experiences of other organisations influenced your organisation's IPv6 adoption plans in any way?
22. What about the vendors and customers? Have they influenced your organisation's decision to adopt IPv6?
23. Do you have any recommendation or comments to accelerate IPv6 adoption in organisations?
24. Is there any documentation that I can look at – meeting minutes, IPv6 documentation?

Initially, this study aimed to augment the interview data with official documentation. Documents are useful for corroborating evidence from other data sources (Yin, 2009). The documentation that was intended to be collected included any IPv6 related written materials (public and official) such as organisational reports, meeting minutes, newspaper articles and internet resources. However, documentation analysis was not used in this research because most of the organisations interviewed did not have documents related to their IPv6 adoption and assimilation process, as they were in the early stages of adoption or had not adopted IPv6. Only one organisation provided a timeline for their IPv6 adoption, and discussed it during the interview. A few participants had email correspondence on their IPv6 adoption plans. However, because of the sensitivity of the correspondence, they did not provide copies.

4.6 Participant Recruitment

Various approaches were employed to recruit the participants for the study. First, the researcher contacted the Global IPv6 Forum to ask for an introduction to the New Zealand IPv6 Task Force. The researcher was familiar with the members of the Global IPv6 Forum, because she had worked with them previously during her post-graduate research in Malaysia. Upon receiving the introduction, the researcher contacted the New Zealand IPv6 Task Force and obtained access to a list of organisations that had shown interest in IPv6 or had started adopting IPv6. These organisations were contacted. The researcher also attended two IPv6 events organised by the New Zealand IPv6 Task

Force to understand the experiences shared by organisations on their IPv6 adoption and to network with other participants of the events. A short advertisement and link was also placed on the CIO (New Zealand) *Linked In* website to attract more participants.

The first four organisations recruited by the researcher were tertiary institutions. A respondent from one of the tertiary institutions introduced the researcher to other potential participants, which included their vendors and internet service providers (ISPs). The introduction was done by the respondent who forwarded the researcher's invitation to his contacts. The potential participants then contacted the researcher stating their interest in participating in the project. These participants then introduced the researcher to other participants. This participant recruitment method is called the snowball sampling method (Browne, 2005) where an initial participant is asked to identify potential participants who can provide an insight into this matter as well. The researcher recruited participants who were at different stages of the IPv6 adoption and assimilation process to understand the events that had occurred in the stage they were at that prevented or encouraged them from moving to the next stage.

As soon as participants signed the consent form (see Appendix A) and looked through the participant information sheet (see Appendix B), the interview started. Each interview lasted between 30 minutes and 1½ hours. Most interviews were carried out face-to-face, but a few were conducted through the phone. The interviewees were interviewed either as individuals or as a pair. All the interviews were recorded with the permission of participants, except for one. The researcher also took notes during the interviews while they were being recorded. The participant who did not give consent for the interview to be recorded was from a government agency in New Zealand and wanted to ensure that his/her privacy was protected. Thus, the researcher wrote down the responses of the participant instead of recording them. The interviews that were recorded were then transcribed. This provided a source of verbatim quotation.

The participants for the interviews were chosen based on their involvement in their organisation's IPv6 adoption process either in terms of decision making or technicality. The participants included senior managers, IPv6 project managers and IPv6 technical staff. The organisations that were chosen had shown interest in adopting IPv6 or had started adopting or assimilating IPv6. The organisations were of different sectors such as education, Internet Service Providers (ISPs), and others. Table 6 provides information on the participants that were interviewed during the data collection. The participants and organisations were given pseudonyms to protect their privacy and confidentiality.

Table 6 Interview Participants Information

Organisation (Pseudonym)	**Number of Participants**	**Participants Pseudonym**	**Position**	**Date of Interview**	**Industry**
1 EduOne	1	InfrEng	Infrastructure Development Engineer	17/6/2013	Tertiary Education
2 EduTwo	1	NetwMgr	Network & Internet Manager	19/6/2013	
3 EduThree	2	NetwLead	Network Team Leader	27/6/2013	
		NetwEng	Network Engineer	27/6/2013	
4 EduFour	2	SenNetEng	Senior Network Engineer	3/7/2013	
		InfrServMgr	Infrastructure Services Manager	3/7/2013	
5 ServProvOne	1	SenSysSpec	Senior Systems Specialist	28/6/2013	Internet Service Providers (ISPs)
6 ServProvTwo	1	CliMgr	Client Manager, Enterprise & Government	12/9/2013	
7 ServProvThree	1	NetArc	Network Architect	1/9/2014	
8 ServProvFour	1	AccMgr	Account	23/4/2014	

			Manager		
9 VendOne	1	BusMgr	Business Manager	8/7/2013	Networking Vendor
10 VendTwo	2	BusDevMgr	Business Development Manager	19/8/2013	
		ServMgr	Service Manager	19/8/2013	
11 VendThree	1	SenSysMgr	Senior Systems Manager	9/7/2013	
12 VendFour	1	NetSuppSpec	Network Support Specialist	19/7/2013	
13 GovOne	2	SenMgrOp	Senior Manager Operations and Infrastructure Services	17/7/2013	Government Agency
		BTSArc	Business and Technology Solution Architect	22/7/2013	
14 GovTwo	1	SolArc	Solution Architect	16/9/2014	
15 FoodRet	2	SAMgr	Strategy and Architecture Manager	12/8/2014	Food Retailer
		TechArc	Technical Architect	12/8/2014	
16 AirTrans	2	CIOff	Chief Information officer (CIO)	15/9/2014	Air Transport Industry
		MgrInfServ	Manager Infrastructure Service Delivery	15/9/2014	
Total Number of Participants	**22**				

As Table 6 above shows, 22 participants from 16 organisations were interviewed by the researcher. Data collection took place from June 2013 until September 2014. The organisations were from different industries such as tertiary institutions, Internet Service

Providers (ISPs), vendors, government agencies, food retailers and the air transport industry. The participants held different positions from Chief Information Officers (CIO) to managers and technical staff. Only one or two participants were selected from each organisation because IPv6 decisions or projects are usually solely handled by one or two individuals in each organisation. As the findings reveal in the next chapter, no team had been set up in any of the organisations to manage IPv6. IPv6 was only decided, managed and/or configured by the one or two individuals who were interviewed. Another important factor that was considered when selecting these participants was that the participants needed to have some IPv6 knowledge or experience. These participants were the individuals in their organisation with the knowledge and/or experience of IPv6.

4.7 Data Analysis

Data collected during the interviews was transcribed using the NVivo software. As highlighted by DiCicco-Bloom and Crabtree (2006), the software tool can be a great help in the management of data and the analysis process. Upon the collection and organisation of data, a detailed descriptive chronology of the factors affecting each organisation's IPv6 adoption and assimilation was prepared. Langley (1999) emphasized that *"the passage from raw data to synthetic models, whether expressed in terms of phases or otherwise, is far from simple"*. Therefore, the visual mapping strategy proposed by Langley (1999) assisted in the understanding of the data collected. Miles and Huberman (1994) also emphasized the usage of matrix and graphical forms as a beneficial way of representing large quantities of information in a small space and their usefulness as a tool for the development and verification of theoretical ideas.

Several versions of visual maps were drawn before arriving at the final visual map for each case. A visual map was drawn for each case study as a within-case analysis. Each visual map represents an organisation's IPv6 adoption and assimilation process. These visual maps show institutional forces (coercive, mimetic and normative) with the organisational resources and/or barriers that they encountered across the phases of IPv6 adoption and assimilation. The visual map for each case (within-case analysis) highlights the uniqueness of each case and identifies the impact of institutional forces and organisational resources at different stages of IPv6 adoption and assimilation.

Next, thematic analysis was conducted on the collected data as a cross-case analysis. The collected data was analysed thematically through the Nvivo software. Thematic analysis is a way to identify, analyse and report patterns found from interview data (Braun & Clarke, 2006). Based on the recommendations of Braun and Clarke (2006), five phases of thematic analysis were applied to this study:

1. Familiarising with the data collected: Data that was collected was transcribed by the researcher. After transcription, the interviews were read by the researcher several times before starting the coding process.
2. Generating initial codes: Once the researcher was familiarized with the data, initial codes were generated through the Nvivo software. Nvivo made the generation of initial codes a simpler process as it allowed codes to be created while reading the interviews.
3. Searching for themes: The researcher then looked for themes from the initial codes.
4. Reviewing themes found: The themes found were then reviewed several times to gain better clarity.
5. Defining and naming themes: Next, these themes were defined and named.
6. Producing the report: Findings from the thematic analysis are reported in the findings chapter as descriptive analysis.

The visual maps and thematic/descriptive analysis are presented as within-case analysis in Chapter 5 as findings from the data collected. A cross-case analysis is conducted in

Chapter 6 to provide a clearer understanding of the findings. Next, these findings are then compared to prior literatures in Chapter 7 to support or differentiate between the two.

To achieve reliability and validity of the findings, this study uses the concept of trustworthiness as proposed by Guba (1981). The concept of trustworthiness provides four criteria to evaluate post-positivist studies. These four criteria are given different terminology to differentiate them from positivist research (Shenton, 2004). The four criteria stated by Guba (1981) are credibility (in contrast with internal validity), transferability (in contrast with external validity/generalisability), dependability (in contrast with reliability), and confirmability (in contrast to objectivity). Credibility can be achieved by conducting the study to include different participants and sites (Shenton, 2004). There were 22 informants from 16 organisations that participated in this study. Having different participants provided *"triangulation through data sources"*, a term used by Shenton (2004) whereby *"individual viewpoints and experiences can be verified against others and, ultimately, a rich picture of the attitudes, needs or behaviour of those under scrutiny may be constructed based on the contributions of a range of people"* (Shenton, 2004, p. 66). The use of different sites in this study provided *"site triangulation"* which lessened the effect of factors relevant to only one organisation and *"greater credibility"* could be achieved when similar findings were found from different organisations (Shenton, 2004, p. 66).

Transferability allows the findings of a study to be applied or replicated in other studies or situations. Since this study included IPv6 experiences of organisations in different stages of IPv6, of different sizes and from different industries and was not restricted by only one organisation or industry or size, this study can be related to and applied to various organisations. Shenton (2004, pp. 70-71) stated that the findings from different settings could provide *"a more inclusive overall picture to be gained"*.

In terms of the dependability of the study, Shenton (2004) suggested thoroughly reporting the processes used in the study, allowing future researchers to repeat the work despite not obtaining the same results. This chapter has reported in detail the research method employed. An extensive report of the findings and analysis of the study are presented in Chapters 5 to 7. The detailed report of the research methods, findings and analysis will allow future researchers to replicate the study, thus, providing dependability of the study.

Shenton (2004, p. 72) stated that *"confirmability"* is the

> *qualitative investigator's comparable concern to objectivity. Here steps must be taken to help ensure as far as possible that the work's findings are the result of the experiences and ideas of the informants, rather than the characteristics and preferences of the researcher*

In order to achieve confirmability, the researcher used the triangulation of different sites and different participants. The participation of different informants and organisations confirmed the findings without the influence of the researcher's bias and perceptions. In addition, informants' quotes are included in Chapter 5 to provide the confirmability of the study.

According to Eisenhardt (1989), in order to achieve the credibility of a study, it is vital to do a comparison of the research findings with the literature. Thus, a comparison of the data collection findings are presented in Chapter 7 to ensure the reliability and validity of the analysis process. The within-case and cross-case analysis strengthened the findings. Multiple-case design also increased the transferability (Eisenhardt, 1989).

4.8 Summary of Chapter 4

In summary, this chapter has discussed the method used to collect data on organisational IPv6 adoption and assimilation, the method used to engage participants and elicit information pertaining to their organisations, and the method used for data analysis. This chapter has also discussed the concept of trustworthiness to achieve reliability and the validity of the findings. The next chapter (Chapter 5) presents the data from the case studies, while the following chapter (Chapter 6) analyses this data to determine patterns and relationships.

Chapter 5: Findings

This chapter presents the data collected through a series of case studies of 16 New Zealand organisations' experience with IPv6. While most of the organisations in the sample had adopted or were adopting IPv6, some were non-adopters. Each case study represents an organisation. Comparing the experiences of organisations from various industries, sizes, and at differing stages of adoption will help clarify the process of new digital infrastructure adoption and the factors that support or hinder it.

The findings are reported in two ways. First, each case is discussed in detail in Section 5.1. A visual map is presented for each case to indicate the adoption timeline, adoption stage, approach, determinants, barriers and other crucial events or details. Table 7 below lists the organisations and their key details, and Table 8 describes the interviewees from each organisation. Generic names are used for the organisations and participants so as to maintain confidentiality. Second, the data is coded thematically following the coding strategy described in Chapter 4, and the results are presented in Section 5.2. Whenever appropriate, participants' statements are quoted to add richness to the analysis. Section 5.1 includes the visual maps. Section 5.2 includes descriptive analysis. The visual maps and descriptive analysis represents the within-case analysis.

Table 7 Descriptive Information about Organisations

	Name	**Industry**	**Size**	**Location**	**Stage of IPv6 Adoption**
1	EduOne	Tertiary education	No. of employees: 3127, total operating revenue: $445 million	Auckland	Assimilating IPv6
2	EduTwo	Tertiary education	No. of employees: 3515, total operating revenue: $327 million	Auckland	Planning IPv6 adoption
3	EduThree	Tertiary education	No. of employees: 1519, total operating revenue: $225 million	Hamilton	Adopting IPv6
4	EduFour	Tertiary education	No. of employees: 2000, total operating revenue: $357 million	Wellington	Planning IPv6 adoption
5	ServProvOne	Telecommunications	No. of employees: 500, total revenue: over $100 million	Auckland (head office)	Adopting IPv6
6	ServProvTwo	Telecommunications	No. of employees: 3,400, total revenue: $1.5 billion	Auckland (head office)	Adopting IPv6
7	ServProvThree	Telecommunications	No. of employees: 5,600, total revenue: $3.6 billion	Auckland & Wellington (head offices)	Not adopting IPv6
8	ServProvFour	Telecommunications	No. of employees: 110, total revenue: $54 million	Wellington (head office)	Adopted and assimilated IPv6
9	VendOne	Vendor	No. of employees: 2000, total revenue: $870 million	Wellington (head office)	Adopting IPv6
10	VendTwo	Vendor	No. of employees: 20	Wellington and Auckland	Planning IPv6 adoption
11	VendThree	Vendor	No. of employees: 2700, total revenue: $615 million	Auckland	Adopting IPv6
12	VendFour	Vendor	No. of employees: 500, total revenue: $167 million	Wellington (head office)	Assimilating IPv6
13	GovOne	Government agency	No. of employees: 3,500	Wellington	Planning IPv6 adoption

14	GovTwo	Government agency	No. of employees: 1,786	Wellington	Adopting IPv6
15	FoodRet	Food Retail	No. of stores: 400, total revenue: $5.5 billion	Auckland	Not adopting IPv6
16	AirTrans	Air Transport	No. of employees: 100, total revenue: $110 million	Wellington	Not adopting IPv6

Table 8 Information about Interviewees

	Name	**Interviewees**	**Role in IPv6 Adoption**
1	EduOne	Infrastructure Engineer (*InfrEng*)	Championing and initial deployment of IPv6
2	EduTwo	Network Manager (*NetwMgr*)	Championed adoption in the technical operations department and developed the IPv6 adoption plan
3	EduThree	Network Team Leader (*NetwLead*)	Developed IPv6 policies
4		Network Engineer (*NetwEng*)	In-charge of IPv6 implementation and configurations
5	EduFour	Senior Network Engineer (*SenNetEng*)	Responsible for IPv6, addressing scheme design and IPv6 implementation
6		Infrastructure Services Manager (*InfrServMgr*)	Managed IPv6 adoption in the organisation
7	ServProvOne	Senior Systems Specialist (*SenSysSpec*)	Led and championed IPv6
8	ServProvTwo	Client Manager (*CliMgr*)	In charge of IPv6 strategy: introducing IPv6 internally and to their customers
9	ServProvThree	Network Architect (*NetArc*)	Responsible for making sure IPv6 is included in all the organisation’s network decisions even though the organisation does not intend to adopt IPv6
10	ServProvFour	Account Manager (*AccMgr*)	Organisation has already adopted IPv6, so does not have an assigned role
11	VendOne	Business Manager (*BusMgr*)	Encouraged the organisation to adopt IPv6 internally
12	VendTwo	Business Development Manager (*BusDevMgr*)	Does not have a role assigned for IPv6 adoption; plans to test IPv6 adoption in a lab environment
13		Service Manager (*ServMgr*)	
14	VendThree	Senior Systems Manager	Does not have an IPv6 role because there are

		(*SenSysMgr*)	no plans to adopt IPv6 internally
15	VendFour	Network Support Specialist (*NetSuppSpec*)	Pioneered deployment of IPv6 in the organisation
16	GovOne	Senior Manager of Operations and Infrastructure Services (*SenMgrOp*)	Responsible for planning of IPv6 adoption
17		Business and Technology Solution Architect (*BTSArc*)	Architect of the firewall replacement project which include IPv6 adoption
18	GovTwo	Solution Architect (*SolArc*)	Leading IPv6 website project
19	FoodRet	Strategy and Architecture Manager (*SAMgr*)	Does not have role assigned for IPv6 because there are no plans to adopt IPv6
20		Technical Architect (*TechArc*)	
21	AirTrans	Chief Information Officer (*CIOff*)	Does not have role assigned for IPv6 because there are no plans to adopt IPv6
22		Manager Infrastructure Service Delivery (*MgrInfServ*)	

5.1 Organisational Vignettes

This section introduces each organisation that participated in this study, and discusses their experiences with IPv6. These experiences were used to develop visual maps for each organisation, which depict the range of institutional and organisational determinants and barriers that affected each organisation's interaction with IPv6. Organisations and participants were approached during the duration of 16 months (between June 2013 and September 2014). Much will have changed since then. The description and discussion in this section is based on the time of the writing.

5.1.1 EduOne

EduOne is a large tertiary education provider in New Zealand with approximately 35,000 students of which 17,000 are distance learning students. EduOne also has 3000 international students from more than 100 countries around the world. It has three campuses across the North Island in New Zealand. InfrEng from EduOne participated in this study and provided information on EduOne's IPv6 adoption and assimilation process. InfrEng is from EduOne's IT department and deployed IPv6 in the organisation.

The organisation started adopting IPv6 in 2004 because KAREN[4], a high speed network linking tertiary institutions in New Zealand, was moving to IPv6. The IPv6 deployment began with a pilot project that set up the new protocol on the boundaries of the network, the firewalls and some key internal services to find out how well it worked and what its impact might be. Then, it was turned on at the distribution layers within the networks and progressively turned on in the access layer in the networks. The last phase of the IPv6 deployment was to configure the wireless network, which currently uses IPv6. In the beginning of 2012, the institution had a complete network upgrade and moved to another networking vendor, whose devices supported IPv6 which meant that it could be turned on everywhere. EduOne has deployed IPv6 fairly broadly on its client devices, services and networks.

Certain problems such as lack of vendor support meant that EduOne did not have external IPv6 connectivity for nearly 18 months (January 2012 onwards). However, this issue was not considered important or a priority for resolution and a funding request to fix it had not been approved as at the time of the interview (June 2013). In addition, senior management declined the quick fix that InfrEng suggested. As Figure 1 indicates, EduOne adopted IPv6 for two main reasons: to meet customer demand (international students) and to align itself with KAREN's evolution. Resources that were available to drive the organisation's IPv6 adoption included InfrEng's IPv6 effort and skills, and the previous CIO's support (Figure 1). Barriers that caused EduOne to lack external IPv6

[4] KAREN stands for "Kiwi Advanced Research and Education Network". It is managed by Research and Education Advanced Network New Zealand (REANZZ).

connectivity were the absence of support from the current CIO, a lack of IPv6 skilled staff, and a lack of vendor support (Figure 1).

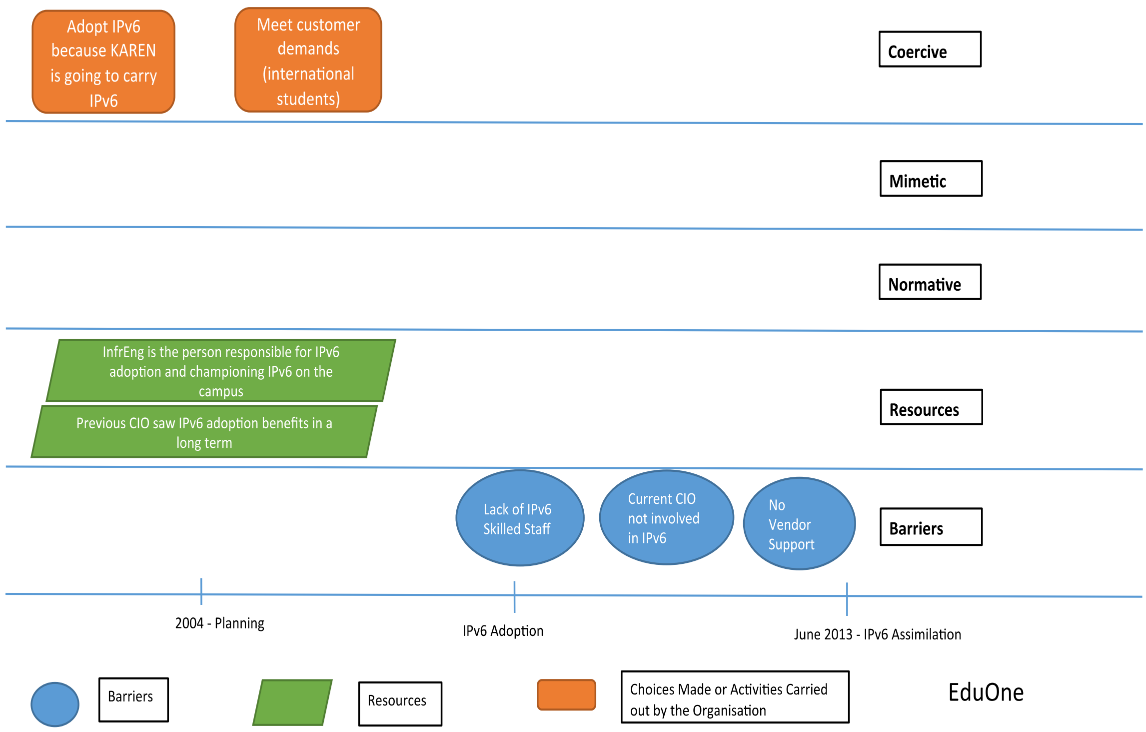

Figure 1 EduOne IPv6 adoption timeline

5.1.2 EduTwo

EduTwo is a large tertiary education provider in Auckland, New Zealand with approximately 30,000 students. EduTwo also has about 3100 international students from more than 85 countries around the world. It has one main campus and three secondary campuses around Auckland. NetwMgr is the Network Manager from EduTwo and participated in this study. He is responsible for creating the organisation's IPv6 adoption plan and driving the IPv6 adoption process.

EduTwo is in the early stages of IPv6 adoption, based on a plan that NetwMgr circulated within the organisation. It started the adoption process in 2012 by putting IPv6 on its border routers and getting its own IPv6 address block. NetwMgr thinks that the complete deployment will be a slow process over the next 5 to 10 years. He believes in slowly incorporating IPv6 deployment into the "business as usual" processes, which means doing little projects all the time. He does not think that a one-year plan dedicated to just IPv6 is feasible as it would be a waste of time since new technologies might be available in a couple of years to push the IPv6 adoption. According to NetwMgr, the plan for June until December 2013 is to roll out IPv6 on more firewalls and websites, and continue planning. Planning involves setting in place border routers and firewalls, and updating websites to IPv6. Overall, the year 2013 is about planning a more detailed IPv6 strategy. NetwMgr stated that it is still unclear whether EduTwo's equipment and applications have IPv6 support and that there are a large number of legacy systems in EduTwo that might not be able to support IPv6. All new equipment purchases, especially in the network, are all IPv6 compliant, and IPv6 compliance is now included in all of their purchase agreements (refer to Figure 2).

Figure 2 shows that the motivation for EduTwo to adopt IPv6 came from the allocation of IPv6 addresses by REANZZ and to meet customer demands (international students). EduTwo intends to learn from other organisations' IPv6 adoption experience to assist its IPv6 adoption process. Staff from EduTwo have attended various seminars over the years to gather information, including an IPv6 training course in May 2013. Barriers to EduTwo's IPv6 adoption include the lack of awareness by senior level management, inadequate time and resources for the IPv6 adoption process, and a huge amount of legacy systems that do not support IPv6 (see Figure 2).

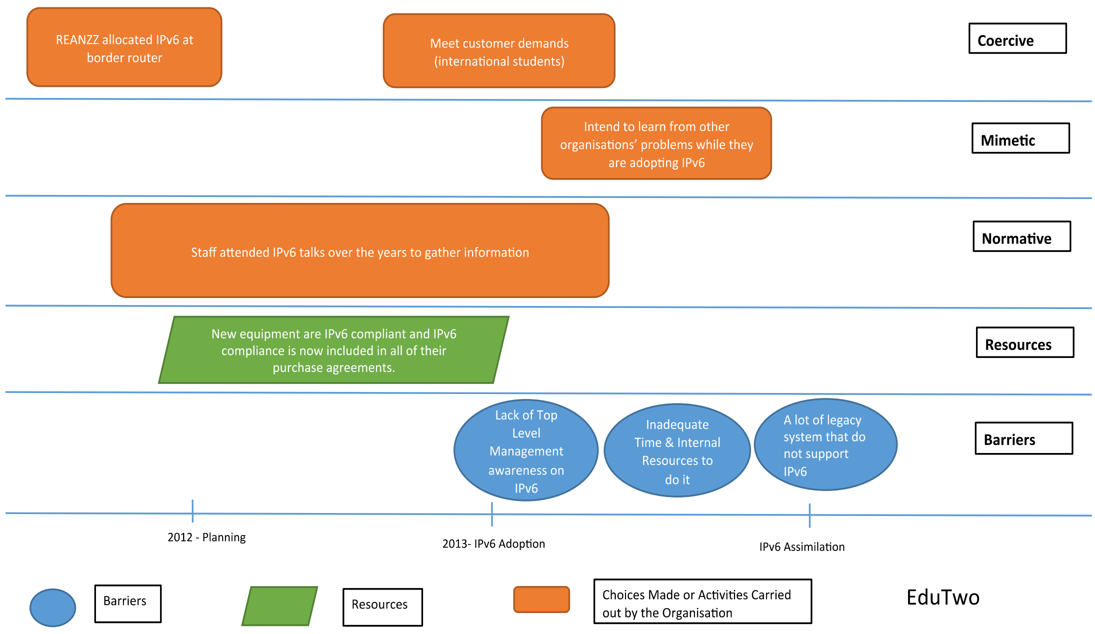

Figure 2 EduTwo IPv6 adoption timeline

5.1.3 EduThree

EduThree is a medium-sized tertiary education provider in New Zealand with approximately 12,000 students. EduThree also has about 1873 international students from around the world. It has two campuses in the North Island of New Zealand. NetwEng and NetwLead from EduThree are participants of this study. NetwLead is the Network Team Leader and NetwEng is the Network Engineer in the organisation's IT department.

EduThree obtained its first IPv6 address from Asia-Pacific Network Information Centre (APNIC)[5] in 2007 and it started its IPv6 efforts in 2009. First, it undertook research on the adoption requirements and then, it tried to learn from the experiences of other organisations. Initially, it had IPv6 visibility on the REANZZ network and then, it moved onto the Internet. It developed its IPv6 addressing plans very early on and is still using the same plan. It designed its IPv6 addressing plan based on its IPv4 experience. EduThree's network is IPv6 ready but not native IPv6 ready; that is, it still has

[5] APNIC is the non-profit regional Internet registry for the Asia Pacific region. APNIC provides number resource allocation and registration services that support the global operation of the Internet.

preference over IPv4 addressing instead of IPv6. A network that is 'native IPv6' is one where all of the network infrastructure has been upgraded to IPv6 and only IPv6 is used. In contrast, EduThree's network has a dual-stack IPv4/IPv6 network and is still native IPv4. EduThree's Domain Name System (DNS)[6] for IPv6 is still being developed and configured. The person in charge of DNS has recently resigned and a new person is taking over that task. The only thing holding the adoption process back is the DNS server, which needs some more thought to move to IPv6. The next step is to have its public facing interface and all its sub interfaces (websites) IPv6-enabled by end of 2013.

Figure 3 shows the determinants (coercive and normative forces), resources available and barriers faced by EduThree during its IPv6 adoption process. EduThree was driven to start planning its IPv6 adoption when APNIC allocated it with its own IPv6 address. EduThree was motivated to adopt IPv6 because of the government's IPv6 readiness drive and also to obtain recognition from adopting IPv6. It also plans to have IPv6 enabled in its websites to meet the demands of international students. Staff from EduThree have attended various IPv6 events which has helped the institution understand other organisations' IPv6 adoption experiences and this understanding has been relayed to the top management. The main barrier identified is that the person responsible for developing and configuring its DNS for IPv6 has resigned.

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[6] Domain Name System (DNS) is an Internet service that translates domain names into IP addresses. For instance, domain name www.educationnetwork345.com might be translated to 193.184.231.4.

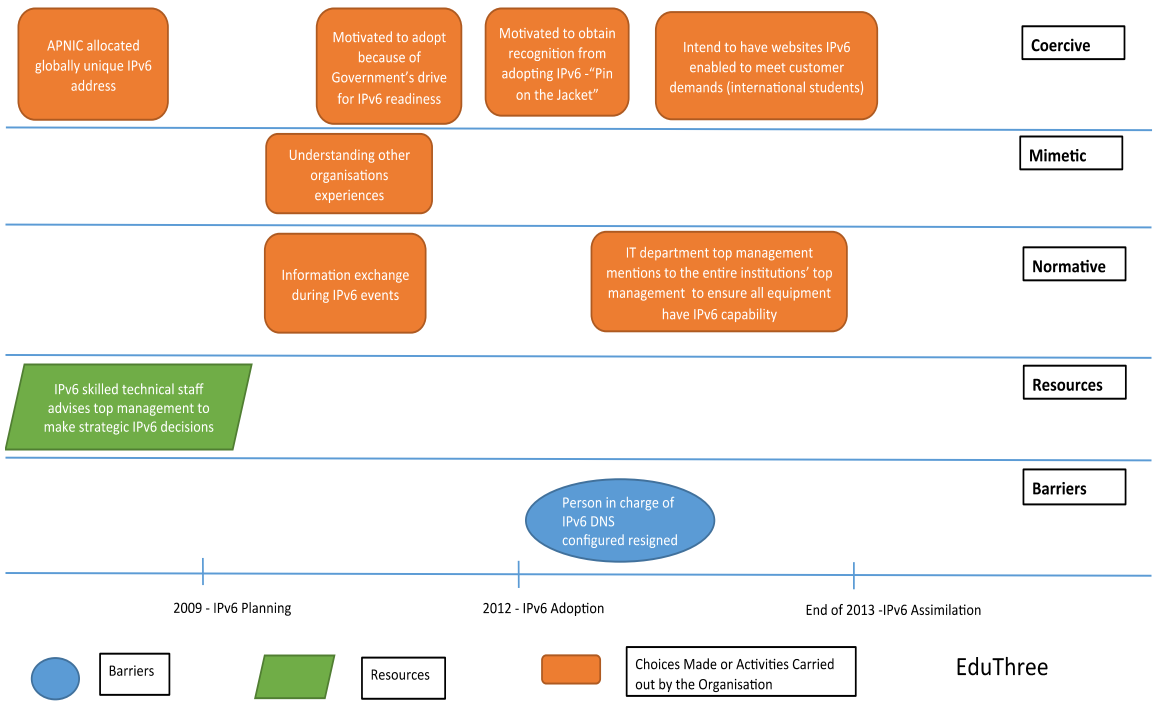

Figure 3 EduThree IPv6 adoption timeline

5.1.4 EduFour

EduFour is a large tertiary education provider in New Zealand with approximately 22,000 students. EduFour has about 3000 international students from 80 countries around the world and has four campuses in the North Island of New Zealand. InfrServMgr, the Infrastructure Services Manager, and SenNetEng, the Senior Network Engineer, from EduFour participated in this study.

EduFour is still in the planning stage for IPv6. It received IPv6 addresses from KAREN and the plan was to wait until the staff had additional time to plan and adopt IPv6. However, EduFour's Computer Science department is adopting IPv6 and insists that the IT department adopt IPv6 across the entire organisation. SenNetEng mentioned that IPv6 has not been configured in the institution's network infrastructure apart from being turned on by default (e.g., Windows operating systems). At a broader level, EduFour does not have any official plan and timeline. The director of the IT department has announced a broad plan and timeline in a statement to the Computer Science department, but it is not definitive. The first stage that the institution plans to do is to make its external webservers IPv6-enabled and visible, and slowly progress from there. SenNetEng mentioned that they are still unsure how far they will go and if they will ever deploy it in end-users' devices (computers).

EduFour's IPv6 adoption determinants, resources and barriers are shown in Figure 4. EduFour's coercive pressures for adopting IPv6 are to meet the demand of its international students, and to become a leader or at least proactive in IPv6. EduFour also plans to learn from other organisations that have had successful adopted IPv6. Internal push by the Computer Science department and information exchange during IPv6 events is also driving EduFour to migrate to IPv6. Staff from the Computer Science department have been given IPv6 addresses to experiment with and have done so for several years. Therefore, they have the required skills to assist the IT department to adopt IPv6 into the entire organisation's network infrastructure. Barriers that were found are the unavailability of an official plan and timeline, and time that staff have to spend to adopt IPv6.

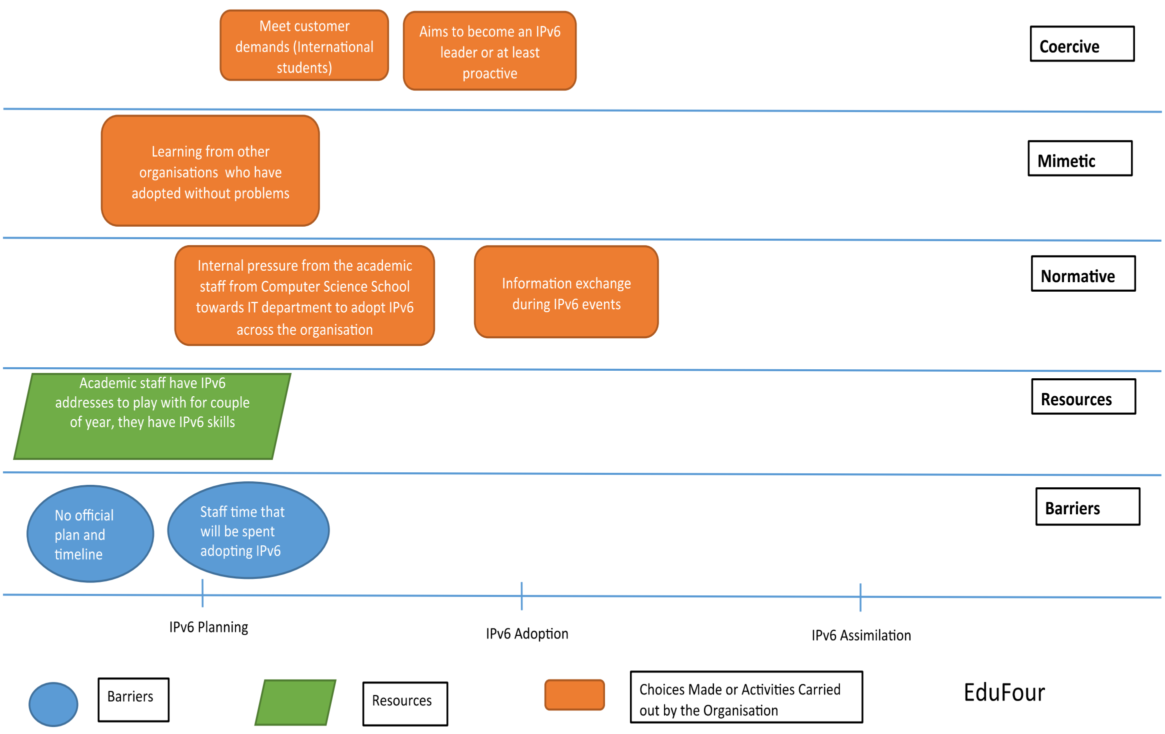

Figure 4 EduFour IPv6 adoption timeline

5.1.5 ServProvOne

ServProvOne is a small Internet service provider in the telecommunication industry with 500 employees and 22,000 customers in New Zealand. Its head office is in Auckland, New Zealand. Its senior systems specialist, SenSysSpec, was interviewed for the study. SenSysSpec is the main lead and champion of IPv6 in the organisation.

ServProvOne's core national network which its customers use to connect to the Internet is IPv6-enabled. It was relatively simple to make this network IPv6-enabled because it is under ServProvOne's control and they did not need to rely on other service providers to implement the change. This network has links to international service providers and national connectivity with other local providers that need to be IPv6-enabled.

The most difficult issue for them is to deploy IPv6 on their customers' (residential and business) sites. Residential customers have to refresh their network equipment to support IPv6. That is quite a challenge as many of them bring their own routers and do not use the routers provided by ServProvOne. The newer customers that sign up are required to provide the details of their network equipment to ServProvOne. This will allow ServProvOne to provide IPv6 upgrades to customers that require it. In contrast, business customers have a different IPv6 scenario. A few business customers require higher bandwidth and they generally have more capable network equipment. However, some of them have not deployed IPv6 yet. Some trial business customers have dual-stack IPv4/IPv6 networks. Parts of ServProvOne's internal network rely on vendors to support and enable IPv6, which prolongs the process of adopting and assimilating IPv6 internally.

Figure 5 displays ServProvOne's institutional determinants, resources and barriers to its IPv6 adoption and assimilation. ServProvOne's reasons for adopting IPv6 is its IPv4 depletion, to meet its customers demand and for the company to continue growing.

SenSysSpec has attended many IPv6 talks during its planning stage to listen to other people's IPv6 adoption experiences. While adopting IPv6, SenSysSpec has attended many technical IPv6 workshop to understand the technicality and to use that knowledge to implement IPv6 in the organisation. Observing other organisations that have successfully implemented IPv6 (a mimetic force), caused ServProvOne to progress from planning to adoption stage. The support and involvement of SenSysSpec's manager is useful for ServProvOne's IPv6 adoption.

According to ServProvOne, one of the barriers initially encountered was the view that IPv6 lacked business benefits, resulting in a lack of priority in the organisation. ServProvOne also lacks staff with IPv6 skills and knowledge. Its internal network requires vendor support in order to get all its devices IPv6-enabled. Despite having an IPv6-capable network, some of its business customers do not see a need to move to IPv6. Its residential customers also need to be equipped with network equipment that supports IPv6.

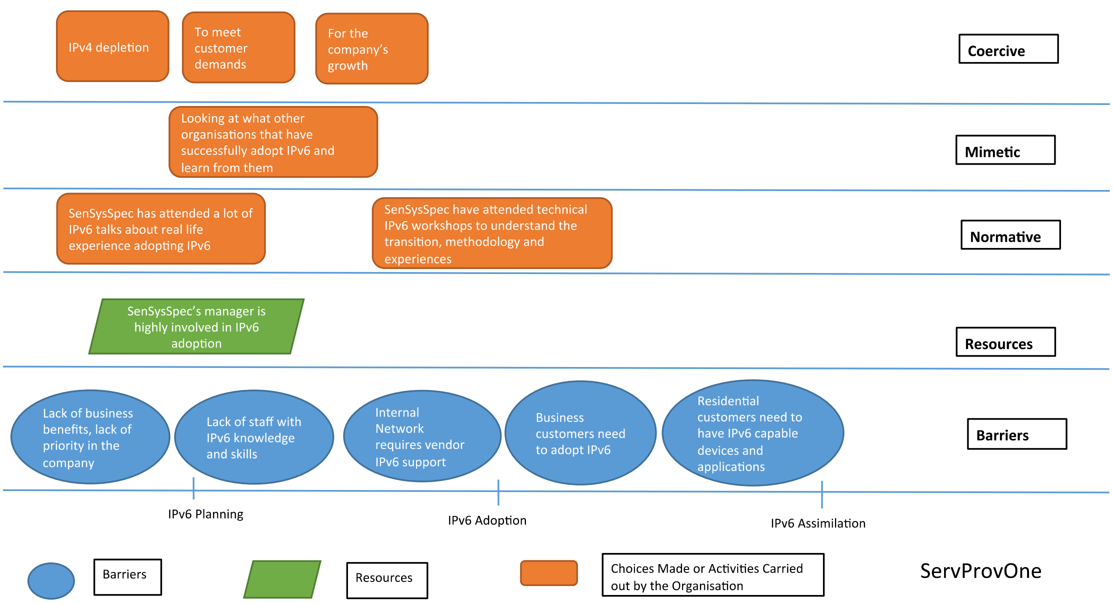

Figure 5 ServProvOne IPv6 adoption timeline

5.1.6 ServProvTwo

ServProvTwo is a large Internet service provider from the telecommunication industry with over 2 million customers in New Zealand. The organisation's head office is situated in Auckland, New Zealand. CliMgr, the Client Manager from ServProvTwo, shared the organisation's IPv6 adoption experiences. CliMgr is in charge of ServProvTwo's strategy to introduce IPv6 internally and to its customers.

ServProvTwo started planning its IPv6 adoption in March 2012. Parts of its network had IPv6 at that point (e.g., devices supporting IPv6) and the planning to introduce IPv6 externally out to all its customers began in March 2012. Since then, ServProvTwo has started adopting IPv6 externally. It has parallel streams of IPv6 projects and some of these projects are already completed. For example, its Ultra-Fast Broadband (UFB) project has IPv6 capability on it, so that customers that sign up for UFB have access to IPv6 by default and do not need to request it. Customers will automatically get IPv6 access if their operating systems and modem supports it. On the other hand, other products, such as dial-up Internet, will not be upgraded to IPv6 because it will eventually be a smaller part of the total Internet usage in New Zealand. Therefore, the upgrading of the dial-up Internet infrastructure would be very costly for customers and the service providers.

ServProvTwo also has other broadband services: Digital Subscriber Line (DSL), Very-high-bit-rate Digital Subscriber Line (VDSL) and Hybrid Fibre-Coaxial (HFC). It plans to have IPv6 on its DSL over the next 12 to 15 months (between September 2014 and December 2014). The project is planned to start in three months' time (December 2013). CliMgr stated that the DSL project will require a great amount of planning because they have a few hundred thousand customers and need to make sure that the introduction of IPv6 will not adversely affect them. The last service, HFC, will be introduced with IPv6 over the next 12 to 18 months (between September 2014 and March 2015).

ServProvTwo has two environments in its internal network infrastructure. It has a corporate network which all its laptops and devices connect to. Introducing IPv6 on this network is not very complex but will be costly because it requires the replacement of many devices that do not support IPv6. The organisation plans to implement IPv6 tied in with other corporate network upgrades that will happen in the next financial year (between April 2014 and March 2015). The other part of its internal network is the data centre infrastructure that includes the corporate infrastructure (such as the corporate file server). That infrastructure has its own private IPv4 addresses. These private addresses are a reserved range of IP addresses for the private network and most of them do not have to be connected to the Internet and do not have to be unique. Hence, there is no reason for ServProvTwo to move that infrastructure to IPv6. Some of that infrastructure, such as their website, portals, and customer portals, are actually on private IPv4 addresses as well. The organisation has firewalls and load balancers that sit on the Internet and translate the addresses to private addresses. However, it is likely to get IPv6 within the next 6 to 12 months (between March 2014 and September 2014). ServProvTwo also have 2G, 3G and (Long Term Evolution) LTE mobile access. IPv6 will be introduced on all of these technologies. This is forecast to happen between April 2014 and March 2015. IPv6 will be introduced on LTE before it is introduced on 2G or 3G.

Figure 6 presents the institutional forces, resources and barriers that ServProvTwo is facing in its IPv6 adoption process. ServProvTwo started planning to adopt IPv6 because it is facing IPv4 depletion and because many major online service providers (e.g., Google) are moving to IPv6. ServProvTwo is learning from the experiences of other service providers globally. The government’s IPv6 adoption campaign has provided IPv6 awareness to the staff and senior level management. IPv6 events have provided ServProvTwo's strategy is to adopt IPv6 in the organisation's products and projects such as UFB and LTE. ServProvTwo has an advantage in terms of IPv6 adoption because it has staff with IPv6 experiences and skills. ServProvTwo's senior level management are involved and support the organisation's IPv6 adoption. The barrier identified is that the organisation has a lot of legacy systems that do not support IPv6.

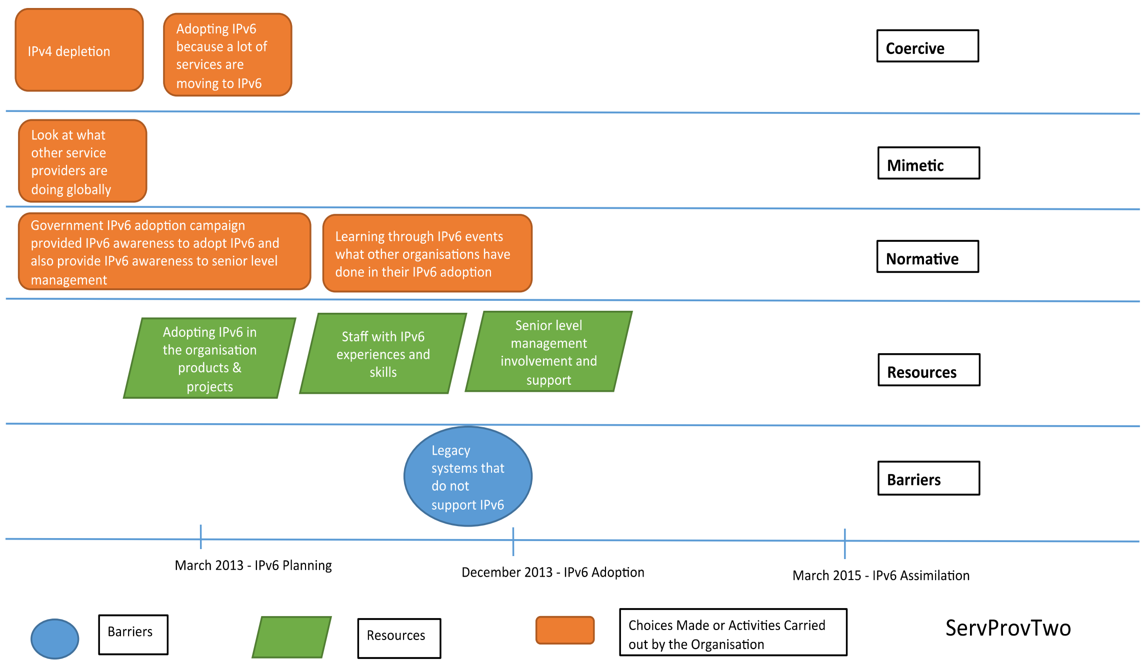

Figure 6 ServProvTwo IPv6 adoption timeline

5.1.7 ServProvThree

ServProvThree is a large Internet service provider with over 2 million users. ServProvThree has two head offices in Auckland and Wellington. ServProvThree's network architect, NetArc, was interviewed.

ServProvThree has not adopted IPv6 because it argues that it only aims to serve customers and has not found a good business case or justification for doing so, especially given its large size. However, ServProvThree has started considering IPv6 – most of its purchase decisions have an IPv6 requirement – but does not have a formal plan to adopt IPv6. Some of ServProvThree's network equipment has IPv6 capability because it is fairly new. NetArc said that although the organisation has not run into problems with IPv4 connectivity, it does not mean that the organisation will not encounter problems with IPv6. ServProvThree's network team did experiment with IPv6, but has not gone further because of the lack of any clear justification.

ServProvThree's IPv6 adoption determinants, resources and barriers are explained in Figure 7. ServProvThree is facing IPv4 depletion and actively using NAT to help with the situation. Although ServProvThree is not planning to adopt IPv6, it still includes IPv6 requirements in all of its purchase agreements. Barriers against ServProvThree's adoption of IPv6 are lack of business case and justifications for IPv6 adoption, the time required for staff to adopt IPv6, and senior management's lack of awareness of IPv6.

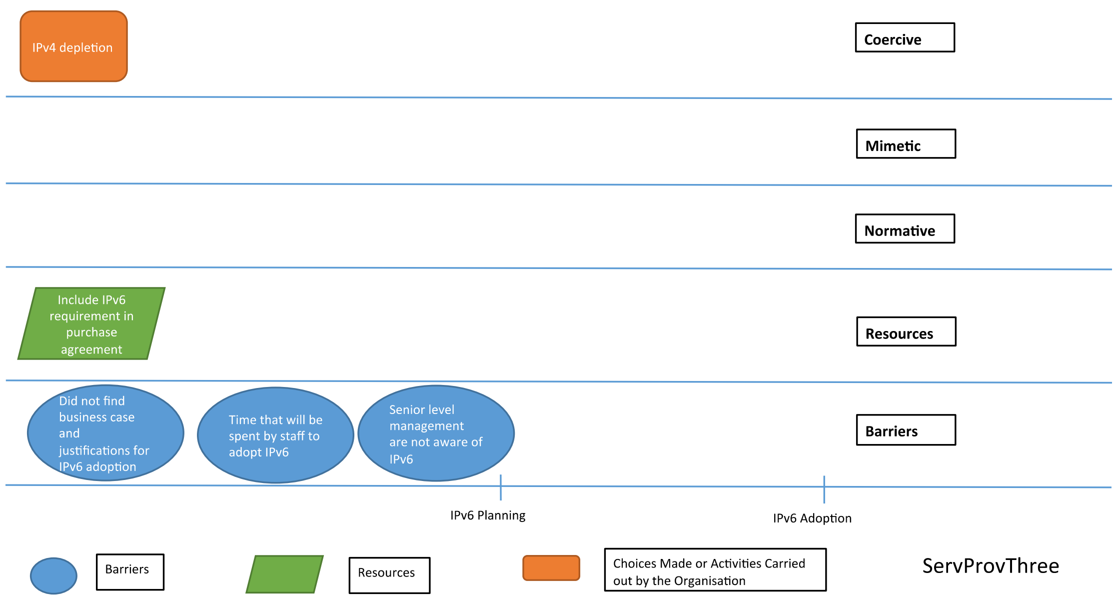

Figure 7 ServProvThree IPv6 adoption timeline

5.1.8 ServProvFour

ServProvFour is a small Internet service provider in the telecommunications industry. It has 365 business customers, including 43 out of 100 top companies in New Zealand. The account manager, AccMgr, from ServProvFour provided insights into the organisation's IPv6 adoption and assimilation process.

ServProvFour is one of the leading adopters of IPv6 in New Zealand. The organisation started adopting IPv6 many years back. ServProvFour's network equipment has been able to support IPv6 since the year 2004/2005. It fully assimilated IPv6 across the organisation in 2007. Initially, ServProvFour approached various vendors and requested supporting papers to guide the organisation's IPv6 adoption. Once it received the required information, it started adopting IPv6. Today, IPv6 is used in the organisation on a daily basis and all of their systems have IPv6 capability. It uses both IPv4 and IPv6. IPv6 is enabled on each and every device on the organisation's network such as computers. The computers can access IPv6 services on the Internet and can revert to IPv4 if the services are on IPv4. Its customers have IPv6 connectivity by default.

Figure 8 presents the institutional forces and resources that drove ServProvFour to adopt and assimilate IPv6. ServProvFour started planning its IPv6 adoption because it faced IPv4 address depletion and wanted to make sure that it could provide IPv6 addresses to customers that required it. ServProvFour was also influenced by other organisations that were adopting IPv6. ServProvFour had vendor support from the beginning as the vendors provided it with guidelines on the IPv6 adoption process. ServProvFour also has IPv6 skilled and knowledgeable staff that helped with the organisation's IPv6 adoption and assimilation.

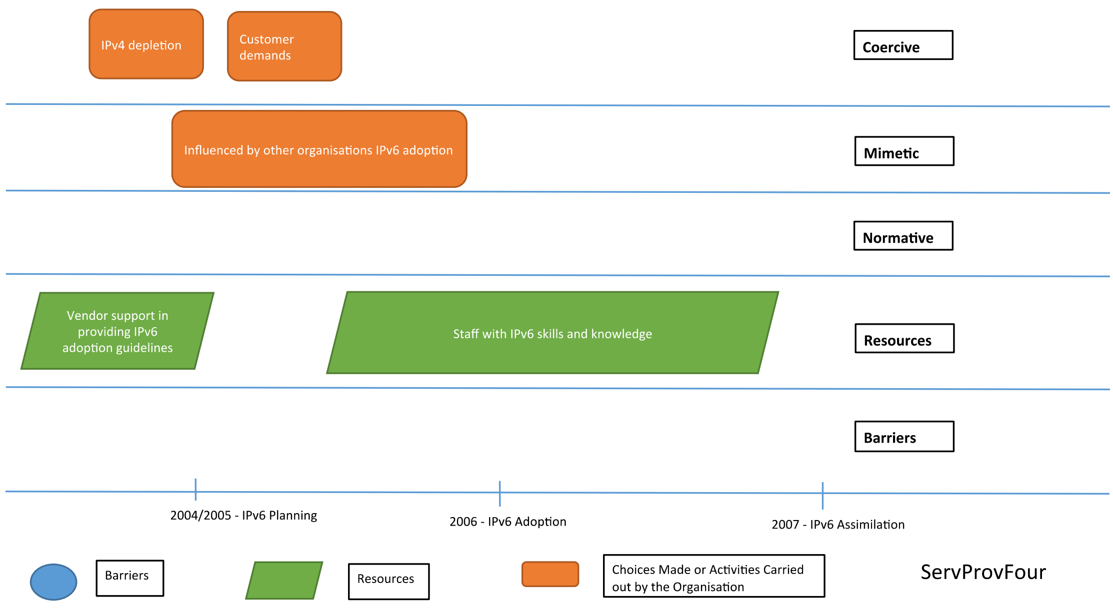

Figure 8 ServProvFour IPv6 adoption timeline

5.1.9 VendOne

VendOne is a medium-sized networking equipment vendor operating in four countries globally. It has 19 office locations around New Zealand with 2000 staff. Data on this organisation's IPv6 adoption was provided by the organisation's Business Manager, BusMgr.

VendOne started planning its IPv6 adoption in 2010. Some of its external network infrastructure is IPv6 capable. Internally, while some branches are IPv6 ready, IPv6 has still not been fully adopted. This is due to the organisation giving priority to providing its customers with IPv6 connectivity. VendOne's network team, which includes BusMgr, experimented with IPv6 when they introduced it in within their own team's infrastructure. They were keen to move to an IPv6-only network, but the equipment and applications required to do so were not available, as most of the available equipment and applications supported only a dual-stack IPv4/IPv6 platform. BusMgr indicated that it is a challenge for established organisations that support thousands of companies, such as VendOne, to adopt IPv6. It would be easier for newly-formed firms to adopt IPv6.

VendOne's IPv6 adoption determinants, resources and barriers are illustrated in Figure 9. VendOne planned to adopt IPv6 to meet its customers' demands. Government IPv6 campaigns encouraged VendOne to start planning its IPv6 adoption. Talks on IPv6 that staff from VendOne attended heightened their awareness of IPv6. The network team has experimented with adopting IPv6 in the team's network infrastructure, which is a step towards IPv6 adoption across the organisation. Support for IPv6 from VendOne's senior management will make it easier for VendOne to fully adopt and assimilate IPv6. The barriers include legacy systems that do not support IPv6, a risk of affecting VendOne's support services for its thousands of clients, and the significant amount of time and effort required to adopt IPv6.

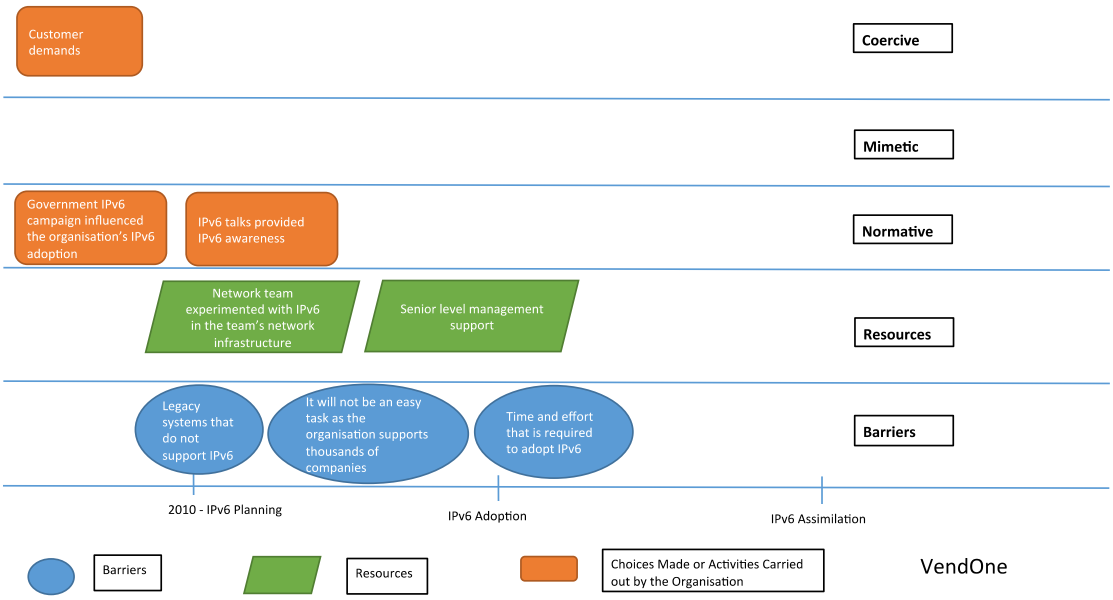

Figure 9 VendOne IPv6 adoption timeline

5.1.10 VendTwo

VendTwo is a small networking equipment vendor with offices in Auckland and Wellington. It has approximately 20 staff and around 10 business customers. Two informants from VendTwo participated in this study: the Business Development Manager, BusDevMgr and the Service Manager, ServMgr.

VendTwo has not adopted IPv6 yet. It is in the middle of upgrading its network, and the new equipment will support IPv6. The next step that the organisation intends to take is to set up IPv6 in a test environment over the next eight weeks (October 2013). The results of the test will help it decide whether to further deploy IPv6.

The institutional forces (mimetic and normative), resources and barriers that VendTwo has experienced are represented in Figure 10. VendTwo is learning from other organisations' IPv6 adoption experiences and applying those experiences to its IPv6 adoption plan. Its staff are also attending the IPv6 talks organised by the New Zealand IPv6 Task Force. Finally, VendTwo's senior management supports the IPv6 adoption plan. However, VendTwo is restricted by a lack of staff with IPv6 skills and experience, and the need to put aside a significant amount of time and effort for the IPv6 project.

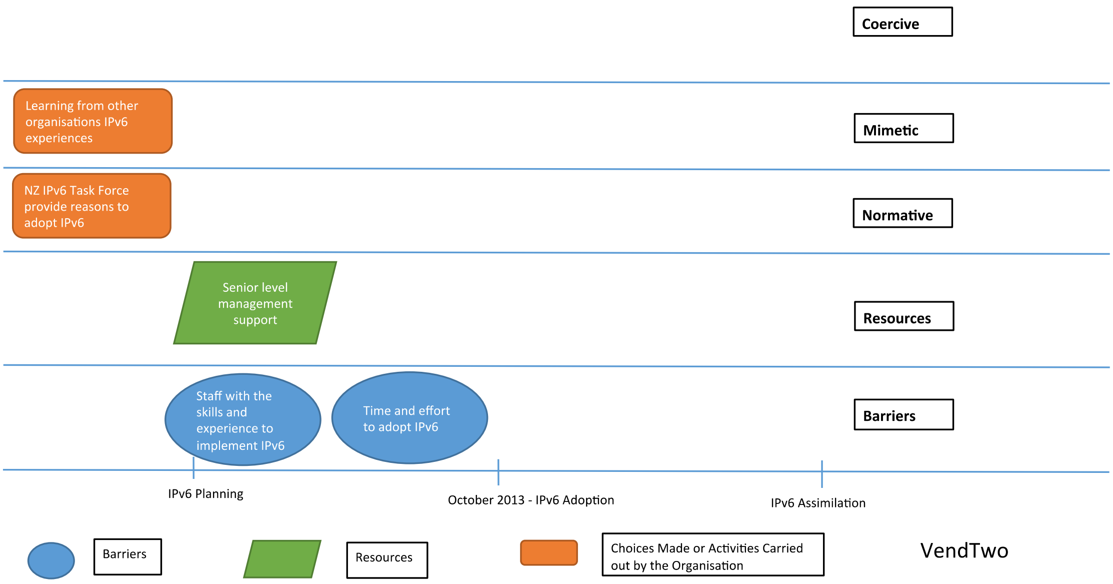

Figure 10 VendTwo IPv6 adoption timeline

5.1.11 VendThree

VendThree is a global networking equipment vendor with 2,000 employees worldwide. The Senior Systems Manager from the New Zealand office (SenSysMgr) participated in this study.

VendThree has IPv6 capability in its products. Customers that purchase those IPv6 ready products can use its IPv6 capability. VendThree also provides IPv6 updates for those products on its website. Its effort to provide IPv6 capability in its products came from the World IPv6 Day in June 2011. However, the organisation has not adopted IPv6 internally. It has products that have IPv6 capability but not an official IPv6 timeline and plan for its internal deployment.

Figure 11 displays VendThree's IPv6 adoption determinants, resources and barriers. The information available on the Internet on IPv4 depletion and the need to adopt IPv6 has driven VendThree to provide IPv6 support on its product. The depletion of IPv4 and World IPv6 Day in 2011 are also influences of the organisation's IPv6 support on its product. Staff of the organisation have also participated in IPv6 events and that has given them a better understanding of IPv6 adoption. VendThree has a technically knowledgeable CIO who is very supportive of IPv6 adoption and will eventually drive the organisation to adopt IPv6 internally. However, VendThree lacks staff with skills and knowledge required to adopt IPv6.

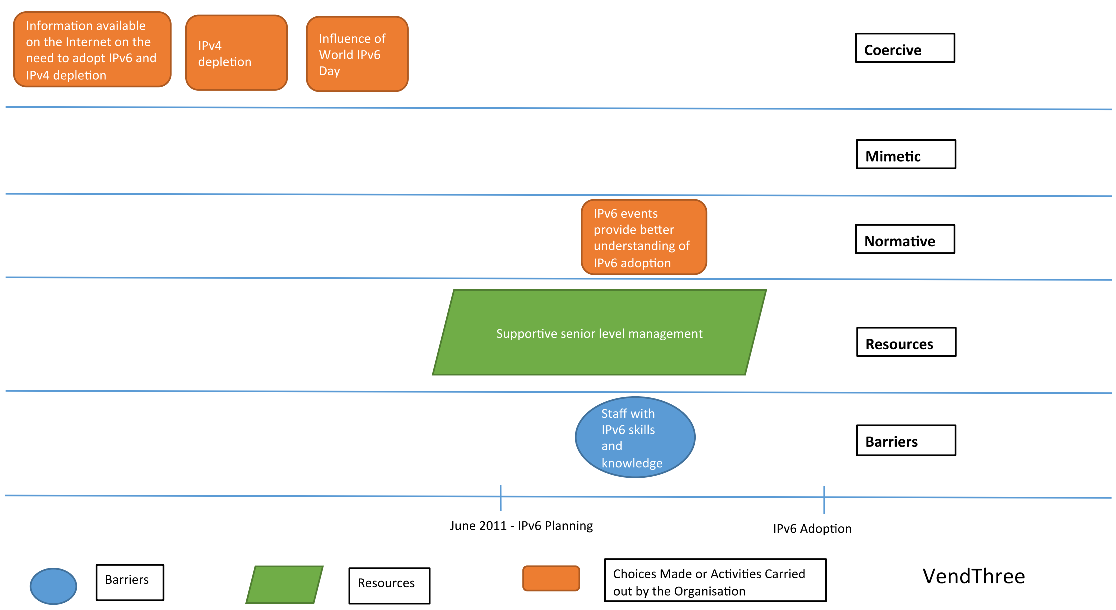

Figure 11 VendThree IPv6 adoption timeline

5.1.12 VendFour

VendFour is one of the top global network equipment vendors. It has nine offices in New Zealand with 500 staff. NetSuppSpec, the Network Support Specialist from VendFour, participated in this study and provided information on its IPv6 experiences.

VendFour has only adopted IPv6 in one of its nine offices. NetSuppSpec works at the office that has deployed IPv6. That office started adopting IPv6 three years ago and has now fully adopted IPv6. The adoption happened because of NetSuppSpec's interest in IPv6. Initially, NetSuppSpec started researching on IPv6. Then, NetSuppSpec started working with the organisation's Internet provider, that is, ServProvFour. ServProvFour turned on IPv6 capability on VendFour's Internet connection and allocated it IPv6 addresses. After that, NetSuppSpec started deploying it in a small test environment in the office. One of the barriers faced by NetSuppSpec is that its DNS is hosted externally and the external DNS host did not support quad A records[7] (IPv6). It was a challenge to get their external DNS to work on their IPv6. NetSuppSpec started pushing its external DNS provider and now they do support IPv6 in quad A records. Later, VendFour joined APNIC and was allocated their own IPv6 address blocks. VendFour moved from obtaining IPv6 address blocks from their ISP to their own set of IPv6 addresses. The organisation plans to adopt IPv6 at its other eight offices. However, there is no timeline for the adoption plan and it will be driven by customer demand.

Figure 12 shows the coercive and mimetic forces, resources and barriers that influence VendFour's IPv6 adoption. Customer demand, IPv4 depletion and to gain competitive advantage are reasons for VendFour's IPv6 adoption planning and adoption. NetSuppSpec believes that it is crucial to understand and experience IPv6 adoption before adopting it widely. The sharing of other organisations' IPv6 adoption

[7] Quad A (or AAAA) record is a DNS record that maps to an IPv6 address.

experiences has driven VendFour to start planning its IPv6 adoption. NetSuppSpec's interest to adopt IPv6 is pushing the office to do so. Initially, its ISP provided IPv6 addresses to VendFour and then, APNIC provided VendFour with its IPv6 addresses. One of the barriers that is experienced by NetSuppSpec is the lack of staff with IPv6 skills and knowledge. NetSuppSpec feels there is no one from the organisation that he can discuss IPv6 adoption with. Another barrier is the DNS host does not support IPv6. The organisation's senior management are also not involved in the organisation's IPv6 adoption plan, which may explain why only one out of nine offices has adopted IPv6.

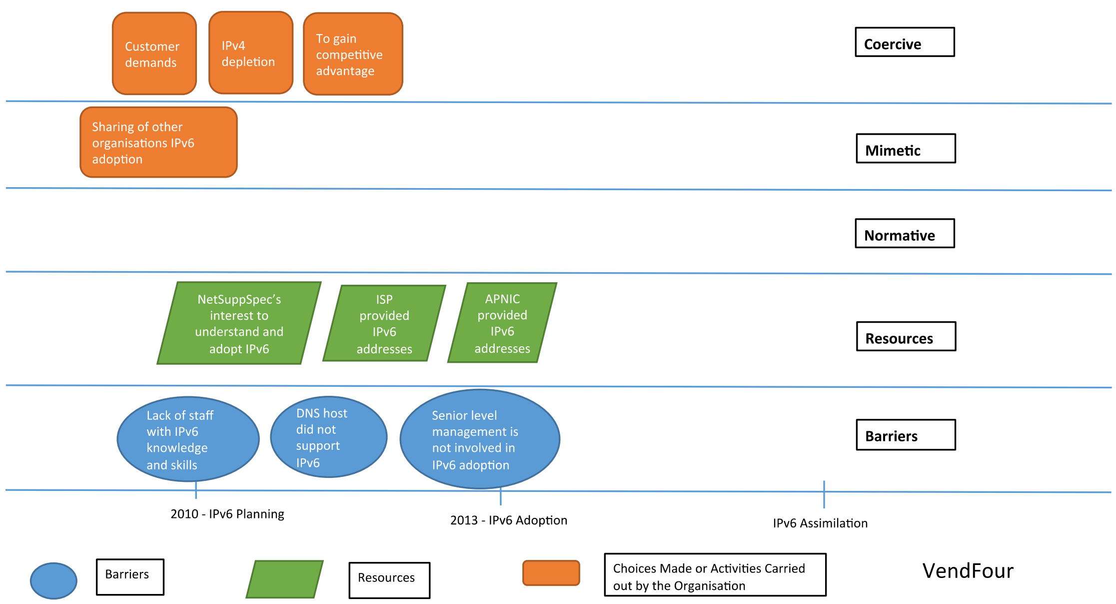

Figure 12 VendFour IPv6 adoption timeline

5.1.13 GovOne

GovOne is a government agency located in Wellington with approximately 3500 employees. Two of its employees were interviewed at two separate interview sessions. The two participants from GovOne were its Senior Manager of Operations and Infrastructure Services, SenMgrOp and its Business and Technology Solution Architect, BTSArc. SenMgrOp's role is to plan the organisation's IPv6 adoption while BTSArc is the architect in charge of its firewall replacement project which will introduce IPv6 into the organisation.

GovOne has not started adopting IPv6. GovOne intends to adopt IPv6 through its existing or upcoming projects (for instance, firewall replacement project). It does not find it necessary to do a special project for IPv6 adoption unless there is mandate from the government. It plans to use its firewall replacement project as a way of getting IPv6 adopted. It does not have a formal long-term plan or strategy for IPv6 adoption. The operational IPv6 experiences obtained through its projects will assist the organisation to progress further. If it does plan to upgrade its core network infrastructure, it may look at upgrading a small part of the organisation's network infrastructure. It will approach IPv6 in three ways. First, it will obtain its own IPv6 block of addresses. Second, it will publish quad A DNS records. Finally, it will deploy IPv6 on a small number of services such as email and websites. SenMgrOp mentioned that IPv6 will be incorporated into its communication and desktop strategy which is developed every three to five years. IPv6 will be included in the projects proposed in the strategy.

Figure 13 presents GovOne's IPv6 determinants, resources and barriers based on the information provided by SenMgrOp and BTSArc. IPv6 depletion is one of the determinants of GovOne's IPv6 adoption plan. It wants to make sure that its customers will always have access to its services and by not adopting IPv6, it might cause the organisation to lose its customers. Learning from other organisations' IPv6 adoption experiences is important to GovOne. Staff from GovOne have been attending IPv6 events and it has influenced the organisation to start planning its IPv6 adoption. IPv6 will be adopted as part of its existing and upcoming projects such as its firewall replacement project. GovOne is also using the government agencies IPv6 guideline to guide its IPv6 adoption, for instance, the upgrading of its hardware and software to IPv6. Barriers that have been identified are lack of priority for IPv6 in the organisation, lack of top management IPv6 awareness, staff who need to be trained in IPv6 and software that does not support IPv6.

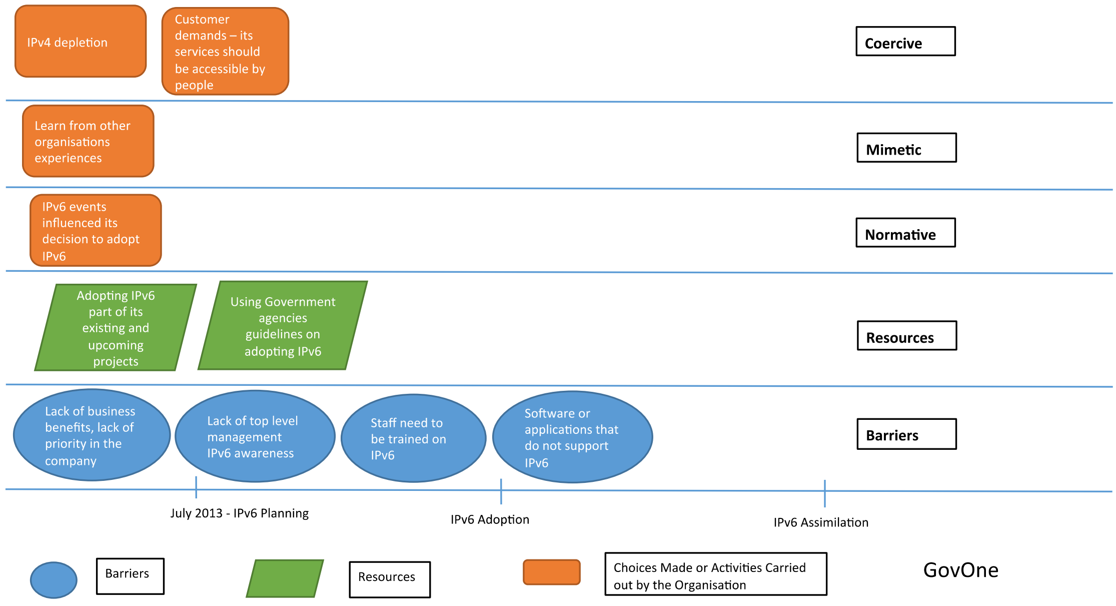

Figure 13 GovOne IPv6 adoption timeline

5.1.14 GovTwo

GovTwo is a government agency located in Wellington with 1,786 employees. SolArc, who is the organisation's Solution Architect, participated in this study and provided insights on the organisation's IPv6 adoption.

GovTwo is the leading government agency providing or selling IT services to other government agencies. These services that are provided to other government agencies are IPv6 ready. In 2009, GovTwo researched what other government agencies were doing in terms of IPv6, and found that no agency was planning to adopt or had adopted IPv6. In 2010, it also noticed that the government's external DNS was not IPv6 ready. GovTwo fixed the DNS and it has been IPv6-ready now for nearly three years. However, it did not have a formal plan and what it has done is to enable IPv6 on all of its external-facing services (websites). However, GovTwo has not deployed IPv6 internally and does not have an official IPv6 project or plan.

GovTwo's IPv6 determinants, resources as well as barriers are shown in Figure 14. The main reason for GovTwo to start planning its IPv6 capability in its services is because of customer demand. It wants to make sure its customers from other countries, especially from countries that have adopted IPv6, are able to access its services. SolArc attended many IPv6 events three years ago, such as seminars and training sessions, that were useful to understand the adoption of IPv6. GovTwo plans to use its hardware refresh cycle to upgrade or replace its equipment to include IPv6 capability. One of the barriers that GovTwo has encountered is lack of IPv6 awareness among its staff. If it plans to adopt IPv6 internally, the cost of training its staff on IPv6 will be a barrier.

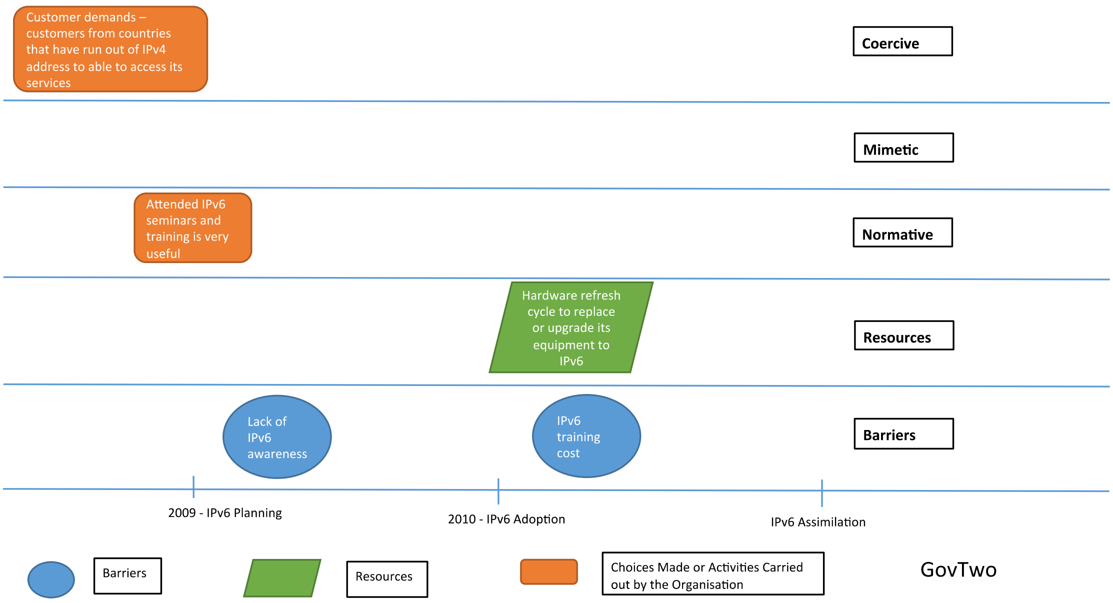

Figure 14 GovTwo IPv6 adoption timeline

5.1.15 FoodRet

FoodRet is a large food retailer with 400 stores around New Zealand. Informants of this study from FoodRet were its Strategy and Architect Manager, SAMgr and its Technical Architect, TechArc.

FoodRet has not adopted IPv6. It has recently performed a network infrastructure review, and upgraded or replaced some of its network equipment with IPv6-ready equipment. It purchased IPv6-ready equipment on the basis of needing it at some point of time. However, it does not intend to adopt IPv6 yet because it has strategic architectural issues that need to be taken care of. Its only IPv6 effort is to ensure any equipment that is purchased has IPv6 capability, which has been happening over the last two years. If FoodRet plans to adopt IPv6, it would not be a "big bang" deployment, as IPv6 adoption will be tested in a low risk part of the network and slowly progress from there. Since FoodRet has 400 stores around New Zealand, it needs to ensure that the adoption does not have any negative impact on its store network.

Figure 15 displays the resources that the organisation has and the barriers to FoodRet's IPv6 adoption. The only resource that the organisation has is its including IPv6 requirement for the upgrading or replacement of its equipment. FoodRet has various barriers preventing it from adopting IPv6. First, it does not see IPv6 adoption as a priority. It is afraid that the adoption of IPv6 might have negative implications for its 400 stores. FoodRet also has many legacy systems that do not support IPv6. Most importantly, its senior management does not see any compelling reasons to adopt IPv6.

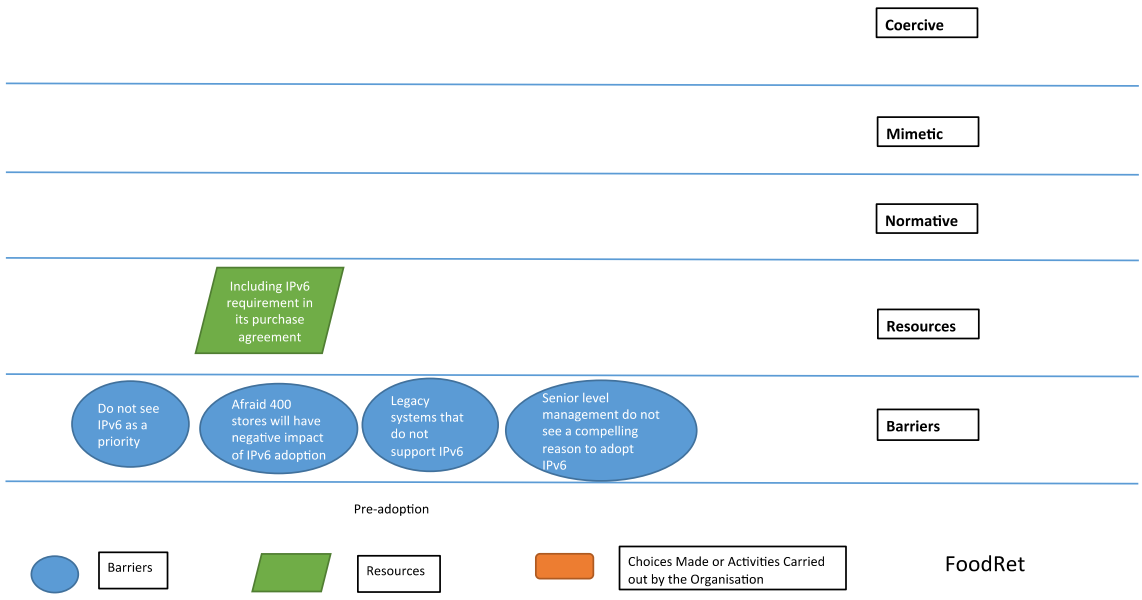

Figure 15 FoodRet IPv6 adoption timeline

5.1.16 AirTrans

AirTrans is a small organisation from the air transport industry with 100 staff and more than 5 million customers yearly. Its Chief Information Officer, CIOff, and its Manager for Infrastructure Service Delivery, MgrInfServ, participated in this research.

AirTrans has not yet adopted IPv6 and does not have any plans to adopt IPv6. Its IT support and services are mostly outsourced and it has only a small IT team in the organisation. AirTrans is currently upgrading its core network infrastructure and it assumes that newer equipment added to its core network has IPv6 capability. However, it did not include IPv6 requirements in its purchase agreement.

Barriers that have caused AirTrans not to consider adopting IPv6 are discussed in Figure 16. One of the barriers is that AirTrans has adequate IPv4 addresses. It also has not received any push from organisations in the same industry. It was also mentioned that it is not easy for the organisation to allocate funding for its IPv6 adoption project. Another barrier is that the organisation's CEO is not even aware of IPv6, which means it will not have priority in the organisation. AirTrans also has not received any IPv6 demands from its customers.

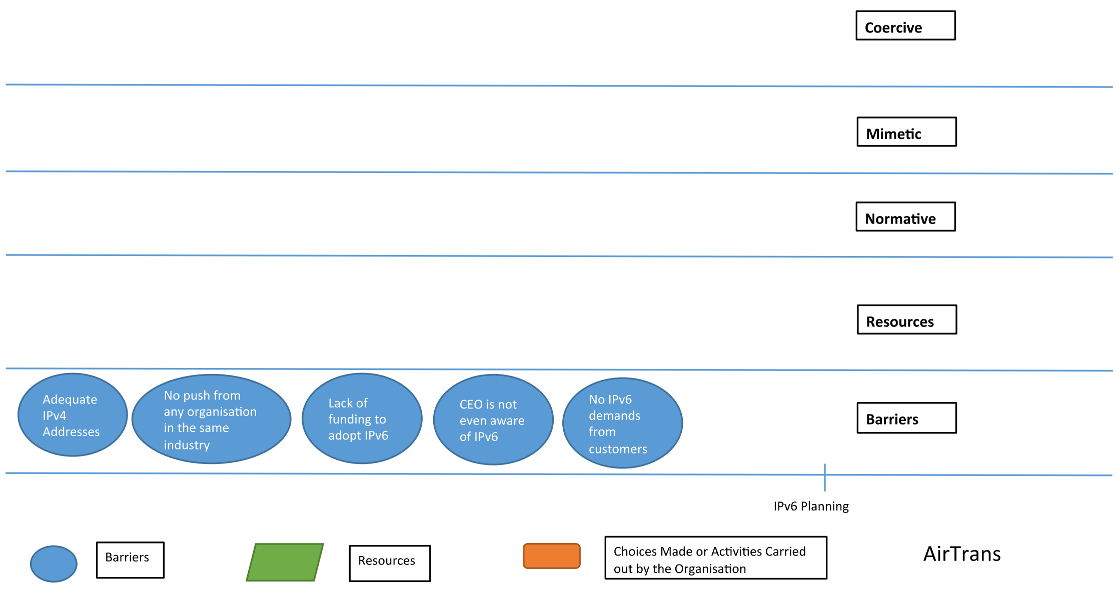

Figure 16 AirTrans IPv6 adoption timeline

5.2 Descriptive Analysis

The descriptive information from the previous section is used to aggregate the 16 case studies to provide insights on the adoption and assimilation of IPv6 in New Zealand.

5.2.1 Summary of descriptive findings

The 16 organisations that participated in this study are classified into five stages of IPv6 adoption and assimilation. The five stages are: 1) non-adoption, 2) planning to adopt, 3) adoption, 4) assimilating, and 5) assimilation. Table 9 shows the stage of IPv6 adoption that each organisation is currently in. Three of the organisations (ServProvThree, FoodRet and AirTrans) have not adopted IPv6. Four organisations that are in the IPv6 planning stage are EduTwo, EduFour, VendTwo and GovOne. Six organisations that are currently adopting IPv6 are EduThree, ServProvOne, ServProvTwo, VendOne, VendThree and GovTwo. Two of the organisations that are assimilating IPv6 are EduOne and VendFour. Only one organisation, ServProvFour, has fully adopted and assimilation IPv6.

Organisations that are adopting or intending to adopt IPv6 are mainly using the dual-stack IPv4/IPv6 approach. This is because the co-existence of IPv4 and IPv6 is the best option at the moment, as most of the Internet today is still IPv4 and it will take many years for it to fully move to IPv6. There is usually a three to five year equipment refresh cycle for organisations. Legacy systems could inhibit the IPv6 adoption by organisations in New Zealand. While some of the organisations have used teams to plan and deploy IPv6, adoption in other organisations have left it to individuals who are solely responsible for the adoption exercise.

Table 9 Organisations by their IPv6 Adoption Stage

No.	**Stage of IPv6 Adoption**	**Organisation**	**Industry**
1.	Not adopting IPv6	ServProvThree	Telecommunications
		FoodRet	Food retail
		AirTrans	Air transport
2.	Planning IPv6 adoption	EduTwo	Tertiary education
		EduFour	Tertiary education
		VendTwo	Vendor
		GovOne	Government agency
3.	Adopting IPv6	EduThree	Tertiary education
		ServProvOne	Telecommunications
		ServProvTwo	Telecommunications
		VendOne	Vendor
		VendThree	Vendor
		GovTwo	Government agency
4.	Assimilating IPv6	EduOne	Tertiary education
		VendFour	Vendor
5.	Adopted and assimilated IPv6	ServProvFour	Telecommunications

Various benefits of adopting IPv6 were mentioned by informants. Some of their responses have been presented below:

> *"It's my understanding that … with the IPv6, it's about future proofing the things that we need the external world to see"*

(CIOff, AirTrans)

> *"The main benefit will be, being able to stay in touch with everybody"*

(SenNetEng, EduFour)

"If you don't go to IPv6, you are going to cut yourself off from other people you need to communicate with"

(InfrEng, EduOne)

"[E]veryone in the world can access IPv6 through services which are IPv6 ready"

(SolArc, GovTwo)

5.2.2 Determinants of IPv6 adoption

The data from the case studies was coded thematically (as described in Chapters 3 and 4). This section presents the results of the coding exercise in order to identify the determinants of IPv6 adoption. The next section describes the findings regarding the barriers that organisations faced in adopting IPv6. Various determinants of IPv6 adoption were identified from the data, including customer demand, internal pressures, internal IPv6 skills, depletion of IPv4 addresses, challenges with Network Address Translation (NAT), the influence of external parties, enhancements to services and applications, a desire to obtain recognition, and others. These are described in detail below.

5.2.2.1 Customer demand

Many organisations mentioned that demand from their customers encouraged them to adopt IPv6, and similarly, a lack of demand led to some organisations not adopting IPv6. In both instances, customer demands were determinants of organisations' IPv6 adoption and assimilation. Both informants from AirTrans, a non-adopter, mentioned that it would start planning to adopt IPv6 if it saw its customers doing so. GovOne was not driven to adopt IPv6 because of the lack of customer demand. VendFour was prepared to accelerate its IPv6 adoption if its customers requested it:

".[I]f we see (airline customer A) or (airline customer B) start moving across and there's talk from the vendor, if they've given us a notice that they are moving, we'll probably start putting it in the roadmaps"

(MgrInfServ, AirTrans)

"[O]ur biggest customer is [airline customer A]. If [airline customer A] made it a requirement that we would be IPv6 compliant, we'd have to because they are just our number one client or our number one customer"

(CIOff, AirTrans)

"Because our customers aren't calling for it… there's no driver" (BTSArc, GovOne)

"[I]f we were to make the decision to do it out of interest and deploy IPv6, we'll be waiting for customers to come and ask us, can we have IPv6?… They would be a big driver deploying it [IPv6] quicker"

(NetSuppSpec, VendFour)

All four tertiary institutions that participated in this study found that the need to interact with international students motivated their adoption of IPv6, since many of the countries where these students originated from, such as China, Korea, and Japan, were deploying IPv6:

"[W]e deemed that it is appropriate to try to ensure if there were going to be islands of IPv6 connectivity that couldn't talk to the rest of the world, we would be in a position to talk to them. I already know that there are half a dozen of Chinese universities who are IPv6 only, and we could talk to them, we can't anymore"

(InfrEng, EduOne)

"I look at it through strategically … because a lot of our students are from Asian regions … those guys, if they want to go to the University website and see where I can go study English, they are going to get to a website that is not IPv6 capable. We lose out on that for that year or two years … it's definitely a strategic thing from my point of view"

(NetwLead, EduThree)

"[O]ur future international students are going to be in countries like India and China which [have] completely exhausted their IPv4 space, [and] make … heavy use of NATing and at some point, if we want to communicate with them for distance learning, we need to be IPv6 compliant"

(NetwMgr, EduTwo)

5.2.2.2 Depletion of IPv4 addresses

The literature on IPv6 has mentioned the depletion of IPv4 addresses as one of the main reasons for IPv6 adoption, and this issue was cited by many organisations in the sample. Organisations wanted to make sure their services were accessible by their customers, since if they ran out of IPv4 addresses, they would not be able to provide those services to their customers, or restrict their growth:

"We need to, in order to be part of government, we need to be accessible by all people.… So we need to do it"

(BTSArc, GovOne)

"[W]e can't ignore IPv4 exhaustion. We are a service provider and we have a finite number of IP addresses assigned to us by APNIC and at some point, we will run out of IP addresses. So by us not introducing IPv6, we will effectively limit our ability to grow"

(CliMgr, ServProvTwo)

"We saw the depletion internationally as being a situation where there were going to be other organisations that we wanted to communicate with who might not be so lucky"

(InfrEng, EduOne)

Some organisations had already faced the stresses arising out of IPv4 depletion:

"Oh terribly, we have a DSL provider as one of our ventures which obviously took off past the APNIC depletion of IPv4 addresses. So we managed to literally scavenge a few/24s just for the customers. We have deployed NAT for them. Otherwise, they wouldn't be able to reach the Internet.... That was the only way"

(NetArc, ServProvThree)

APNIC has played a major role in IPv6 adoption in the Asia Pacific region, as highlighted here:

"[T]he policies that are enforced by APNIC to control the IPv4 addresses get in the way of some of our customers getting the number of addresses that they

wanted.... We can get a hold of any number of IPv6 addresses but we've got to provide quite detailed justifications to be able to get an IPv4 address space"

*(*AccMgr, ServProvFour)

5.2.2.3 Network Address Translation (NAT) usage

The usage of NAT also drove organisations to adopt IPv6. Although NAT is a solution for IPv4 depletion, there are also problems with its usage in the long run:

"The more NAT that you put in the Internet, the slower things go"

(CliMgr, ServProvTwo)

"Obviously, we could take the approach that we don't do v6 and just NAT everything but I think that's an unrealistic approach because you do break certain parts of the Internet connectivity because you got the customer doing NAT and you're double NATing things. On the whole, it might work but it is not going to be nice, it's going to be nasty"

(SenSysSpec, ServProvOne)

The problems with NAT make it more beneficial to invest in IPv6:

"[T]he advice that I give to people to accelerate IPv6 is don't invest in your IPv4 NAT technology. Invest that same money into rolling out IPv6 in the infrastructure because the more traffic you get on to v6 that's routed, the less traffic you have to NAT… you can reduce the IPv4 traffic you have, therefore, reduce the problems you have with IPv4"

(CliMgr, ServProvTwo)

5.2.2.4 Enhancements to IT services and applications

The ability to deploy new IT services and applications in organisations that used IPv6 only had an impact on organisational decisions to adopt IPv6. For example, Microsoft DirectAccess is a technology that automatically connects computers to an intranet when they are connected to the Internet, thus helping system administrators manage remote devices. It played a part in two organisations' IPv6 plans:

> *"One example is Microsoft Direct Access technology, which is IPv6 only. That is … a very tangible business benefit to give your staff an easy way to give remote access to the organization…. I think as more IPv6-only features come out in either the Microsoft stack … or other applications, you will see business actually saying, well, 'we need DirectAccess, we need some other features, we need IPv6 to do that. Let's do it now', and I think that could also be a driver for IPv6"*
>
> (NetwMgr, EduTwo)

> *"[T]he closest that we've come to considering potential IPv6 in any capacity would be Microsoft DirectAccess.... So that is something that we really would [see] as a potential access solution quite a few years ago, three or four years ago. There were some challenges there…. DirectAccess is probably the closest we've ever come to"*
>
> (TechArc, FoodRet)

Other organisations adopted IPv6 as part of enhancements to other aspects of their IT infrastructure.

> *"[T]he firewall [replacement] project is being used as a mechanism to start the ball rolling…. Piggybacking… the existing firewall platform is aging and has*

got end of service updates coming up within the next two years on the hardware… that means the firewall project is prioritized within the Ministry"

(BTSArc, GovOne)

"We don't run IPv6 as a project. IPv6 is a capability that needs to be available across all technologies, so we make sure that as projects are deployed and new services are deployed, for example, UFB [Ultra-Fast Broadband]. *UFB has IPv6 and that was driven as a requirement of that project, not as a separate IPv6 project. So IPv6 becomes part of our DNA now across all services. That's how we plan to rollout IPv6. Every project needs to consider it as a requirement…. So, for example, if an element is going to be upgraded with software in two months' time, we will make sure that element has IPv6 capability in it when the software is upgraded or we would choose an appropriate software version to make sure it does"*

(CliMgr, ServProvTwo)

5.2.2.5 To obtain recognition in their industry

Some organisations adopted IPv6 to obtain a reputational advantage over their rivals or peers:

"We should be seen to be adopting it [IPv6] early. So I think we should be a leader on that or we should be trying to get a production webserver on it as soon as we possibly can. So even if no one is using it, or very few people are using it, we should at least be seen doing it or being proactive"

(SenNetEng, EduFour)

"[E]verybody wants their name to be noticed…. If we can actually be one of the first to go natively [IPv6 only] in New Zealand, that's a huge, huge, you know,

pin on our jacket to say…. You obviously want to stand out…. We want to be noticed. We want to make sure that we get noticed as one of the first, if not the first, to actually go natively IPv6"

(NetwLead, EduThree)

"[W]e need to be present [on the IPv6 Internet] as an accessible government department"

(BTSArc, GovOne)

5.2.2.6 Presence of IPv6 skills

Organisations that had employees with IPv6 skills and experiences were able to adopt IPv6 more easily:

"We have been a little bit lucky in that the focus on the Engineering and Computer Science group have offered to help us out…. They have been given some address space (IPv6) to play with for… a couple of years maybe... also fortunately, we have a guy who works in Engineering and Computer Science … who is well known in the IP. He belongs to the AARNET, overarching group that drives IPv6. So he has offered to help us out"

(InfrServMgr, EduFour)

"I played around with it for many years. So, I found mistakes, like certain functions had issues with IPv6. So that kind of stuff is unheard off"

(BTSArc, GovOne)

"I wanted something new to learn and IPv6 was around at that time and I'd done a bit of reading about it"

(NetSuppSpec, VendFour)

However, a lack of experience could be remedied during the adoption process:

> *"It is a learning curve for the team and once you get them on board, it is not hard"*
>
> (SolArc, GovTwo)

5.2.2.7 Influence of external parties: networks, partners, and peers

Sharing of IPv6 adoption experiences by other organisations influenced organisations' IPv6 adoption:

> *"We are just learning from other organisations that have run into problems like they want to do IPv6 but they find a feature they need within their firewall or border router is not IPv6 compliant. And they are really stuck until either the vendor update the code on the equipment or they replace it"*
>
> (NetwMgr, EduTwo)

> *"For adoption to start occurring, we need to actually see evidence that people know how to adopt"*
>
> (SAMgr, FoodRet)

> *"[Y]ou can bounce off and learn shared experiences and that kind of stuff"*
>
> (BTSArc, GovOne)

> *"We've learned about what other organisations have done right and wrong. Yes they definitely have influenced our plan. Internationally, they're internationally reading up on what people have done but also locally the experience that we get from other service providers"*
>
> (CliMgr, ServProvTwo)

"[T]he other one would be probably be the airways.... They drop us a lot of feeds and if they say you must be IPv6 compliant, we'd have to be compliant tomorrow. So I guess it's somebody more important up the food chain or our mothership...who are our owners"

(CIOff, AirTrans)

The technological decisions of organisations were influenced by networks they interacted with:

"The incentive to go to IPv6 was that KAREN was going to carry IPv6…. We deemed that it is appropriate that we should have IPv6 as well. Ok, that was the decision point that we decided that we were going to do it and then actually doing it. Whenever there was an opportunity to enable IPv6, we took it"

(InfrEng, EduOne)

"[T]he necessity from IPv6 came from KAREN because it was there"

(NetwLead, EduThree)

5.2.2.8 Internal pressures

Internal pressure motivated one organisation to start planning its IPv6 adoption. The IT department in EduFour were pressured by the academic staff from the tertiary institution's Engineering and Computer Science department to adopt IPv6:

"Now I think, we have a bit of pressure put on us by academic friends who made the noise about it. They are maintaining that because they are adopting it [IPv6] 100%, it doesn't reflect well on their organisation, stuff like that"

(InfrServMgr, EduFour)

5.2.2.9 Impact of government or task force IPv6 campaign

Government and New Zealand IPv6 Task Force IPv6 campaigns also influenced organisational decisions to adopt. The 16 informants who attended IPv6 information and education events are listed in Table 10 below.

Table 10 Attendance at IPv6 Events

Organisation	**Participants**	**Attendance at IPv6 information and education events**
EduOne	InfrEng	Yes
EduTwo	NetwMgr	
EduThree	NetwLead	
	NetwEng	
EduFour	SenNetEng	
	InfrServMgr	No
ServProvOne	SenSysSpec	Yes
ServProvTwo	CliMgr	
ServProvThree	NetArc	No
ServProvFour	AccMgr	
VendOne	BusMgr	Yes
VendTwo	BusDevMgr	
	ServMgr	
VendThree	SenSysMgr	
VendFour	NetSuppSpec	
GovOne	SenMgrOp	
	BTSArc	No
GovTwo	SolArc	Yes
FoodRet	SAMgr	
	TechArc	No
AirTrans	CIOff	Yes
	MgrInfServ	No

Participants that attended IPv6 events highlighted the importance of these IPv6 events:

> *"I went along to one of the sessions that they ran and it was actually quite good to listen to some of the organisations that have gone further than us and some organisations that haven't even thought about it yet. So it was quite good to listen to all those and also listen to the experts talking about the adoption plans and it's good that they are being proactive about it"*
>
> (SenNetEng, EduFour)

"It definitely influenced in the sense that once I was there, I saw the necessity for it, for the IPv6 adoption and also the government was trying to do a good thing, was trying to make companies aware of the fact of, you know what, this is happening. Don't wait until the end and get that started in the dark. I think that the message is the thing I brought over across, is to say well we need to look at it but in all honestly, my managers were not unclear about that fact in any case. When I got back and related, we all sort of agreed that even though it had to be said in their point of view, it was something that we internally knew in any case"

(NetwLead, EduThree)

"I think it provided heightened awareness that we should be doing something with v6…. It definitely created awareness in our executives as well"

(CliMgr, ServProvTwo)

5.2.2.10 Impact of IT infrastructure components evolution

The evolution of organisational IT infrastructure over time was able help organisations adopt IPv6, according to the experiences of some participants. For example, some organisations began by including IPv6 requirements when they purchased network infrastructure components.

"We make sure anything we purchase now, it's part of the decision. I don't think the kit we've got now is influencing our decision to move forward faster or something"

(SenNetEng, EduFour)

"Yes, mainly operating systems rollover as people go towards rollover all of their IT systems, IP sticks come up to that. So you find after a while that all the users, a lot of IT departments forgetting to turn off IPv6 on their client

computers. So they end up coming into an environment where all their laptops and desktop users are already IPv6 ready. All you need to do is configure the automatic IP addressing on the router and basically all good. So yeah, I would say so"

(AccMgr, ServProvFour)

"I think it helps, I think at that time, it will help. If you have the conversation five years ago and IPv6 has been around a long time and you talked about at least the idea of putting IPv6 into your infrastructure, there's so many pieces that just don't fit. And so, you've got a 100 pieces that you need to put together and 90 of them don't intend to do"

(BusMgr, VendOne)

5.2.2.11 Role of content providers

Content providers such as Facebook, Google, YouTube and others also had a significant role in organisations' adoption of IPv6. These organisations were motivated to adopt IPv6 because these large content providers had adopted or were adopting IPv6.

"In fact, all the big players – Yahoo, Google, Facebook – all of those people now have running v6 satisfactorily and don't seem to be experiencing issues. Seems to me that it's a bit of a no brainer, if it causes a problem, you turn it off. Otherwise you turn it on"

(InfrEng, EduOne)

"If Amazon or some of the other big ones suddenly come out and say, you can only use cloud services base on IPv6, then we might pay more attention but at the moment, even Microsoft hasn't done that"

(SAMgr, FoodRet)

"[A] lot of services are moving on to IPv6. And so Google, Facebook, a lot of the major content providers already have IPv6 connectivity…. Content is going to v6. So we have to give our customers access to that content"

(CliMgr, ServProvTwo)

5.2.2.12 Senior management support

Senior management support for IPv6 and involvement in IPv6 projects encouraged organisational adoption.

"The previous CIO when the project began, with the thought that there was an impact physically [the depletion of IPv4], *he was prepared to go for it. He could see the benefits in the longer terms. He didn't ask for it. It was my suggestion that we do it. But he did not have a problem with it being done"*

(InfrEng, EduOne)

"For my organisation, we are reasonably unique because we are a technology company. People within our company are certainly aware of the technology at all levels. Our CEO, all our executives are technical people and they a have very, very deep understanding of technology because that's their business"

(VendFour, BusMgr)

The senior management of the IT department in EduThree was very involved in the IPv6 adoption process and had included it in its personal goal setting strategy:

"*So they have been involved in it. My manager has always asked us and always made it part of our PGS, we've got our personal goal setting exercise which we do once a year and IPv6 is every year on mine and NetwEng's list. Me, to make* *sure it gets done and it gets overseen and the strategy it follows. NetwEng side, NetwEng needs to do the configurations and the technical bits and the background"*

(NetwLead, EduThree)

The senior management at ServProvTwo were actively involved in their IPv6 adoption process and had approved the funding required for the adoption:

"There are actively involved. So the management, of course, gets to review and approve all of our strategy papers and all of our investments. So they may not be aware of the inner details of when each platform is getting updated … they've been involved in approving and guiding the investment for IPv6 to make sure that it actually does happen"

(CliMgr, ServProvTwo)

5.2.3 Barriers to IPv6 adoption

There were several barriers to IPv6 adoption found from the interviews such as staff training costs, an adequate number of existing IPv4 addresses, IPv6 not being seen as a priority, lack of senior level management support, time constraints, influence of external parties, complexity of IPv6, organisation size, difficulties of obtaining funding for IPv6 and IT support being outsourced. The barriers are discussed in this section.

5.2.3.1 Adequate IPv4 addresses

Although much of the IPv6 literature states that IPv4 depletion is a driver for organisations to adopt IPv6, some organisations in New Zealand do not face IPv4 depletion or are not driven to adopt IPv6 because of the depletion of IPv4. The following statements from informants illustrate that if an organisation has an adequate number of IPv4 addresses, there is little reason for the organisation to adopt IPv6:

> *"I think we are lucky because we got whole class B to ourselves, so we've never had any problems. We a lot luckier than other organisations. I am sure there are a lot of organisations struggling and that's a big influence on them but we are not in that position"*
>
> (SenNetEng, EduFour)

> *"The chances of us running out of IPv4 addresses in the next 10 years is really, really low"*
>
> (NetwLead, EduThree)

> *"Probably the simplistic answer to that is no.... My previous organisation was running out of IP addresses but here in this organisation, we haven't had that problem"*
>
> (SenMgrOp, GovOne)

5.2.3.2 Influence of external parties

Although APNIC allocates IPv6 addresses for organisations in the Asia Pacific region and pushes the IPv6 adoption in the region, it also has a role in prolonging IPv4 addresses usage by organisations:

> *"I was reading some articles that said APNIC is trying to recover unused v4 address space and all around the place are very serious and then reusing that to overcome the shortage problem and the feeling was, the articles I was reading,*

that would keep things going for some time, you know…. Something we can look at possibly"

(InfrServMgr, EduFour)

So, despite APNIC's role in motivating organisations to adopt IPv6, it also tries to extend the life of IPv4 addresses, which may be a barrier towards IPv6 adoption.

Organisations' partners or owners also played a vital role in some organisations' IPv6 adoption. If partners or owners did not push for IPv6 adoption, the organisation may not have see a reason for adopting IPv6:

"We aren't getting any push from any major organisations in our sector which is transport"

(CIOff, AirTrans)

"[B]ecause we don't have the bandwidth to do it ourselves. We need partners that already have done it a number of times and know what the risks are and how to do it"

(TechArc, FoodRet)

The sharing of IPv6 adoption experiences by other organisations in its network was also seen as a barrier to an organisation's adoption of IPv6 as opposed to it being a determinant, as in Section 5.2.2.13. Organisations may have been inclined to wait to adopt IPv6 after looking at the experiences of organisations in their networks:

"If anything, it slowed down our plans, because what I have learned is that the organisations that have tried to adopt early ran into all sorts of problems and really wasted a lot of time, a lot of effort, got nowhere, you know, had to rethink their strategy,

realised that they were very little of their infrastructure was IPv6 ready, the vendors weren't ready"

(NetwMgr, EduTwo)

Lack of vendor support is likewise a barrier to an organisation's IPv6 adoption. If organisations do not have IPv6 capable equipment in their networks, they will be unable to adopt IPv6. Some participants mentioned vendor support as a problem, as well as the tendency for vendors to charge licensing fees to support IPv6:

> *"I think the biggest issue that we came across was that vendors who said their equipment was IPv6 ready and IPv6 capable, but when you actually try to use it and it turned out that that was not actually the case at all.… The only way they could see fixing the IPv6 was to downgrade back to an earlier version of the software which we can't do cos we needed the features of the newer version. We then sort of said that how are you going to fix this? You told us that it would work. They said oh well, what we will do is we will give licensing, you can run a standalone IPv6 firewall, so we did that. And then they wouldn't give us the license. The vendor made a commitment which they were not honouring.… As I said, where vendors have stated compliance with IPv6 and support for it, it turns out that they don't. That amounts to in my opinion, to lying to your customers and when you have made a significant investment in a particular technology from a particular company and say yes we can, and it turns out that it can't. And they don't support you"*

(InfrEng, EduOne)

> *"By getting their roadmap aligned with our timeframes, yeah, it's difficult but that's typical with vendors, it's sort of out of our control. That point we think*

we've got to swap vendors to another vendor that got the capability coz we're waiting for roadmap for another vendor that says they're going to have v6 capability in a year but they haven't delivered it. Then you have to make decisions about going elsewhere but again its commercial as well as just technology based"

(SenSysSpec, ServProvOne)

"That's an interesting question. It's a bit of a sore point from my perspective, it really depends. If you ask a vendor is this piece of equipment that I buy IPv6 capable, the answer you would get for just about everything is yes. The question is what does that mean? You know, for example, are all features IPv6 capable? No, not necessarily. If I enable IPv6, is that equivalent to something compared to IPv4 in the equipment? Do I have to pay a license fee to use IPv6 and it's quite sort of, so, we ask these questions and we've been caught out with the answers before. Even new equipment, brand freaking new, been released today by well-known vendors, it doesn't fully support. And the same level of performance functionality that you get with IPv4 is not there and there are still a number of vendors that insist on charging a license fee over and above what you pay for the equipment. So the answer is, is it capable? Yes. Is it the same with IPv4 in just about all cases? No. And it's one of the big problems"

(BusMgr, VendOne)

5.2.3.3 Complexity of IPv6

Although IPv6 has existed for a number of years, IPv6 adoption is still not a straightforward process. There is still uncertainty pertaining to IPv6 adoption. IPv6 was seen by organisations as a complicated technology:

"At this stage, we are more seeing the complications and everything has challenges rather than any immediate issues that we are suffering so badly that we will want to [adopt IPv6]*"*

(TechArc, FoodRet)

IPv6 was also seen as less mature than IPv4, which meant that issues were foreseen in its adoption:

"I guess the difficulty lies in the fact that there might be initial functionalities available but perhaps it's not as mature as IPv4 implementation which means that even though we don't have any problems with IPv4, we might run into problems with IPv6 inside the same setup which is only to be expected. There's going to be a little bit of trial and error initially, I am pretty sure"

(NetArc, ServProvThree)

Network engineers found it difficult to remember IPv6 addresses like they used to be able to do with IPv4 addresses:

"The biggest thing that we noticed with IPv6 is for our network engineers who live and breathe this stuff who used to be able to remember addresses and things on the top of their heads, they are not able to do that"

(BusMgr, VendOne)

The lack of practical experience with IPv6 was also viewed as a challenge:

"I mean IPv6 is around, I don't know, 14 years now but no one really ever worked with IPv6 really deeply. So there are no experiences which is with previous projects. There are no experts on this area. So I think first point is companies, they don't know what it is, they have to do. A normal engineer

doesn't know about IPv6, maybe a little bit but not practical, experience is not hands-on and I think that's the biggest challenge"

(ServMgr, VendTwo)

5.2.3.4 Staff training costs

All of the informants identified staff training as the biggest IPv6 adoption cost. It required time and effort for staff in charge of IPv6 to be trained in its use. For example, technical staff needed to learn how to plan and configure IPv6 in the organisation's network infrastructure:

"It's going to be human resources … the re-configuration, you know. We are changing addresses in our system. That would be a significant body of work"

(SenMgrOp, GovOne)

5.2.3.5 IPv6 is not seen as a priority

Some organisations did not see IPv6 as a priority and did not see a reason to adopt IPv6:

"That's not important until you absolutely have to move"

(MgrInfServ, AirTrans)

"[I]t is really very, very early days. We are aware of that but we don't see it as urgent because we are going through a huge amount of transformation in multiple levels like now. So we don't see IPv6 rollout as a very high priority at this stage"

(TechArc, FoodRet)

"[A]nd from a business requirement, it's not a high priority, and because there's no government mandate that we must be IPv6 enabled today or not some

deadline coming up that says you are going to have to do IPv6 in the next six months. It's not a strong driver. So that is, its prioritisation is low within an organisation"

(BTSArc, GovOne)

EduOne had adopted IPv6 but encountered problems with its equipment support and this required fixing. However, the fix was not prioritized by the organisation:

"I am a bit angry about it because it was other people in the organisation when the IPv6 connectivity broke. They did not consider it to be important or a priority to get it resolved"

(InfrEng, EduOne)

5.2.3.6 IT support outsourced

One of the organisations had outsourced its IT support, which poses an issue if the organisation decides to adopt IPv6:

"So we outsource our websites to a provider, so we aren't hosting internally but we manage the IP range"

(CIOff, AirTrans)

Should the company decide to adopt IPv6, it will need to discuss this with their IT support company, who may or may not have adopted IPv6 itself.

5.2.3.7 Lack of IPv6 skilled staff

The lack of staff with IPv6 skills and knowledge was also seen as a barrier to organisations' adoption of IPv6. Several organisations were struggling to recruit staff with IPv6 skills:

"I don't know whether other companies are finding the same thing but we are struggling to find people"

(InfrEng, EduOne)

"It's hard to find good people and when we do find, there is a lack of knowledge about what IPv6 is, how it works"

(SenSysSpec, ServProvOne)

"I think especially for New Zealand market, the IT market is very thin. To find the right Network Engineer is quite hard for companies already and if I try to find the right Engineer with IPv6 experiences, that's even harder"

(ServMgr, VendTwo)

"Yes, definitely. Yeah, so if I wanted to discuss my deployment plan with somebody else or consult with a customer on why they would need it. It's very difficult to find a resource that understands it"

(NetSuppSpec, VendFour)

5.2.3.8 Difficulties of obtaining funding for IPv6

Organisations also regarded the difficulties of obtaining funding for IPv6 adoption as a barrier. This was particularly so in the case of AirTrans that had not yet adopted IPv6 and also for EduOne that had adopted IPv6 but had equipment problems that required funding.

"For this particular organisation, I think it will be really hard to go to my executive teams and say oh, we've got this thing called IPv6, we should invest

money in being secured. I think it will be really hard to sell when they line it up at the end"

(CIOff, AirTrans)

"In fact, it has stayed broken for 18 months and the fix is part of a project which is at this stage, hasn't been approved for funding"

(InfrEng, EduOne)

5.2.3.9 Organisation size

Organisation size was also specified as a barrier to organisations' IPv6 adoption. While a large organisation might find it costly and time consuming to adopt IPv6, a small organisation might not find it necessary to adopt IPv6 because of adequate IPv4 addresses:

"It's easier if you are a start-up than if you have a very large mixed set of equipment, PCs and end-points. If you are buying everything brand new, there is really no reason why you can't adopt it quite quickly…. When you look at an organisation of our size, we have crossed all of the stores, over 20,000 employees but a tiny, tiny fraction of those deals with networks and technical stuff. It's a fraction of a percent. So we might, a 100 out of 20,000 that actually worry about the technology"

(SAMgr, FoodRet)

5.2.3.10 Time constraints

Time constraints were also seen by participants as a barrier to an organisation's IPv6 adoption.

"Given the amount of work we've got to do, we were hoping to leave it until we found a time to do it. So we do as much as we have to be compatible, talk to everybody but really do it when we find some time"

(InfrServMgr, EduFour)

"So I think the biggest impact will be the internal time we have to spend on it … in the future, the barrier would be basically time, internal resources to do it, to make necessary changes"

(NetwMgr, EduTwo)

"Absolutely, you know, time is money and it's going to cost a lot of time to get those things rolled out…. Well its again the cost of implementation, the time and effort. Time and effort cost money"

(NetArc, ServProvThree)

"Generally time goes in setup. If you want pretty slick deployment, you are going to invest a lot more time and getting it right, building it from scratch you know, testing it, then going live in production. There's a lot of businesses and again its resource, time and money"

(BusDevMgr, VendTwo)

5.2.3.11 Lack of senior management support

Participants regarded lack of senior level management involvement and support as another obstacle in organisations' IPv6 adoption:

"No, he would not be aware in any way, shape or manner"

(CIOff, AirTrans)

"Not at all, only barely aware of it"

(NetwMgr, EduTwo)

"Not at all, they don't really care"

(NetArc, ServProvThree)

"Not at all"

(NetSuppSpec, VendFour)

5.2.4 Importance of an IPv6 test bed

In addition to the determinants and barriers of IPv6 adoption in organisations, the importance of an IPv6 test bed was also identified from the data collected. Before fully adopting IPv6, the literature recommends that organisations should adopt it in a test environment to control their costs and mitigate any risks to their network infrastructure. Some organisations tested IPv6 in a test environment before adopting it across their networks and others planned to do the same as part of their adoption process:

"We originally configured the boundaries, firewalls and some key internal services just to see what it was like and what the impact might be. When it was deemed to have an impact, we then turned on the distribution layers within the networks and started moving out towards the access layer in the networks"

(InfrEng, EduOne)

"I'm not saying organisations need to look at their research department to enable them but they could say well, let's just use the small part of the network

and get them ready. They don't have to jump in headfirst and try to do the entire freaking thing"

(NetwLead, EduThree)

"Test at probably a low risk part of the network and build it up from there"

(SAMgr, FoodRet)

"So the next step is setting up in lab and testing IPv6 with our vendor technology ... so there's a lot of things, yeah, you have to take care of and that's the reason why you do need a lab, you do need to cover these things to make sure that"

(ServMgr, VendTwo)

5.3 Summary of Descriptive Analysis

Twelve determinants and 11 barriers of IPv6 adoption and assimilation have been identified through the preceding descriptive analysis (Table 11). Testing IPv6 in a test environment has also been found to be a crucial factor in the adoption and assimilation of IPv6. Table 11 shows the number of times these factors were mentioned in the data. The most influential determinant of IPv6 adoption and assimilation identified by the target organisations was the impact of governmental or task force campaigns (mentioned 16 times), followed by customer demand (11 times). The biggest barrier to IPv6 adoption and assimilation, mentioned 16 times, was the staff training costs, followed by the influence of external parties, mentioned 11 times.

Table 11 Determinants and Barriers to IPv6 Adoption and Assimilation

Determinants of IPv6 adoption and assimilation	**Number of times mentioned**
Impact of government or task force IPv6 campaigns	16
Customer demand	11
Depletion of IPv4 addresses	10
Senior level management support	8
Impact of IT infrastructure components	7
Internal IPv6 skills	4
Influence of external parties: network and partners	4
Role of content providers	4
NAT usage	4
To obtain recognition in the marketplace	3
Services and applications enhancement	2
Internal pressures	1
Barriers to IPv6 adoption and assimilation	
Staff training costs	16
Adequate IPv4 addresses	8
IPv6 is not seen as a priority	8
Lack of IPv6 skilled staff	7
Influence of external parties	11
Lack of senior level management support	7
Time constraints	5
Organisation size	4
Complexity of IPv6	4
Difficulties of obtaining funding for IPv6	2
IT support outsourced	1
Other factors	
Importance of an IPv6 test bed	4

5.4 Summary of Chapter 5

This chapter has presented findings from 22 participants who came from 16 organisations of different sizes and from different industries that, at the time of the study, were in varying stages of IPv6 adoption. As indicated in Table 9, three organisations were in the non-adoption stage, four organisations were in the planning to adopt stage, six organisations were in the adoption stage, two organisations were in the assimilating stage, and one organisation was in the assimilation stage. These organisations comprised nine large-sized organisations, three medium-sized organisations, and four small-sized organisations. Four of these organisations were tertiary institutions, four organisations were telecommunications organisations, four organisations were IT vendors, two organisations were government agencies, one was a food retailer, and one was an air transport organisation.

Sections 5.1 introduced each organisation that participated in this study and its IPv6 experiences. A visual map was developed for each organisation's IPv6 experiences consisting of institutional forces and organisational resources that were determinants or barriers of IPv6 adoption and assimilation.

Section 5.2 provided a descriptive analysis of all the organisations' IPv6 adoption and assimilation experiences. The descriptive information from Section 5.1 was used to aggregate 16 case studies to provide the insights on organisational IPv6 adoption and assimilation presented in this section. The findings in this section were presented as IPv6 adoption and assimilation determinants, barriers and other factors. Eleven barriers, 12 determinants and one other factor were found to be important for organisations' IPv6 adoption and assimilation. This chapter served as a within-case analysis.

The next chapter (Chapter 6) builds on the within-case analysis that has been discussed in this chapter and presents a cross-case analysis of the study.

Chapter 6: Analysis

In the previous chapter, the data from the 16 case studies on IPv6 adoption were presented in detail. First, visual maps were developed for each case that showed the adoption timeline for each organisation, and the determinants or barriers that influenced the organisation's adoption process. Second, an aggregate list of the determinants of and barriers to IPv6 adoption and assimilation was developed from the individual process maps.

This chapter begins by summarising the case studies (Section 6.1), and then conducts cross-case analysis by comparing the findings across various dimensions, that is, the adoption stage, organisational size and the source of the pressure to adopt IPv6 (Sections 6.2 to 6.4). The chapter next classifies these barriers and determinants into institutional forces, organisational resources and network externalities, following the categories established in the literature review, and examines how different configurations of these factors were found in distinct clusters of organisations (Section 6.5). Section 6.6 reviews the occurrence of these factors across the stages of IPv6 adoption. Section 6.7 focuses on the role played by network externalities across the varying stages of IPv6 adoption and assimilation. Finally, Section 6.8 presents a process model that depicts how the various factors influence organisations at various stages of IPv6 adoption and assimilation.

6.1 Summary of Case Studies

Table 12 summarises the 16 case studies. Three organisations had not adopted IPv6, four were planning to adopt it, six organisations were in the process of adopting it, two were assimilating it into their organisations, and one had succeeded in assimilating IPv6 in its organisation. Nine were large organisations, three were medium-sized organisations and four were small organisations. The impetus to adopt IPv6 originated from senior management in seven organisations ("top-down"), while IPv6 adoption in the other nine organisations was driven from lower down in the organisational hierarchy ("bottom-up").

Table 12 Organisation Size, Source of IPv6 Adoption Pressure and IPv6 Adoption Stage

Stage of IPv6 Adoption	**Organisation Name**	**Organisation Size**	**Source of push to adopt IPv6**
Not adopting IPv6	ServProvThree	Large	Bottom-up
	FoodRet	Large	Bottom-up
	AirTrans	Small	Bottom-up
Planning IPv6 adoption	EduTwo	Large	Top-down
	EduFour	Large	Bottom-up
	VendTwo	Small	Top-down
	GovOne	Large	Bottom-up
Adopting IPv6	EduThree	Medium	Bottom-up
	ServProvOne	Small	Bottom-up
	ServProvTwo	Large	Top-down
	VendOne	Medium	Top-down
	VendThree	Large	Top-down
	GovTwo	Medium	Top-down
Assimilating IPv6	EduOne	Large	Bottom-up
	VendFour	Large	Bottom-up
Adopted and assimilated IPv6	ServProvFour	Small	Top-down

Table 12 lists the major barriers to and determinants of IPv6 adoption and assimilation.[8] The most significant barriers to adoption were the cost of training (mentioned by all 16 organisations), the influence of external parties (mentioned by 11 organisations), and

[8] Table 11 in Chapter 5 lists all the barriers and determinants that were found in the case studies, and the number of organisations that mentioned each one. Table 13 lists those barriers and determinants that were found in more than five organisations (i.e. approximately 30% of the sample).

hiring staff (mentioned by seven organisations) with the appropriate skills and knowledge. An equal number of organisations (seven) stated that IPv6 adoption was held back by a lack of support from senior management and vendors. Half of the organisations in the sample believed that they had an adequate number of IPv4 addresses, and thus IPv6 was not seen to be a priority.

The most important determinant of IPv6 adoption was participation in events organised as part of the IPv6 adoption campaign by the government or the IPv6 Task Force. Customer demand led 11 organisations to adopt IPv6, while eight organisations did so because of support from their senior management. Ten organisations were motivated to adopt IPv6 because of their awareness of the depletion of IPv4 addresses, while seven organisations did so as part of their installation of new IT infrastructure components.

Table 13 Significant IPv6 Adoption and Assimilation Factors

Barriers	**Number of organisations**
Staff training costs	16
Influence of external parties	11
Adequate IPv4 addresses	8
IPv6 not seen as a priority	8
Lack of IPv6 skilled staff	7
Lack of senior management support	7
Determinants	
Impact of government or task force IPv6 campaign	16
Customer demand	11
Depletion of IPv4 addresses	10
Senior management support	8
Impact of IT infrastructure components	7

In the next section, these factors are organised according to their occurrence in the various stages of IPv6 adoption and assimilation.

6.2 IPv6 Adoption and Assimilation Factors across Various Stages

This section describes the barriers to and determinants of IPv6 adoption and assimilation across organisations at different stages of IPv6 adoption (Table 14). As shown in Table 11, three organisations were non-adopters, four were planning to adopt, six organisations were currently adopting, two organisations were assimilating, and one organisation had assimilated IPv6. Broadly, Table 14 shows that the ratio of barriers to determinants decreased from the non-adoption to the assimilation stage (except for the assimilating stage). The pattern of findings across each stage is discussed in detail below.

Table 14 Barriers to and Determinants of IPv6 Adoption by Adoption Stage

	IPv6 adoption stage				
Barriers	**Non-adoption (3)***	**Planning to adopt (4)**	**Adopting (6)**	**Assimilating (2)**	**Assimilation (1)**
Adequate IPv4 addresses		3	3	2	
Influence of external parties	2	4	3	2	
Complexity of IPv6	2	1	1		
Staff training costs	3	4	6	2	1
IPv6 not seen as a priority	3	2	2	1	
IT support outsourced	1				
Lack of IPv6 skilled staff	1	2	2	2	
Lack of funding for IPv6	1			1	
Organisation size	3	1			
Time constraints	1	3	1		
Lack of senior management support	3	1	2	1	
Number of mentions by interviewees	**20**	**21**	**20**	**11**	**1**
Determinants					
Customer demand	2	3	3	2	1
Depletion of IPv4 addresses	3	1	3	2	1
NAT usage		1	3		

Services and applications enhancement	1	1			
To obtain recognition in the marketplace		2	1		
Internal IPv6 skills		2	2		
Influence of external parties: networks, partners, and peers	1	1	1	1	
Internal pressures		1			
Impact of government or IPv6 Task Force campaign	3	4	6	2	1
Impact of IT infrastructure components	1	2	3		1
Role of content providers	2	1		1	
Senior management support		3	4	1	
Number of mentions by interviewees	**13**	**22**	**26**	**9**	**4**
Ratio of (barriers) to (determinants)	**20/13 = 1.54**	**21/22 = 0.95**	**20/26 = 0.77**	**11/9 = 1.22**	**1/4 = 0.25**

** The numbers in the brackets refer to the number of organisations in each stage.*

6.2.1 Non-adoption stage

The three organisations that had not adopted IPv6, ServProvThree, FoodRet and AirTrans, stated that the key barriers for them to do so were staff training costs, a lack of prioritisation of IPv6, organisation size, and lack of senior management support. Although these organisations were non-adopters, they mentioned that there was motivation to adopt IPv6 based on the depletion in IPv4 addresses, and their participation in the campaigns by the government and the IPv6 Task Force. In terms of a count, the total number of barriers was greater than the total number of determinants for the organisations in this stage, in line with their lack of adoption of IPv6. However, it is worth remembering that a count does not account for the severity or seriousness of each factor, or how easily they could be resolved by individuals.

6.2.2 Planning to adopt stage

Four organisations in this stage – EduTwo, EduFour, VendTwo and GovOne mentioned twenty-one barriers and 22 determinants. The barriers they faced included staff training costs, a lack of skilled staff, influence of external parties, adequate IPv6 addresses, and time constraints. IPv6 adoption was not considered a priority in two organisations. All four organisations found that the government or IPv6 Task Force's effort influenced their IPv6 adoption. Other important determinants were customer demand, senior management support, a desire to obtain recognition in the marketplace, the presence of staff with the right skills, and changes in IT infrastructure components.

6.2.3 Adoption stage

Six organisations were in the midst of adopting IPv6 when the data was collected – EduThree, ServProvOne, ServProvTwo, VendOne, VendThree and GovTwo. All six organisations shared the view that staff training costs were a barrier to IPv6 adoption, but they were encouraged to adopt the new protocol by participating in the campaign by the government or IPv6 Task Force. Other significant barriers were the influence of external parties and the perception that they had adequate IPv4 addresses. However, some of them had the opposite perception – they felt they had a shortage of IP addresses, and this spurred them to adopt IPv6. Their decision to adopt was also driven by support from senior management, customer demand, the challenges of NAT usage, and the upgrading of IT infrastructure components. Barriers to IPv6 adoption were mentioned 20 times while determinants were mentioned 26 times. However, it is important to note that the same caveat mentioned in the non-adoption stage (Section 6.2.1) applies here.

6.2.4 Assimilating stage

Two organisations were in the midst of assimilating IPv6 – EduOne and VendFour. Both mentioned staff training costs, the lack of IPv6 skilled staff, and influence of external parties as barriers to adoption. Their decision to adopt IPv6 was supported by customer demand, and the campaigns run by the government or IPv6 Task Force. Slightly more barriers than determinants were mentioned by these firms, perhaps indicating that, by progressing toward assimilation, they had arrived at a deeper understanding of the adoption phenomenon.

6.2.5 Assimilation stage

Only one organisation in the sample, ServProvFour, stated that it had assimilated IPv6. The only barrier it mentioned was staff training costs, and the determinants included customer demand, information campaigns run by the government or IPv6 Task Force, and the deployment of new IT infrastructure components.

6.2.6 Summary

Staff training costs were mentioned as a barrier to IPv6 adoption by all 16 organisations, while the campaigns by the government or IPv6 Task Force were a common determinant across the entire sample. The human resource implications of adoption were visible in that the lack of IPv6 skilled staff was cited as an obstacle for organisations in the planning to adopt and assimilating stages. IPv6's status as a mature technology was seen in that its complexity was only mentioned by non-adopters, who also did not see it as a priority. The lack of attention to IPv6 could be due to the perception that there were enough IPv4 addresses, and also the influence of external parties, which were mentioned as adoption barriers by most organisations in the planning to adopt, adoption and assimilating stages. Important motivators of IPv6 adoption, besides IPv6 adoption campaigns, included customer demand, the depletion of IPv4 addresses, the role of content providers, the deployment of new IT infrastructure components, and support from senior management.

The next section (Section 6.3) shows how the presence of these factors varied by organisational size.

6.3 Comparison of Barriers to and Determinants of IPv6 Adoption and Assimilation by Organisation Size

Table 15 shows how the findings of the case studies varied by organisation size. Organisation size was measured by staff strength and total operating revenue. The organisations in the sample were divided into three groups (small, medium and large) based on these indicators: 1) small organisations: ≤ 1000 employees, ≤ $200 million total revenue, 2) medium-sized organisations: 1001-2000 employees, $201-300 million total revenue, and 3) large organisations: >2000 employees, > $300 million total revenue. The sample consisted of four small organisations, three medium-sized organisations and nine large organisations.

Table 15 Comparison of Barriers to and Determinants of IPv6 Adoption and Assimilation by Organisation Size

	Organisation size		
	Small (4)	**Medium (3)**	**Large (9)**
Barriers			
Adequate IPv4 addresses		2	6
Influence of external parties	3	1	7
Complexity of IPv6	1	1	2
Staff training costs	4	3	9
IPv6 not seen as a priority	2	1	5
IT support outsourced	1		
Lack of IPv6 skilled staff	2		5
Lack of funding for IPv6	1		1
Organisation size	2		2
Time constraints	1	1	3
Lack of senior management support	1	1	5
Determinants			
Customer demand	2	2	7
Depletion of IPv4 addresses	3		7
NAT usage	1	1	2

Services and applications enhancement			2
To obtain recognition in the marketplace		1	2
Internal IPv6 skills		2	2
Influence of external parties	1	1	2
Internal pressures			1
Impact of government or IPv6 Task Force campaign	4	3	9
Impact of IT infrastructure components	2	1	4
Role of content providers	1		3
Senior management support	2	2	4

6.3.1 Small organisations

The four small organisations in the study were AirTrans, VendTwo, ServProvOne and ServProvFour. Together they brought up 18 barriers and 16 determinants. Although it could be assumed that small organisations would find it easier to adopt IPv6, two of the organisations in this group stated that their small size was a problem. The main barriers stated by all four organisations were staff training costs, the low priority placed on the project, the lack of IPv6 skilled staff, and the influence of external parties. All four organisations' adoption decisions were influenced by the government/ IPv6 Task Force campaigns. Other factors that made them decide to adopt IPv6 included IPv4 address depletion, customer demand, the deployment of IT infrastructure components, and the support of senior management.

6.3.2 Medium-sized organisations

Three medium-sized organisations participated in this study: EduThree, VendOne and GovTwo. As with small organisations, staff training costs were an IPv6 adoption barrier, as was the perception that they had adequate IPv4 addresses. The IPv6 adoption campaigns encouraged them to adopt IPv6. Other determinants of IPv6 adoption were customer demand, the presence of IPv6 skills and senior management support.

6.3.3 Large organisations

Nine large organisations participated in this study: ServProvThree, FoodRet, EduTwo, EduFour, GovOne, ServProvTwo, VendThree, EduOne and VendFour. All nine organisations stated that staff training costs were a barrier to IPv6 adoption. Other significant barriers were the presence of an adequate number of IPv4 addresses (related to IPv6 not being seen as a priority), the influence of external parties, the lack of IPv6-skilled staff, and little support from senior management. As with previous groups, the publicity campaigns by the government or IPv6 Task Force influenced their IPv6 adoption decision. Other factors that had an impact on their adoption included customer demand, the depletion of IPv4 addresses, the deployment of IT infrastructure and senior management support. Although management support was found to be a barrier and a determinant, this was because different organisations reported different experiences with this factor.

6.3.4 Summary

Overall, human resource issues, such as staff training costs and the lack of skilled staff, were the critical barrier across all organisations. The lack of senior management support was more obvious in large organisations than in small and medium-sized firms. In terms of determinants, the factors common across firms of different sizes were customer demand, and the publicity campaigns by the government or the IPv6 Task Force. There were few differences in other factors, both determinants and barriers, indicating that organisational size had little impact on the salience of different factors. The next section (Section 6.4) compares the incidence of IPv6 adoption and assimilation factors based on the source of the impetus to adopt IPv6.

6.4 Comparison of IPv6 Adoption and Assimilation Factors across Different Sources of IPv6 Adoption Pressure

Out of the 16 organisations that participated in this study, the IPv6 efforts of nine of them began from lower down in the organisational hierarchy ("bottom-up"). For the other seven organisations, IPv6 deployment was directed by senior IT managers ("top-down"). The nine organisations that adopted a bottom-up approach were ServProvThree, FoodRet, AirTrans, EduFour, GovOne, EduThree, ServProvOne, EduOne and VendFour. The seven organisations that used a top-down effort were EduTwo, VendTwo, ServProvTwo, VendOne, VendThree, GovTwo and ServProvFour. Table 16 shows how the incidence of the IPv6 adoption barriers and determinants varied across these two groups.

Table 16 IPv6 Adoption and Assimilation Factors: Source of IPv6 Adoption Pressure

Barriers	**Top-Down (9 organisations)**	**Bottom-Up (7 organisations)**
Adequate IPv4 addresses	3	5
Influence of external parties	3	8
Complexity of IPv6	2	2
Staff training costs	7	9
IPv6 not seen as a priority	1	7
IT support outsourced		1
Lack of IPv6 skilled staff	3	4
Lack of funding for IPv6		2
Organisation size	1	3
Time constraints	3	2
Lack of senior management support	3	4
Determinants		
Customer demand	4	7
Depletion of IPv4 addresses	3	7
NAT usage	2	2

Services and applications enhancement	1	1
To obtain recognition in the marketplace		3
Internal IPv6 skills	1	3
Influence of external parties		4
Internal pressures		1
Impact of government or IPv6 Task Force campaign	7	9
Impact of IT infrastructure components	4	3
Role of content providers	1	3
Senior management support	3	5

Figure 17 depicts the IPv6 adoption barriers that were faced by at least 50% of the organisations in each group, and Figure 18 depicts the IPv6 adoption determinants cited by at least 50% of the organisations in each group.

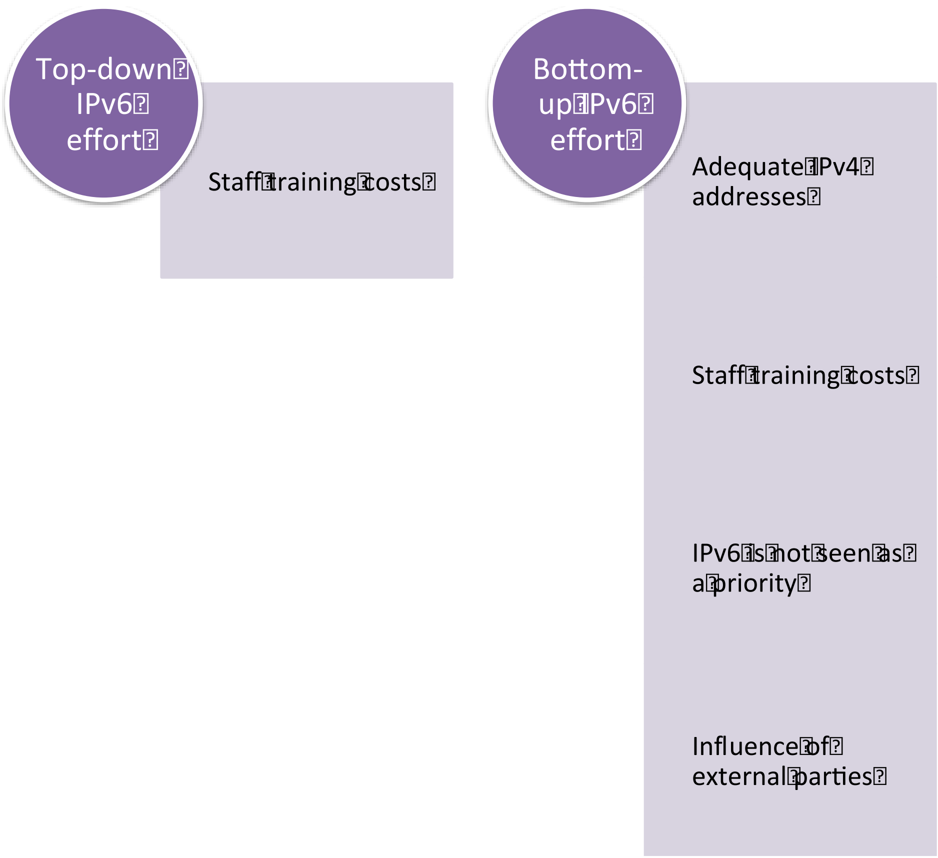

Figure 17 IPv6 adoption barriers faced by organisations with top-down and bottom-up IPv6 effort

As before, staff training costs were a barrier for most organisations, regardless of the source of pressure to adopt IPv6. As expected, IPv6 was not seen as a priority in organisations where the drive to adopt IPv6 came from lower in the hierarchy. These organisations also had to deal with a perception that there was an adequate number of IPv4 addresses, perhaps coming from those higher in their organisational hierarchies.

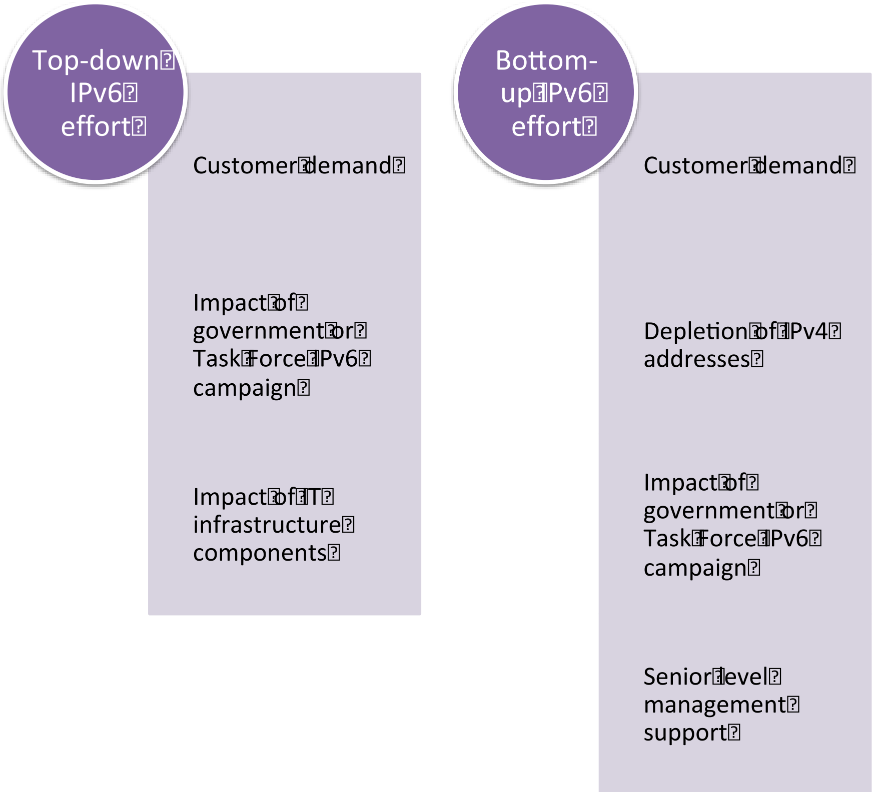

Figure 18 IPv6 adoption determinants faced by organisations with top-down and bottom-up IPv6 effort

Across both groups, customer demand and government or task force campaigns were important determinants of IPv6 adoption. Organisations where adoption was a top-down project were able to leverage the deployment of new IT infrastructure to introduce IPv6, while organisations with bottom-up IPv6 adoption efforts were more aware of the challenges that would be faced as the number of IPv4 addresses fell. In the next section, the findings are categorised into institutional forces, organisational resources and network externalities, following the conceptual framework described previously.

6.5 Institutional Forces, Organisational Resources and Network Externalities

This section categorises the IPv6 barriers and determinants into institutional forces, network externalities and organisational resources, following the conceptual framework from Chapters 2 and 3 (Table 17).

Table 17 Factors Mapped into Institutional Forces, Organisational Resources and Network Externalities

	Barriers	**Determinants**
Organisational resources	<u>Human resources:</u> • Staff training costs • Lack of IPv6 skilled staff • IPv6 not seen as a priority • Lack of funding for IPv6 • Time constraints <u>Technological resources:</u> • Influence of external parties • Adequate IPv4 addresses • Complexity of IPv6 • IT support outsourced <u>Relationship resources:</u> • Lack of senior management support • Influence of external parties	<u>Human resources:</u> • Internal IPv6 skills <u>Technological resources:</u> • NAT usage • IPv6 test bed • Services and applications enhancement • Impact of IT infrastructure components <u>Relationship resources:</u> • Senior management support
Network externalities	• Influence of external parties • IT support outsourced	• Influence of external parties • Customer demands • Internal pressures
Coercive forces		• Customer demands • To obtain recognition in the marketplace • Role of content providers

Mimetic forces		• Impact of government or IPv6 Task Force campaign
Normative forces		• Internal pressures • Impact of government or IPv6 Task Force campaign
Other features	• Organisation size	

6.5.1 Organisational resources

The findings indicated the criticality of organisational resources for IPv6 adoption, as the lack of organisational resources were a barrier while the presence of organisational resources was a determinant. As Section 3.2 of Chapter 3 stated, the various organisational resources relevant for adoption can be categorised into human resources, technological resources, and relationship resources. The findings have been mapped into these three categories (Table 17) and are discussed below.

1. Human resources, such as IPv6 skills and knowledge, are vital for successful IPv6 adoption and assimilation. The data showed that the lack of these resources was the most cited barrier by the organisations that were studied, while their presence motivated organisations to adopt IPv6. The barriers included a lack of IPv6 skilled staff, staff training costs, the limited time available to staff, IPv6 not being seen as a priority, lack of funding for IPv6, while the determinant was internal IPv6 skills.

   Some organisations found it difficult to allocate time for the adoption of IPv6 when their resources were occupied with fulfilling other tasks, because as an infrastructural component, the implications of changing to IPv6 are extensive and much time is needed to plan and execute the changes.
2. Technological resources, such as network-related assets and support for the hardware and software required to run IPv6, are important for adopting and

assimilating IPv6. One of the challenges that organisations have in terms of IPv6 adoption was that their existing hardware and software do not support IPv6 (Networks, 2011). The data showed that technological barriers to IPv6 adoption included an adequate number of IPv4 addresses, the complexity of IPv6, IT support outsourced and the influence of external parties. Some organisations in New Zealand still have an adequate number of IPv4 addresses and are not motivated to adopt IPv6. This was evident in several of the organisations that were studied. The complexity of IPv6 was also mentioned by some organisations as a barrier. Some interviewees felt that IPv6 was not as mature as IPv4, and other individuals argued that remembering lengthy IPv6 addresses would be difficult, compared to the shorter IPv4 addresses. Organisations who had outsourced their IT support were unable to make IT adoption decisions, such as moving to IPv6, by themselves, as they were reliant on the skills of their support providers.

Technological determinants of IPv6 adoption include the use of NAT, the ability to enhance other services and applications, the ability to "piggy-back" on the purchases of other IT infrastructure components, and the presence of an IPv6 experimental site or test bed. Although NAT is used to overcome a shortfall in the number of IPv4 addresses, it can cause problems and thus encourage organisations to adopt IPv6. Adoption is also easier to carry out if the organisation wants to use other technologies that rely on IPv6. An example was EduTwo's aim to use DirectAccess technology. The use of a test environment for IPv6 minimises the risk and costs of IPv6 adoption. Finally, as organisations refresh their IT infrastructure over the years to keep it up to date, they can incorporate an IPv6 requirement when purchasing other components as a way to introduce IPv6 into their organisation in a less visible way.

3. Relationship resources, such as support from senior management and vendors, are essential for successful IPv6 adoption and assimilation. Senior management who know the importance of IPv6 adoption can provide the resources for a successful IPv6 adoption project (Mason & Mahindra, 2011). Vendors can benefit from including support for IPv6 in their devices and designing them to make use of the features of IPv6 (Hovav & Schuff, 2005). The case studies showed that the lack of senior management support and influence of external parties (vendors), the low priority given to IPv6, and the difficulty of obtaining funding for IPv6 were barriers to IPv6 adoption, while senior management support encouraged adoption.

   The influence of external parties such as lack of vendor support could be seen in the EduOne case. EduOne encountered this problem when it purchased equipment from a vendor who had claimed it had IPv6 capability when it did not. EduOne had also purchased equipment that was said to have IPv6 support but only after an additional licensing fee was paid, something that was only mentioned after the purchase. Organisations that have the support of their senior management find it easy to adopt IPv6. For example, EduThree's senior management was very involved and supportive of IPv6 adoption and even included it in its personal goal-setting exercise.

6.5.2 Organisational size as a barrier

Generally, large organisations, such as FoodRet with its 20,000 employees and 400 stores, find it difficult to adopt IPv6 because of the large number of applications and equipment that have to be replaced or upgraded to support IPv6. On the other hand, small organisations might not be able to afford to adopt IPv6 and might not find it necessary to do so because they have enough IPv4 addresses.

6.5.3 Coercive forces

Coercive forces, as described by DiMaggio and Powell (1983), are formal and informal pressures applied on an organisation by other organisations that they rely on, and by cultural expectations in the society that the organisation functions in. In the data, these factors were categorised as coercive forces: 1) customer demand, 2) a search for recognition from industry peers, and 3) the adoption decisions of content providers.

Customer demand encourages organisations to adopt IPv6 while a lack of customer demand causes organisations not to adopt IPv6. For instance, tertiary institutions are motivated to adopt IPv6 to support the demands of their customers from countries such as China, Korea and Japan who are adopting IPv6. Many organisations that took part in this study stressed the criticality of IPv4 address depletion and customer demand was seen as a coercive force that was pushing them to adopt IPv6. Organisations were also driven to adopt IPv6 to obtain recognition in the marketplace – a *"pin on the jacket"*, in the words of an interviewee from EduThree. Content providers, such as Facebook, Google and YouTube, are adopting or have adopted IPv6, and organizations without IPv6 will find it difficult for their customers to access that content.

6.5.4 Mimetic forces

Mimetic isomorphism results from a response to uncertainty, and uncertainty motivates imitation (DiMaggio and Powell (1983). Therefore, organisations that do not have resources and skills to adopt IPv6 tend to model themselves after organisations that have successfully adopted IPv6. One way this occurs is through the sharing of experiences by other organisations. EduTwo and ServProvTwo both made use of other organisations' learnings when deploying IPv6. As a corollary, FoodRet mentioned that it would adopt IPv6 once it had learnt about others who had adopted it. The IPv6 campaigns run by the government or IPv6 Task Force often featured presentations from organisations that had gone through the adoption experience and this helped allay the doubts of many attendees at the campaign events. All of the organisations that participated in this study mentioned the IPv6 campaigns run by the government and the IPv6 Task Force. The campaigns increased awareness of the issue and encouraged them to adopt IPv6.

6.5.5 Normative forces

Normative forces result from professionalisation (DiMaggio & Powell, 1983). The socialization of organisations' representatives during IPv6 events creates normative pressure that pushes organisations to adopt IPv6. Normative forces that push organisations to adopt and assimilate IPv6 are: 1) internal pressures, and 2) campaigns run by the government or IPv6 Task Force. In some organisations, such as EduFour, academic staff pressured the organisation's IT staff to adopt IPv6 as they were responding to messages disseminated in their community. Attendance at the campaigns run by the government or IPv6 Task Force was also a normative force. The personnel who attended the campaign events interacted with peers from their professions, generating an expectation that IPv6 adoption was the generally-agreed upon direction in the industry.

<u>Institutional Theory</u>

As indicated in Sections 6.5.3, 6.5.4 and 6.5.5, the findings have shown that coercive forces, mimetic forces and normative forces are crucial in influencing organisational digital infrastructure adoption and assimilation. Each one of these isomorphic forces gives an explicit justification for claiming legitimacy through official, moral or cultural authorization (Scott, 2008). As emphasized by Currie (2012), institutional isomorphism has contributed tremendously to the literatures of institutional theory. Scott (2008, p. 429) highlighted that institutional forces are *"symbolic"* and appealing because they constructs *"cognitive schema, normative guidance, and rules that constrain and* *empower social behavior”*. Therefore, this study highlighted the role of institutional forces in driving organisations to adopt and assimilate digital infrastructure.

Questions have often been raised to whether the institutional environment is really important to organisations. Furusten (2013) argued that organisations that do not adhere to institutional pressures will lose the legitimacy required for them to operate, which would lead to the loss of customers and suppliers. Currie (2009) stated that institutional theory is a strong theoretical lens to study the adoption and assimilation of IT across organisations and markets. However, there is a lack of studies on the impact of institutional factors on digital infrastructure and the studies that exist are more focused on the technical aspects, rather than the institutional perspective (Iannacci, 2010). Thus, this study stresses the importance of institutional theory on the adoption and assimilation of digital infrastructure.

The only research paper closest to this study is Currie’s (2012) study on the impact of institutional forces on the adoption of electronic records by patients in England. However, this study only focused on the impact of institutional forces on digital infrastructure adoption, instead of all stages of digital infrastructure adoption and assimilation. Also, it focused collectively on individuals and organisations, rather than organisational adoption and assimilation of digital infrastructure only. Hence, this study emphasizes the institutional factors that influence organisations at varying stages of digital infrastructure adoption and assimilation to understand why organisations decide to adopt and/or assimilate digital infrastructure.

Since digital infrastructure subsumes and affects other infrastructural components, platforms, applications, and IT capabilities, the adoption process can affect all these components. These other components are dependencies of the new piece of digital infrastructure that is being introduced. When a certain piece of digital infrastructure is being upgraded or replaced, the components that are connected need to be able to support it. The adoption of a digital infrastructure will thus have an impact on the operations of its dependencies.

It is possible that the adoption of digital infrastructure could lead to negative impacts more broadly. For example, controlling digital infrastructure, especially when change is being implemented, is not easy (Nielsen & Aanestad, 2006). While controlling traditional IT itself is really challenging, controlling digital infrastructure is much more difficult because it consists of various dependencies. The returns from digital infrastructure adoption also take much longer to be realized that those from traditional IT adoption because the former is far more costly. With the high level of uncertainty, costs and risks, organisations tend to delay or put off adopting and assimilating digital infrastructure, and instead try various methods to extend the life of their current digital infrastructure. Therefore, external pressures play a crucial part in driving organisations to adopt and assimilate digital infrastructure.

The findings of this study confirm that that institutional pressures are crucial in driving organisations to adopt and assimilate digital infrastructure across the various stages. These pressures take various forms, such as changes in professional norms, encouragement from regulatory bodies, or adoption by well-regarded peer organisations. For instance, organisations are driven to adopt IPv6 to obtain recognition in the marketplace. When organisations see that their peer organisations are adopting IPv6, they want to ensure that they have started adopting IPv6 or are further in the stages of the adoption process. These pressures help overcome the inherent aversion to undertake the complicated, costly and risky exercise of digital infrastructure adoption and assimilation.

6.5.6 Network externalities

As indicated in Section 3.3 in Chapter 3, network externalities are important to understand organisational adoption and assimilation of IPv6. Network externalities include the influence of partners (e.g., suppliers and customers) and peers (e.g., organisations in the same industry) (Lai et al., 2007; Zhu et al., 2006). Table 17 shows that the network externalities that acted as barriers to organisations' IPv6 adoption were: 1) influence of external parties (for example, APNIC's role and lack of vendor support), and 2) the outsourcing of IT support. Network externalities that encouraged IPv6 adoption included: 1) demand from customers, networks, partners, and peers, and 2) internal pressure.

Despite APNIC's role in encouraging organisations in the Asia Pacific region to adopt IPv6, it is also recovering unused IPv4 addresses, which has led to some organisations considering these as an alternative to adopting IPv6 if they run out of IPv4 addresses. Other organizations rely on outside vendors to manage their IT systems and cannot propose new technologies such as IPv6 if the vendor is not ready or does not intend to adopt IPv6. Vendors who do not support IPv6 or only do so after additional expenses also hinder the adoption of IPv6. Organisational networks, consisting of customers, partners and industry peers, which encourage their members to adopt IPv6 or share their experiences with IPv6, also increase the likelihood of adoption. However, negative experiences could lead to other network members slowing down their IPv6 adoption plans, as in the case of EduTwo.

This section has presented the findings by categorising them into institutional forces, network externalities and organisational resources. The next section discusses the number of times these factors were mentioned by the participating organisations.

6.6 Comparison of the Incidence of IPv6 Adoption and Assimilation Factors by Thematic Categories

Table 18 shows the frequency with which the determinants of and barriers to IPv6 adoption and assimilation were mentioned, in terms of their higher-level categories. The most important barrier to IPv6 adoption and assimilation was the lack of organisational resources, mentioned 69 times by interviewees. The corollary is true for the determinants: the most influential determinant was the presence of organisational resources, mentioned 29 times. Industry and market-level pressures were mentioned less frequently: coercive forces 18 times, normative forces 17 times and mimetic forces and network externalities 16 times. Thus, the biggest obstacle to IPv6 adoption appears to be organisational shortcomings, which persist despite the presence of significant industry-level or market-level forces promoting IPv6 adoption.

Table 18 IPv6 Adoption and Assimilation Factors

IPv6 adoption and assimilation factors		**Number of times mentioned**
Barriers	Lack of organisational resources	69
	Network externalities	12
	Organisation size	4
Determinants	Coercive forces	18
	Mimetic forces	16
	Normative forces	17
	Presence of organisational resources	29
	Network externalities	16

Table 19 distributes the figures in Table 18 across the various stages of IPv6 adoption. As table 19 shows, while the presence of organisational resources increased from the non-adopting to adopting stage, their absence was still being reported across those stages. The lack of organisational resources was a barrier for organisations in all stages. Network externalities were both a barrier to and determinant of IPv6 adoption across the different stages, and were reported at a fairly steady level. Organisation size was a barrier for organisations in the non-adoption and planning to adopt stage. This suggests that organisations that adopted IPv6 were able to use other resources or were influenced by other forces to offset the negative consequences of being large or small in terms of IPv6 adoption

Table 19 IPv6 Adoption and Assimilation Factors across IPv6 Stages

IPv6 adoption and assimilation factors		**IPv6 adoption stage**				
		Non-adoption	**Planning to adopt**	**Adopting**	**Assimilating**	**Assimilation**
Barriers	Lack of organisational resources	17	20	20	11	1
	Network externalities	3	4	3	2	0
	Organisation size	3	1	0	0	0
Determinants	Coercive forces	4	6	4	3	1
	Mimetic forces	3	4	6	2	1
	Normative forces	3	5	6	2	1
	Presence of organisational resources	3	10	13	2	1
	Network externalities	3	5	4	3	1

The next section (Section 6.7) focuses on the role that network externalities played in the different stages of adoption by the organisations.

6.7 Network externalities

Organisations in the different stages were influenced by their networks either not to adopt IPv6, to start planning to adopt IPv6, to adopt IPv6, or to assimilate IPv6. Figures 19, 20, 21, 22 and 23 below depict the effect of networks in the different stages of IPv6 adoption, and they are discussed in detail below.

Figure 19 illustrates the network externalities affecting organisations that were non-adopters of IPv6. Organisations in the non-adoption stage (AirTrans, FoodRet and ServProvThree) indicated that networks had an important role in their IPv6 decision. AirTrans was the only organisation that outsourced its IT support among all the organisations that participated in this study. Its reliance on the IT support company made it challenging for it to adopt IPv6. If the IT support company did not have IPv6 capability or any interest in adopting IPv6, it would prevent or delay AirTrans from adopting IPv6. In addition, organisations in this stage also mentioned that the lack of push by its partners and lack of customer demands had resulted in it not adopting IPv6.

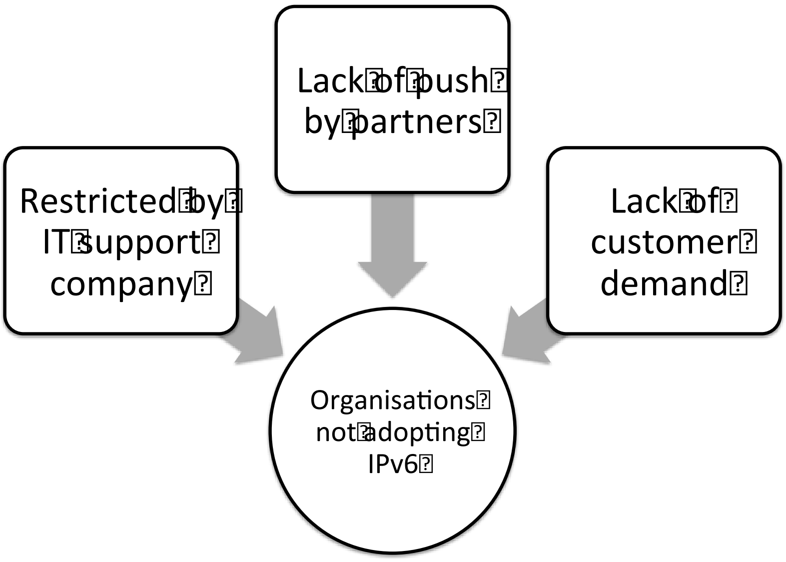

Figure 19 Network diagram for organisations at the not adopting stage

Figure 20 shows the network externalities for organisations that were planning to adopt IPv6. These organisations were EduTwo, EduFour, VendTwo and GovOne. Networks impacted organisations that were planning to adopt IPv6 in the form of barriers and determinants. An example of networks as a barrier for organisations' IPv6 adoption in this stage is the role of APNIC in recovering unused IPv4 addresses, thus extending the life of IPv4 and causing organisations to delay their IPv6 adoption. While the sharing of IPv6 adoption experiences by other organisations in their networks provided organisations with useful knowledge, it also had negative impacts; for example, EduTwo slowed down its IPv6 plans after learning that other organisations in its networks encountered problems adopting IPv6. Organisations at this stage also indicated the lack of vendor support as an issue. While low customer demand inhibited some from adoption (for instance, GovOne), it influenced others to do so (for example, to support international students). Networks of relevant internal others also had an effect – EduFour in this stage experienced pressure from staff.

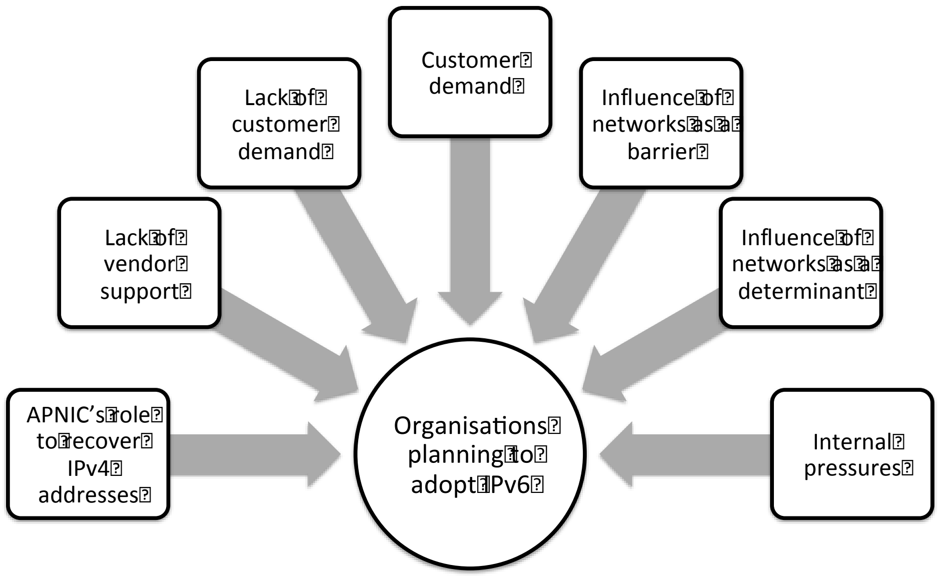

Figure 20 Network diagram for organisations in the planning to adopt stage

Figure 21 illustrates the network externalities for organisations that were in the adoption stage. Organisations that were adopting IPv6 were EduThree, ServProvOne, ServProvTwo, VendOne, VendThree and GovTwo. The networks had mostly influenced organisations in this stage as a determinant rather than a barrier. Some of the organisations in this stage were driven to adopt IPv6 to meet customer demand. For instance, EduThree wanted to make sure that if international students accessed its website, they could access it using their IPv6 connection. External parties also influenced organisations in this stage. For example, the impetus for EduThree's IPv6 adoption came from its involvement in the KAREN research and education network. Lack of vendor support was a barrier for some organisations in this stage. VendOne had encountered trouble with its vendor. Its vendor did not state that the equipment it purchased needed an additional licensing fee for its use.

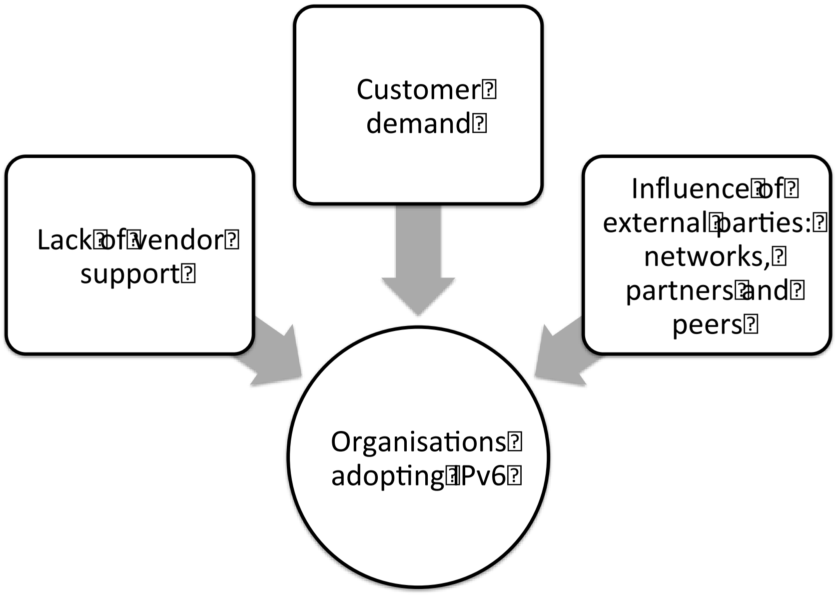

Figure 21 Network diagram for organisations in the adopting stage

Figure 22 shows the network externalities of organisations that were assimilating IPv6. Organisations that were assimilating IPv6 were EduOne and VendFour. Organisations in this stage were influenced by similar network externalities to the organisations in the adoption stage. Customer demand was a determinant for organisations in this stage. For instance, one of the reasons that EduOne adopted IPv6 was because of its customers, Chinese universities, who were IPv6 only. Organisations in this stage were also influenced by their partners. For example, EduOne adopted IPv6 because its research and education network, KAREN, was going to carry IPv6. However, the lack of vendor support was a problem for organisations in this stage. EduOne, for instance, stressed that the lack of vendor support had created problems with its IPv6 assimilation. Vendors had stated that its equipment had IPv6 support and when EduOne purchased the equipment, it realised that it did not provide what it initially promised. A licensing fee was also required for the equipment to support IPv6.

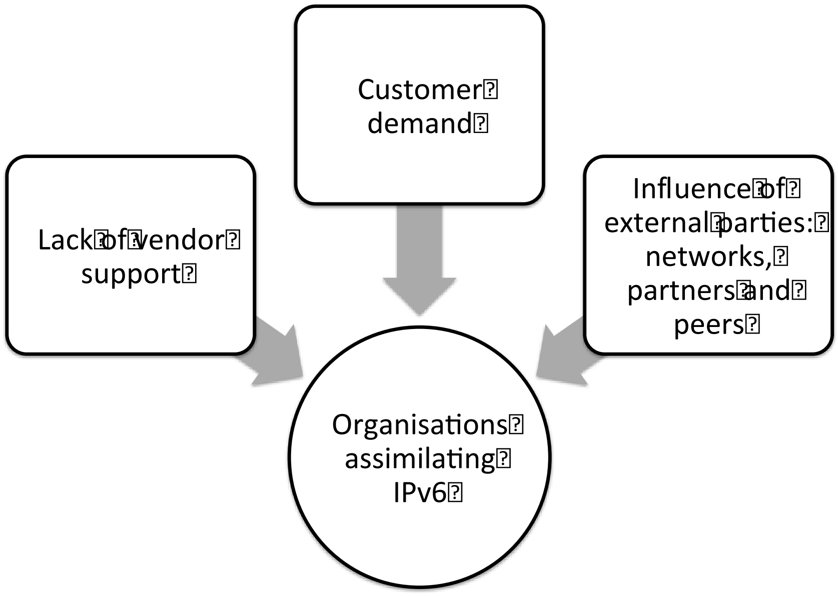

Figure 22 Network diagram for organisations in the assimilating stage

Figure 23 illustrates the network externalities for one organisation (ServProvFour) that had assimilated IPv6 across the organisation. Networks had impacted the organisation in this stage in a positive manner. The two ways ServProvFour was influenced by networks were by meeting customer demand and vendor assistance. ServProvFour wanted to make sure that its customers were provided with IPv6 services and this motivated the organisation to adopt and assimilate IPv6. ServProvFour approached various vendors for guidance when it decided to adopt IPv6. After obtaining the information on the adoption process, ServProvFour started the adoption process. Thus, vendors played an important role in the adoption and assimilation of IPv6 by ServProvFour.

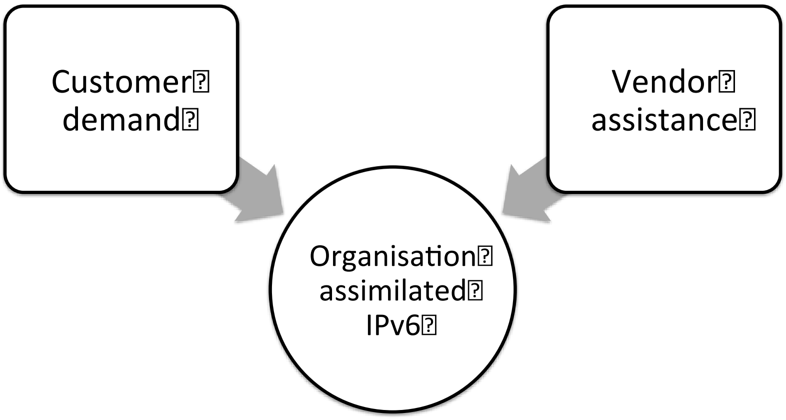

Figure 23 Network diagram for organisations in the assimilation stage

Overall, network externalities were fairly influential for the IPv6 adoption decision. These networks, consisting of customers, vendors, and industry peers, acted both as barriers to and determinants of IPv6 adoption. Broadly, comparing the network figures above shows that customer demand was key for encouraging adoption, while the lack of vendor support was the crucial issue that hindered adoption. While industry peers had some impact, this was more in terms of acting as stories of success or failure that could be drawn upon when making the adoption decision, instead of direct industry support.

6.8 Stages Maps of Organisational IPv6 Adoption and Assimilation

This section develops an overall stages model of digital infrastructure adoption and assimilation. First, a stage map that aggregated the various visual maps in the previous chapter was created. Figure 24 indicates that fewer factors affected organisations as they advanced in their IPv6 deployment projects. In the beginning, many issues were salient to organisations when they were making their adoption decision. As they progressed, the number of issues they considered decreased. Two issues that remained a challenge across the various stages of adoption and assimilation were customer demand, and participation in the government/task force adoption campaign. Staff training costs were the only barrier that affected organisations at all stages.

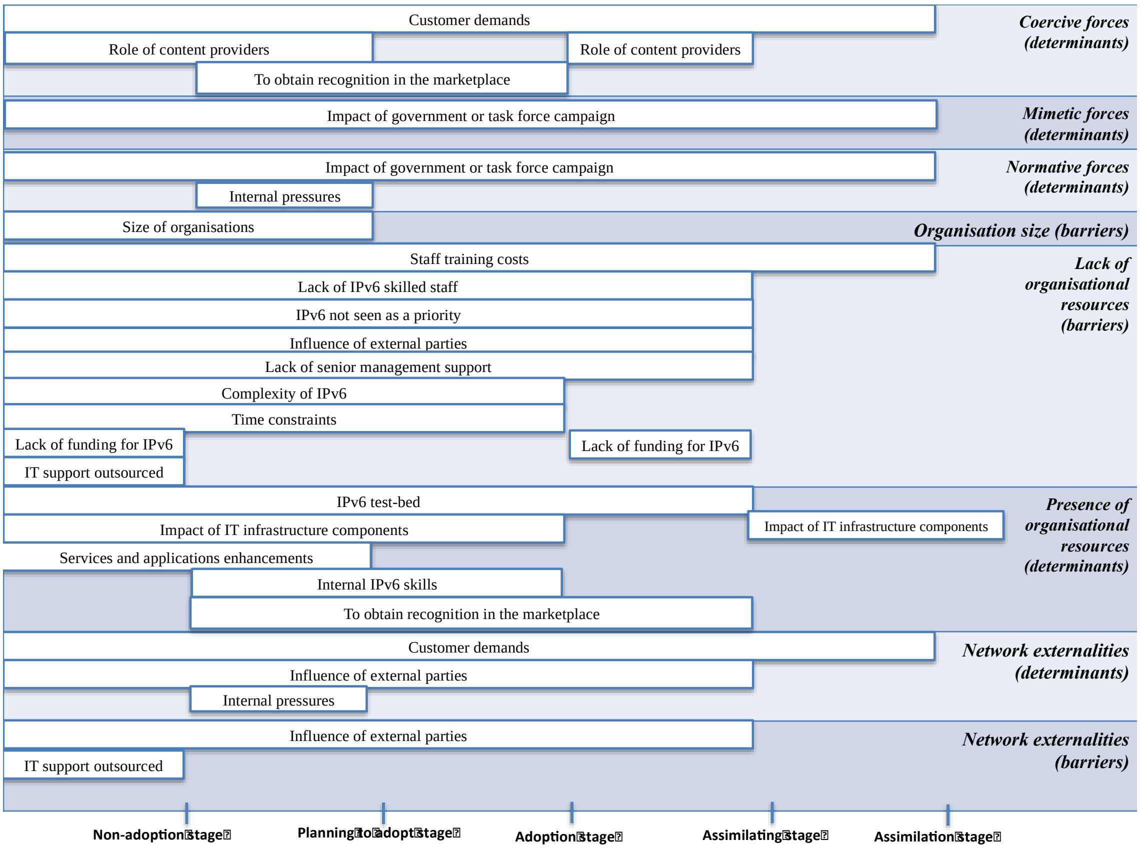

Figure 24 Stage map of organisations' IPv6 adoption and assimilation

Figure 25 is a stage model of digital infrastructure adoption and assimilation and is derived from Figure 24. Figure 25 shows that digital infrastructure adoption and assimilation was motivated and driven by determinants such as network externalities, presence of organisational resources, coercive forces, mimetic forces, and normative forces. Organisations at all stages of digital infrastructure adoption and assimilation were hindered from moving forward to the next stage because of a lack of organisational resources. Network externalities were also a barrier to organisations in the non-adoption, planning to adopt, adoption and assimilating stages. The stage map (Figure 24) and stage model (Figure 25) will be discussed further in the next chapter (Chapter 7).

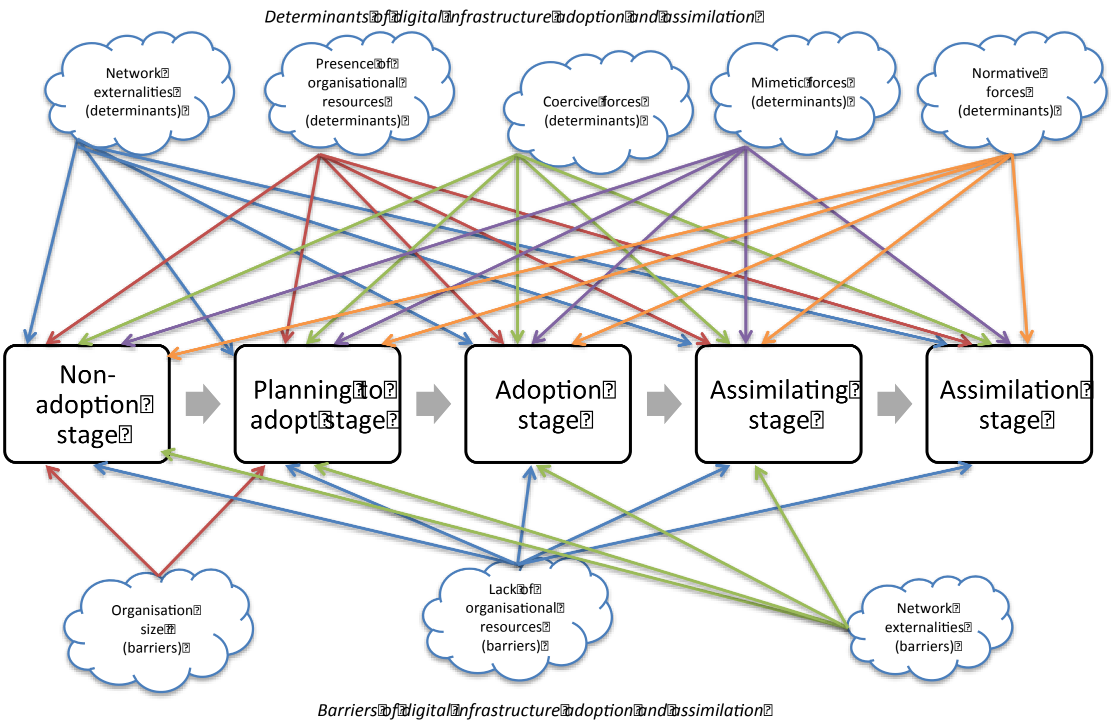

Figure 25 Stage model of digital infrastructure adoption and assimilation

6.9 Summary of Chapter 6

This chapter has summarised the results of a series of cross-case analyses that compared the results across various dimensions, such as adoption stage and organisational size, and examined how different configurations of factors were found in distinct clusters of organisations. The cross-case analysis supported the view that IPv6 adoption and assimilation was influenced by a variety of organisational-, industry- and network-level issues. Organisations that lacked resources either were not planning to adopt IPv6 or were in the planning stages. Organisations that were adopting and assimilating IPv6 also had limited resources, which could prevent or delay their progress to the next stage of adoption. Only organisations that did not lack relevant resources, such as trained staff, were able to assimilate IPv6. Network externalities were also significantly affected by different types of networks: customers, vendors and industry peers. The next chapter (Chapter 7) discusses these findings in relation to the broader theoretical framework, and concludes the study.

Chapter 7: Discussions and Conclusion

This study investigates the adoption and assimilation of IPv6 in organisations of varying sizes, from a range of industries and at varying stages of adoption. The previous chapter summarised the case studies and compared them across various dimensions: adoption stage, organisation size and the source of the pressure to adopt IPv6. The barriers and determinants that were found in the cases were classified into three categories: institutional forces, organisational resources and network externalities. Next, the different configurations of these factors that were found in distinct clusters of organisations and the occurrence of these factors across different stages were examined and reviewed. Thereafter, the role of network externalities across various stages of IPv6 adoption and assimilation was discussed. Finally, a stage map of IPv6 adoption and assimilation and a stage model of digital infrastructure adoption and assimilation derived from the literature and findings were presented.

This chapter discusses these findings, and clarifies the theoretical and practical contributions of this study. This chapter also discusses the limitations of this study and proposes avenues for future research. Specifically, Section 7.1 discusses the findings, Section 7.2 presents the theorizing about digital infrastructure adoption and assimilation, Section 7.3 examines the theoretical contributions of the study, Section 7.4 enumerates the practical contributions of the study, and Section 7.5 discusses the study’s limitations and proposes future research. Finally, Section 7.6 concludes the study.

7.1 Discussion of the Results

The two main research questions and one sub-question guiding this study were answered in the following way:

Research Question 1: What are the determinants of IPv6 adoption and assimilation in organisations?

Twelve determinants were identified in the study and classified into different categories. First, IPv6 adoption and assimilation was positively influenced by other types of network externalities (customer demand and influence of external parties), the presence of organisational resources (enhancements to IT infrastructure, services and applications, NAT usage, IPv6 test-bed, senior management support and internal IPv6 skills), coercive forces (demand from customers and content providers, and a desire to be recognised in the industry), mimetic forces (successful IPv6 deployments publicised during government/Task Force campaign), and normative forces (participation of professional networks in government or task force campaign, and internal pressures). Four of these 12 determinants had not been mentioned in prior studies: the role of content providers, internal pressures, internal IPv6 skills, and service and application enhancements.

Research Question 1a: How do institutional factors impact different stages of the adoption and assimilation of IPv6?

This study highlights the impact of coercive forces, mimetic forces and normative forces at the different stages of the adoption and assimilation of IPv6. The institutional factors identified in this study are customer demand, role of content providers, obtaining recognition in the marketplace, impact of government or task force campaigns, and internal pressures. Customer demand and impact of government or task force campaign impact organisations at all stages of IPv6 adoption. The role of content providers only affects organisations in the non-adoption, planning to adopt and assimilating stage. The desire to obtain recognition in the marketplace only impacted organisations in the planning to adopt and adoption stages. Internal pressures only affected organisations in the planning to adopt stage. Overall, this study clarified the role of institutional factors in driving organisations to adopt and assimilate IPv6.

Research Question 2: What are the barriers of IPv6 adoption and assimilation in organisations?

Eleven barriers were identified in the study and classified into different categories. IPv6 adoption and assimilation was hindered by limited organisational resources (staff training costs, a lack of skilled staff, not being seen as a priority, a lack of senior management support, technical complexity, time constraints, limited funding, adequate IPv4 addresses, and outsourced IT support), network externalities (influence of external parties and outsourced IT support), and organisation size. Seven of these barriers had not been mentioned in prior studies: staff training costs, IPv6 not being seen as a priority, time constraints, a lack of funding, technical complexity, outsourced IT support, and adequate IPv4 addresses.

Limited organisational resources were a barrier across all five stages, network externalities played a part in four stages (non-adoption, planning to adopt, adoption, and assimilating), and organisation size was a barrier in the initial stages. The lack of organisational resources was mentioned as a barrier across the various stages, indicating the necessity of organisational resources for organisational IPv6 adoption and assimilation. These resources include human resources (such as skilled staff), technical resources (such as IPv6-compatible equipment) and relationship resources (such as the support of vendors). The presence of all three types of resources enables organisations to proceed with their IPv6 adoption and assimilation plans.

Interaction between Barriers and Determinants

Some organisations were put off by the complexity of IPv6, and this was compounded by the lack of IPv6-skilled staff in certain cases. The one organisation that had assimilated IPv6 mentioned that its only barrier was staff training costs. This was remedied by the support of its vendor, which provided guidelines for IPv6 adoption and skilled staff. In some cases, internal challenges, such as a lack of funding and skilled staff, could be offset by external forces from relevant institutions and network members. In other cases, external pressures to adopt, such as peer influence, were counterbalanced by other external forces, such as a lack of vendor support.

The lack of senior management support was apparent in all three non-adopters, and that prevented funding being allocated for staff training and equipment purchases. This internal barrier countered external pressure from customers and content providers, and technological drivers, such as improvements to services, applications and IT infrastructure components. Some organisations, both large and small, were concerned that their size made IPv6 adoption more difficult.

External Influences on Adoption

Organisational resources, network externalities and institutional forces motivated organisations to adopt and assimilate IPv6, while the lack of organisational resources hindered organisations at all stages of IPv6 adoption and assimilation. Network externalities were interesting in that they were relevant to organisations in most stages of adoption as determinants and barriers. This indicates that an organisation's external environment has a stronger role in encouraging adoption compared to its internal resources. The influence of the external environment can be either 'vertical' pressure from institutions, or 'horizontal' pressure from relevant networks. For instance, all of the organisations that participated in this study were motivated by the IPv6 campaigns, regardless of the stage of adoption they were at. These campaigns influenced them in two ways: by highlighting successful adopters so firms would imitate them (mimetism) and by developing an expectation in the IT profession of the appropriateness of adopting this technology (normative pressure).

Horizontally, organisations were affected by the networks they operated in. The role of networks in the studies of digital infrastructure has often been neglected but this study shows that networks play an important role. The word *networks* here refers to actors within an organisation's network that interact with or matter to the organisation and includes customers, vendors, competitors, and others. IPv6 adoption and assimilation are subject to network externalities. Hovav et al. (2004, p. 270) stated that the *"adoption of innovation depends upon the number of current and future adopters in the community"*. As more organisations adopt IPv6, more positive network externalities are created, reducing the risk of adopting IPv6 (Hovav et al., 2004). These network externalities consist of partner influence (such as the influence of suppliers, customers, and others) and peer influence (such as the influence of organisations that are in the same industry) (Zhu et al. (2006); Lai et al. (2007)). The lower risk from network externalities is due to, for example, greater vendor support of IPv6. As more organisations adopt IPv6, the easier it becomes to attract skilled staff, and the higher the level of assurance felt that the new technology will exist in the future because of its widespread use.

7.2 Theorizing about Digital Infrastructure Adoption and Assimilation

The discussion above provides an understanding of the interaction between the various determinants and barriers of IPv6 adoption and assimilation. In this section, the findings are used to theorise the phenomenon of digital infrastructure adoption and assimilation.

The section begins by explaining the frameworks used to support the theory-building process, based on Gregor (2006) and Langley (1999), and then uses these to describe the particular theory being built in this study.

7.2.1 Frameworks

The essence of a theory is the *"abstraction and generalization about phenomenon, interactions and causation"* (Gregor, 2006, p. 616). Gregor (2006) defines five types of theories in information systems research: 1) theory for analysing, 2) theory for explaining, 3) theory for predicting, 4) theory for explaining and predicting, and 5) theory for design and action. Table 20 shows the different types of theories and their attributes.

Table 20 Gregor's (2006, p. 620) Taxanomy of Theory Types in Information Systems Research

Theory Type	**Attributes**
1. Analysis	Say what is. The theory does not extend beyond analysis and description. No causal relationship among phenomena are specified and no predictions are made.
2. Explanation	Say what is, how, why, when and where. The theory provides explanations but does not aim to predict with any precision. There are no testable propositions.
3. Prediction	Say what is and what will be. The theory provides predictions and has testable propositions but does not have well-developed justificatory causal explanations.
4. Explanation and prediction (EP)	Saw what is, how, why, when, where, and what will be. Provides predictions and has both testable propositions and causal explanations.
5. Design and action	Say how to do something. The theory gives explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artefact.

Based on the above classification, this study develops a type 2 - theory for explaining. This theory explains how, why, and when digital infrastructure is adopted and assimilated, but does not provide any testable propositions. Langley (1999) research is useful for guiding the theory-building process. This study uses one of the seven strategies proposed by Langley, the visual mapping strategy, as part of the process of theory building.

The benefits of using the visual mapping strategy according to Langley (1999, p. 702) is that *"the mapping strategy may be most fruitful as a theory development tool for the analysis of multiple holistic or embedded cases"*. The visual mapping strategy was used to develop a visual map for each organisation that participated in this study. Then, the data from these visual maps was used to conduct a descriptive analysis. Thereafter, a cross-case analysis was conducted to come up with the determinants and barriers of organisational IPv6 adoption and assimilation.

7.2.2 Multi-level model of digital infrastructure adoption

Although existing models of digital infrastructure adoption focus on a single level (Iannacci, 2010), the case studies indicated that organisations responded to factors from multiple levels, both internal and external to them, when deciding whether to adopt digital infrastructure. It is worth exploring two related multi-level models in the information systems field, namely those of Jeyaraj and Sabherwal (2008) and Frambach and Schillewaert (2002), to distinguish them from the model that will be presented here.

Jeyaraj and Sabherwal (2008) studied how the actions of various actors within organisations affected the adoption of innovations. Unlike this study, they did not examine the actions of actors outside organisations. Frambach and Schillewaert (2002) proposed a framework to study IS adoption at the organisational and individual levels. The most notable difference between the model presented in this study and that in Frambach and Schillewaert (2002) study is that this study's model includes technological factors and the influence of external actors. These dissimilarities reflect the differences between the adoption of digital infrastructure and the adoption of other types of IT. The former is more challenging to adopt because changing infrastructure has implications for a broader range of hardware, platforms, applications and IT capabilities than it does for non-infrastructural IT.

Figure 26 depicts the multi-level model of digital infrastructure adoption. The individual and technological issues interact with the organisational characteristics, which are in turn influenced by the attributes of the environment, comprising institutions and networks.

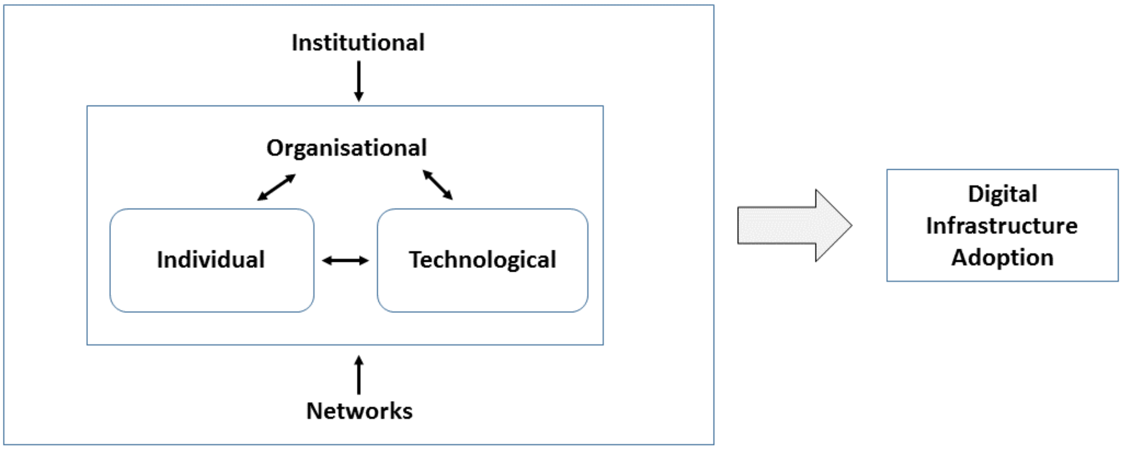

Figure 26 A multi-level model of digital infrastructure adoption

<u>Organisational factors</u>

Organisational support for digital infrastructure adoption, in terms of funding, senior management support and attention, and staff training, is difficult to obtain, mainly because the role and impact of digital infrastructure, like its physical counterpart, is less obvious (Edwards et al., 2009). Compared to digital infrastructure, non-IT managers are more likely to focus on IT projects that lead to more immediate and visible outcomes. The lack of a clear return on investment (ROI) for digital infrastructure projects encourages organisations to delay adoption or not plan to adopt it at all by extending the usage of the current infrastructural components. The delay in obtaining an ROI for infrastructure projects means that the support of senior managers, especially those in non-technical roles, is crucial for driving the project internally (Low et al., 2011). This is particularly important in contexts where external institutional or network pressures are absent. The attention of senior management and their awareness of the broader, longer-term advantages of the new infrastructure will help ensure that adequate time is set aside for planning the digital infrastructure adoption process, since the adoption of digital infrastructure is more complex than the adoption of IT software or hardware (Hanseth & Lyytinen, 2010).

Individual factors

Implementing new digital infrastructure requires IT staff to possess the relevant skills and knowledge, as a lack of these hinders adoption. Technical staff also influence infrastructure adoption through changing norms in their profession. These changing norms are diffused through professional networks and associations where peers exchange their knowledge and experiences. Besides the direct impact of these changing norms on their own organisations' infrastructure adoption, these shifts also signal to IT professionals the kinds of skills they should obtain so as to enhance their value.

Technological factors

Since infrastructure adoption by itself can be a challenging project to obtain funds for or to interest senior management in, technical managers can "piggy-back" on other IT projects to overcome the lack of support for their infrastructure adoption plans. These projects could include enhancements or upgrades of IT services, applications and other components. The lack of support for infrastructure adoption may also result in short-term workarounds being used. However, these too have limited utility or certain shortcomings, and non-infrastructure projects provide avenues to introduce the new infrastructure through alternative channels.

Institutional and network factors

The influence of the external environment can be either ‘vertical’ pressure from institutions, or ‘horizontal’ pressure from relevant networks. Organisations might not find it necessary to adopt new infrastructural components if the members of their network are not adopting them or encouraging or supporting their adoption. On the other hand, organisations may be motivated to adopt these innovations if the members of their various networks adopt them for reasons such as to ensure that they do not lose their competitive edge. This highlights the interdependence between members of the network and the role of digital infrastructure as a mechanism that can bind them together. For example, the use of IPv6 may enable an organisation to strengthen its links with its customers, or be used as a ‘showcase’ site by its vendors.

The signals sent by forces from the broader environment indicate to the organisation or the individuals in it what they should pay attention to. Customer demand can motivate senior management to prioritise the adoption of the infrastructure and expend resources on training, planning and new technology. On the other hand, changing norms in professional communities may encourage technical employees to pursue the adoption of new infrastructure, but to little avail, because the non-technical managers have not been made aware of these innovations in their networks, and thus are reluctant to allocate funds for such projects.

7.2.3 A stage model of digital infrastructure adoption and assimilation

The next stage of theorising examines the influence of organisational resources, institutional forces and network externalities across the varying stages of organisational digital infrastructure adoption and assimilation. A key goal of the study was to understand the stages of digital infrastructure adoption, since digital infrastructure is introduced, implemented and assimilated in stages. This approach incorporates how the various factors interact and reveals patterns which are especially effective or ineffective in accomplishing successful adoption.

An analysis of the data (Figure 24 in Chapter 6) traced which barriers and determinants were perceived to matter at each stage. The factors that mattered at the two major events – adoption and assimilation – were then compared. This led to the following model (Figure 27):

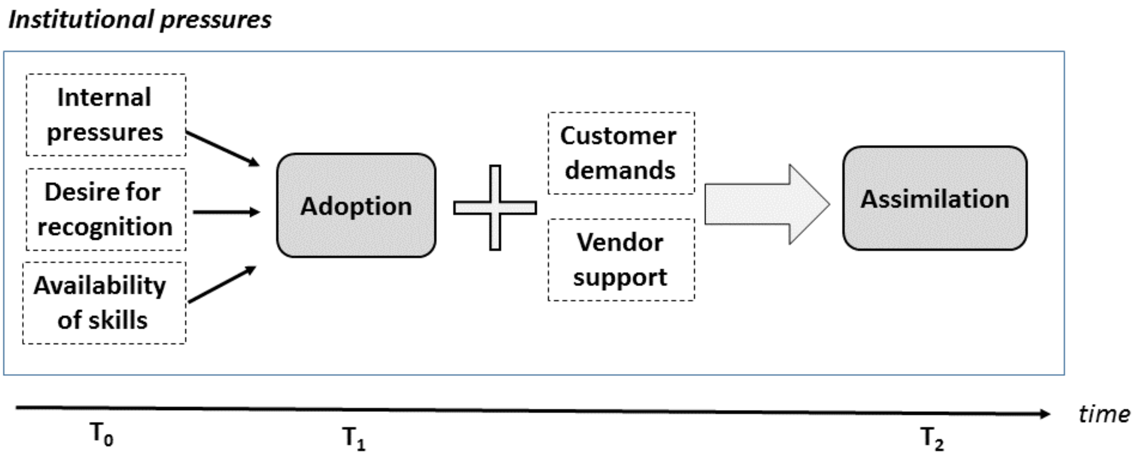

Figure 27 Stage model of digital infrastructure adoption and assimilation

The role of institutional pressures (Figure 27) reflects the unique characteristics of digital infrastructure. Compared to digital infrastructure, non-infrastructural IT, such as applications, servers and mobile devices, has fewer interdependencies with other aspects of an organisation's IT architecture. The interdependencies of digital infrastructure mean that changing it takes time as the process requires negotiation with other involved parties (Star, 1999). Thus, the adoption of non-infrastructural IT is relatively less complicated and driven more by factors internal to an organisation (Jeyaraj & Sabherwal, 2006). Conversely, digital infrastructure adoption is more complex, undertaken less often, and often requires broad-based external pressure to come into fruition. These external influences are crucial because of the uncertainty that often accompanies new types of infrastructural components, be they standards, protocols or platforms. The inherent conservatism required to ensure a stable infrastructure means that changing any such components, in the absence of a mandate, usually requires some external pressure from industry, government, vendors or professional bodies. Encouragement from institutions such as these reduces the level of uncertainty as they lend their credibility and legitimacy to the innovation.

The presence of various forms of institutional pressures, such as changes in professional norms, encouragement from regulatory bodies, or adoption by well-regarded peer organisations, is a necessary but not sufficient condition for the adoption of digital infrastructure. The initial adoption decision at T_1 depends on conditions within an organisation, particularly the availability of technical skills. Organisations that have outsourced the management of their digital infrastructure are typically less knowledgeable about developments in that field, and may thus lack the skills to assess whether these developments are beneficial. The possession of such knowledge and skills, both technical and non-technical, may drive internal efforts to adopt new digital infrastructure because of a desire for industry recognition and an awareness of the broader, non-technical benefits of the new infrastructure.

Once an organisation has adopted a new digital infrastructure component, usually in an experimental test-bed, obtaining the broader benefits of the new technology requires it to be assimilated. This involves fully deploying the protocol across the organisation's networks, applications and other services. Doing so entails interacting with vendors and customers to ensure that members in the former group are able to support the new technology, and that interaction and communication with those in the latter group will not be impeded. In other organisations, the test-bed may be set up as a trial by the technical staff without any intention of rolling it out to the wider organisation, perhaps for reasons of limited funding or a lack of interest from senior management. In such cases, demand from customers who are more advanced in their use of the new technology will motivate the organisation to diffuse it across all of their branches, departments or business units.

7.3 Theoretical Contributions

Despite its complex nature and importance, digital infrastructure has been under-studied in the information systems (IS) field (Tilson et al., 2010a), especially its adoption and assimilation. Prior research has examined organisational and national infrastructure adoption efforts, and this study has sought to integrate these previous studies and build on them to come up with models to explain this phenomenon more holistically.

This study contributes by presenting two models to aid in the understanding of digital infrastructure adoption and assimilation: a multi-level model of digital infrastructure adoption, and a stage model of digital infrastructure adoption and assimilation. These models fulfil various issues present in past research. First, they study the joint influence of institutional forces, network externalities and organisational resources on digital infrastructure adoption and assimilation. Second, although the influence of organisational resources on infrastructure adoption and assimilation has been discussed previously, this study classifies those resources and explains their impact on the process of adoption and assimilation. Third, the study deepens our understanding of the role of networks in infrastructure adoption and assimilation by clarifying the various sources of network externalities.

Overall, this study has identified the barriers and determinants of organizational digital infrastructure adoption and assimilation. This thesis also provides an in-depth understanding of the influence of institutional forces, network externalities and organizational resources on the varying stages of organizational digital infrastructure adoption and assimilation.

Digital infrastructure adoption and assimilation is more complex than the adoption of traditional IT because it involves a complicated set of dependencies on other platforms, applications and IT capabilities. The upgrading or replacement of new digital infrastructure means that these dependencies need to be able to support the new or upgraded digital infrastructure. If problems occur when adopting digital infrastructure, the dependent items will also be affected, possibly involving the entire organisation's network infrastructure. Thus, digital infrastructure adoption and assimilation is complex, uncertain, costly and risky. Therefore, the decision to adopt digital infrastructure is usually a hard one and organisations tend to delay as long as possible.

Hence, in the absence of a mandate, external pressure from industry, government, vendors or professional bodies are vital in pushing organisations to adopt digital infrastructure. Encouragement or motivation from these institutions reduces the level of uncertainty because they provide credibility and legimacy to the new digital infrastructure. Not only are external pressures important, organisations also require internal resources such as human (skills), technological (equipments that support digital infrastructure) and relationship (top management support) to adopt digital infrastructure. In addition, once the organisation has decided to adopt a certain digital infrastructure, it will need to interact with members of its networks such as its vendors and customers. Thus, this study contributes theoretically by stressing that institutional forces, organizational resources and network externalities are crucial for organizational digital infrastructure adoption and assimilation. This study also highlights that these factors are vital for varying stages of digital infrastructure adoption and assimilation, especially the non-adoption and assimilation stages that are often neglected.

This section has discussed the theoretical contributions of this study. The next section (Section 7.4) discusses the practical contributions of this study.

7.4 Practical Contributions

This study provides an understanding of the barriers and determinants of digital infrastructure adoption and assimilation in the context of IPv6. The experiences and perspectives of the participants presented in this study can help other organisations plan their IPv6 adoption and assimilation. They will be aware of the barriers that they might encounter and the ways to handle these barriers. This study also highlights the factors that support organisational IPv6 adoption and assimilation across its various stages. While the practitioner literature has mentioned some of them, others have been less talked about. For instance, vendor support and top management support are crucial, and an organisation at the assimilation stage was not able to proceed further because of shortcomings in these two areas. Also, some organisations in the study were pushed to adopt IPv6 by their customers. It would be better for organisations to pre-empt such events by adopting IPv6 earlier. That way, they will be able to plan the deployment, obtain the necessary resources, and deploy it so that it fits the overall evolution of their ICT infrastructure.

The impact of the presence or absence of the different types of organisational resources, such as human, technological and relationship resources, can be used as a guide for organisations to plan and acquire the necessary resources, and obtain support from staff at different levels of the hierarchy and from different functions (business and technical). In addition, this study specifies how the various members of organisational networks, such as customers and vendors, affect the adoption and assimilation of IPv6. This understanding will help organisations realise the role of network externalities in determining the outcome of IPv6 adoption. In summary, organisations can thoroughly plan their IPv6 adoption and assimilation by identifying the institutional forces, organisational resources and network externalities that they might encounter or require support from during various stages of its IPv6 adoption and assimilation. Finally, the results of this study can be used as guidelines for organisations adopting other types of digital infrastructure besides IPv6.

7.5 Limitations of the Study and Future Research Opportunities

While this study has investigated the joint influence of institutional, network and organisational factors on digital infrastructure adoption and assimilation, future research could explore each aspect in more detail. For example, an aspect of institutional theory that has not been explored here is the concept of 'institutional logics'. Institutional logics are *"bundled sets or ensembles of higher order meanings, values, norms, and/or rules that frame how individuals make sense of the world around them and consequently know how to act. They reflect organizing principles that help frame collective action"* (Cloutier and Langley (2013, p. 361). Researchers could use this concept to deconstruct the specific ways that the different institutions view digital infrastructure adoption and assimilation and their roles in it, and what influences their understanding of the process. This would also address a shortcoming of this study, which was the inability to assess to what extent the logics of the various institutions were aligned or divergent, and whether and how these differences affected digital infrastructure adoption.

A second aspect that needs further examination is the role of network externalities. There is a need for further research on the interactions and links between various members of the different networks that organisations are part of and which are relevant to the adoption and assimilation of digital infrastructure. This would improve our understanding of the various externalities and their differing levels of influence on the adoption process. This study identified some of these externalities, and future studies should investigate how any of them act as countervailing or supporting forces. More broadly, resource dependency theory (Pfeffer, 1981), which examines how organisations manage their dependence on others or others' dependence on them for scarce and valuable resources, is a theoretical lens that could be fruitfully applied in expanding our understanding of the impact of networks on infrastructure adoption.

This study initially aimed to collecting process or longitudinal data by studying an organisation's IPv6 adoption over a period of time as it progressed from non-adoption to planning to adoption, and finally to assimilation. However, the researcher was unsuccessful in obtaining an organisation that allowed such data collection. Therefore, the researcher intends to conduct a longitudinal study in the future to identify the mechanisms that enable organisatinos to go across the stages.

While this study was conducted in New Zealand, it would be worth replicating it in different countries with cultural differences, based on Png et al. (2001) finding that individuals from countries with lower levels of uncertainty avoidance [9] are more prepared to adopt digital infrastructure compared to people from countries with higher levels of uncertainty avoidance. Therefore, this study could be expanded to a cross-country study that includes organisations from different cultural backgrounds. It would be interesting to understand the differences or similarities of digital infrastructure adoption and assimilation experiences of organisations from different countries. Finally, as this study was developed in the IPv6 context, the models should be applied in other contexts to examine the adoption of other types of digital infrastructure and to assess their validity and comprehensiveness.

7.6 Conclusion

With the continuous growth and increasing number of Internet-enabled devices, IPv4 is depleting rapidly and the need for IPv6 is inevitable. Additional Internet-enabled devices will not be able to connect to the Internet once IPv4 has been depleted. Although IPv6 adoption is crucial, organisations are still in the initial phase of the

[9] Level of uncertainty avoidance refers to the magnitude that people from a culture feel unprotected by uncertainty or unknown situations.

adoption (OECD, 2014). To address this problem, this study aimed to provide insights into the issue of IPv6 adoption and assimilation. Broadly, this was done in the hope of enhancing the understanding of digital infrastructure adoption and assimilation.

Through a literature review, data collection and analysis, this study developed two models of digital infrastructure adoption and assimilation. These models highlight the importance of network externalities, institutional forces and organisational resources on the varying stages of digital infrastructure adoption and assimilation. These models also act as guidelines for organisations that are adopting IPv6. In conclusion, it is hoped the results of this thesis spur the adoption of IPv6 and help policy-makers in future infrastructural adoption campaigns.

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Appendix A

Consent Form for Participant

Project title: ***A Process Theory of IT Infrastructure Adoption: The IPv6 Story***

Project Supervisor: ***Dr Harminder Singh, Prof Felix Tan***

Researcher: ***Awinder Kaur***

- I have read the Participant Information Sheet and understand the nature of the research, why I have been selected and what is expected of me.
- I have had the opportunity to ask questions and have them answered to my satisfaction
- I agree to take part in this research
- I understand that I am free to stop participating at any time, and to withdraw any data traceable to me up to three weeks after the last interview
- I understand that my supervisor/manager has given an assurance that my participation or non-participation will not affect my employment status
- I understand that my employer will not be provided access to the transcript of my interview. The information collected from the interview will be aggregated and anonymized, so that it will not be linked to any particular individual(s).
- I agree / do not agree to be audio-recorded
- I wish / do not wish to have the opportunity to edit the transcripts of the recording
- I understand that I will not be identified in any publications resulting from this research
- I understand that data will be kept for at least 6 years, and will be destroyed at the end of the research period

Participant's signature.................................…………………………………………………………

Participant's name:...............................……………………………………………………………..

Participant's Contact Details (if appropriate):

………………………………………………………………………………………..

………………………………………………………………………………………..

Date:

Approved by the Auckland University of Technology Ethics Committee on *22 March 2013,* AUTEC Reference number *12/305*.

Note: The Participant should retain a copy of this form.

Appendix B

Participant Information Sheet

Date Information Sheet Produced:

25/02/2013

Project Title

A Process Theory of IT Infrastructure Adoption: The IPv6 Story

An Invitation

I, Awinder Kaur, am studying the adoption and assimilation of IPv6 in organisations for my doctoral research. Participation is voluntary and you are free to withdraw at any time. Your help is appreciated. Please be assured all replies are confidential and your responses will remain anonymous. Thank you for helping me complete my doctoral research. Please read the rest of this information sheet for full details of this study.

What is the purpose of this research?

The purpose of this research is to understand the determinants and barriers of IPv6 adoption and assimilation in organisations.

How was I identified and why am I being invited to participate in this research?

You have been selected to participate in this research because of your direct and/or indirect involvement in the IPv6 adoption and assimilation in your respective organisation.

What will happen in this research?

The interview will take approximately 50-60 minutes to complete. Please answer each question as carefully as possible. You may decline to answer any specific question if you wish to. If you feel that you are not able to answer a question, you can proceed to the next one. If you agree, the interview will be recorded. It will be transcribed based on my notes and/or the audio-recording. The data collected and its analysis will provide an insight into an organisation’s decision to adopt IPv6 and assimilate it into its operations. The data analysis will be published in my doctoral thesis, as well as papers in academic journals and conferences.

What are the discomforts and risks?

We will not cause any discomforts and risks for participants as the information collected will be aggregated and anonymized, so that it will not be linked to any particular individual(s). Your individual data will not be shared. However, some of your answers may require you to disclose sensitive information-commercial or otherwise. For example, the answer to a question on why an IPv6 innovation is not adopted may involve company secrets. Alternatively, you may feel the answer to a sensitive question might make you personally identifiable. You are free to choose not to answer any questions asked.

How will these discomforts and risks be alleviated?

Our research will not identify any individuals or attribute information or comments to any organisation. We will not divulge your name or the organisation you represent.

What are the benefits?

This study aims to develop an IPv6 technology adoption model which will assist organisations in their IPv6 adoption. The results of this study will guide managers and policy makers in their decision-making and planning for IPv6 adoption.

How will my privacy be protected?

All data will be held in secure locations within AUT University in compliance with Auckland University of Technology Ethics Committee (AUTEC) regulations. Since the interviews will be held at your workplace, your co-workers will be aware of their involvement in this project. However, please be assured that your confidentiality will be preserved and all information will be de-identified. All documents, including the summary report, will not mention individuals or organisations.

What are the costs of participating in this research?

The time commitment will be 50-60 minutes. Your participation is vital for the completion of this research project. Should you prefer not to participate, or you wish to cease participation at any time, you are free to do so.

What opportunity do I have to consider this invitation?

Two weeks.

How do I agree to participate in this research?

A consent form will be given to you when we meet to conduct the interview. By attending the interview, you indicate your consent to participate.

Will I receive feedback on the results of this research?

Results of this research will be available on request from the researcher.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr Harminder Singh, WF1005, Faculty of Business and Law, AUT University, Private Bag 92006, Auckland. Tel +64 9 9219999 ext. 5029 email: hsingh@aut.ac.nz

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Dr Rosemary Godbold, *rosemary.godbold@aut.ac.nz* , 921 9999 ext. 6902.

Whom do I contact for further information about this research?

Researcher contact details:

Awinder Kaur, Faculty of Business and Law, Auckland University of Technology (AUT), Private Bag 92006, Auckland. Tel +64 9 9219999 ext. 5744 email: awkaur@aut.ac.nz

Project Supervisor Contact Details:

Dr Harminder Singh, WF1005, Faculty of Business and Law, AUT University, Private Bag 92006, Auckland. Tel +64 9 9219999 ext 5029 email: hsingh@aut.ac.nz

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Approved by the Auckland University of Technology Ethics Committee on *22 March 2013*, AUTEC Reference number *12/305*.