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# Analysis of IPV6 Readiness of End-user Enterprises in the North Carolina Eastern Region

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# ANALYSIS OF IPV6 READINESS OF END-USER ENTERPRISES IN THE NORTH CAROLINA EASTERN REGION

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# ABSTRACT

On February 3rd, 2011, the Internet Addressing and Numbers Authority (IANA) allocated the last five /8 blocks of IPv4 addresses to each of the five Regional Internet Registries (RIRs). Since that event, four of the five RIRs have depleted their IPv4 allocations and began operating under final IPv4 address depletion policies. The exhaustion of the IPv4 address pools maintained by the registries means that IPv4 is now a legacy protocol and that all future Internet growth will be over IPv6. This exhaustion also means that organizations must take action to accommodate IPv6 adoption or risk compromising business agility and continuity – especially those organizations with public-facing content that rely on the Internet. Yet, anecdotal evidence and recent published studies indicate that few organizations have moved to adopt IPv6. The evidence suggests a low sense of urgency and lack of understanding among organizational leaders regarding the potential consequences that IPv4 exhaustion will have on their organization's business model. An understanding pertaining to the IPv6 adoption readiness within organizations is needed so that programs can be established to raise the awareness of organizational decision makers to risks of not having an IPv6 strategy and to inspire them to take action. This study achieved this objective by investigating the IPv6 readiness of enterprise organizations located in eastern North Carolina through a survey sent to the senior IT decision makers of 463 end-user enterprise organizations. IPv6 readiness was measured across five facets of organizational IPv6 preparedness; training, high-level planning, assessment of the current environment, IPv6 policy, and IPv6 deployment. Statistical analyses identified the significant technology adoption factors associated with IPv6 readiness as measured on a six-stage Guttman scale, ranging from simply “aware” of IPv6, to general IPv6 deployment. Results revealed that the majority of organizations have made little to no preparation toward IPv6 adoption and do not see IPv6 adoption as an urgent issue. Further it was found that the factors most significantly associated with low levels of IPv6 readiness were lack of perceived advantages of IPv6 and lack of perceived pressures from industry partners and customers to adopt IPv6. Based on the findings of this study, a recommended approach to developing an effective IPv6 strategy, as well as, a framework for IPv6 adoption planning is presented for organizational leaders and IT decision makers to use as a guide toward a successful IPv6 transition.

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## INTRODUCTION

On February 3rd, 2011, a milestone in Internet history was reached when the Internet Assigned Numbers Authority (IANA) made the final IPv4 allocations to the five Regional Internet Registries (RIRs; ARIN, 2014). With the exception of the African Information Network Center (ARFINIC), the remaining RIRs have since exhausted their IPv4 address pools and are now operating under final IPv4 depletion policies. The only remaining IPv4 addresses for assignment are those held in the reserve address pools of each RIR, Local Internet Registries (LIRs), and Internet Service Providers (ISPs). It is only a short matter of time before these providers begin denying IPv4 address assignment requests by organizations. The exhaustion of the IPv4 address space marks an inflection point for the Internet and for all organizations that rely on their IT ecosystem for their business – any future investments in IPv4 are now an investment in an end-of-life technology.

Some may ask, “Why do we care if there are no more IP addresses?” The answer is Internet growth. The number of people connecting to the Internet with personal computers (PCs) and mobile devices, each of which needs a unique IP address, is expected to grow at the rate of approximately 300 million per year ("Internet World Stats," 2013); however, the number of non-human smart devices (machines, robots, and sensors) being used is growing even faster. It is estimated that more than 20% of all current Internet traffic is generated by billions of “smart” devices that make up what is known as the Internet of Things (IoT) (Atzori, Iera, & Morabito, 2010). In the IoT, any system component can be connected to and communicate on the Internet, such as: automobiles, power meters, sensors, light bulbs, radio frequency (RF) tags. This components list is expansive and can include anything and everything that needs to be located, managed, controlled, or audited. Some experts predict that within the next ten years the IoT could include more than 50 billion devices connected to the Internet (Cisco, 2013).

Accommodating billions of additional Internet enabled smart devices requires that the Internet undergo its first "fundamentally disruptive change since it was privatized from the Advanced Research Projects Agency Network (ARPANET)", or more specifically, it must transition to the next generation Internet protocol, IPv6 (Czyz et al., 2013). As Dell (2010) explains, the necessity for a new Internet protocol is the consequence of the depletion of IPv4 addresses which act as Internet access permits. Since running out of IP addresses (i.e. permits) would prevent any new users or devices from connecting to the Internet, it would also prevent the future growth of existing networks and prevent new enterprises from joining the Internet to conduct commerce (IEEE, 2009). With the global IPv4 address pool now exhausted, sustaining the future growth of the Internet can only come from the adoption of IPv6 (OECD, 2010).

IPv6 is not a new protocol as it was standardized as a successor to IPv4 in 1995, specifically to address the imminent problem of IPv4 address exhaustion. The problem stems from the IPv4 design which has a 32-bit address field, limiting the total number of unique IPv4 addresses to approximately 4.3 billion. When IPv4 was initially developed in the 1980s as part of the TCP/IP protocol suite, there seemed to be an infinite number of addresses since there were only a few dozen nodes on what was a private government research network. IPv6 on the other hand, was designed to support a global public Internet and has an address space of 128-bits, allowing for more than 340 undecillion (10^36) unique IPv6 addresses (Hinden & Deering, 1995). In addition to providing a larger address space, IPv6 includes many technical enhancements, such as the use of extension headers, a flow labeling mechanism, address auto-configuration, mobility support, and support for IP security (IPsec) (Hinden & Deering, 1995).

Despite the exhaustion of the IPv4 address space and the technical superiority of IPv6, widespread adoption of the IPv6 among enterprise organizations has not yet materialized. Without financial business drivers to encourage adoption, the adoption rate among organizations is “deplorably low” (Horley, 2014, p. 2). Studies in the extant literature indicate that many organizations view the transition to IPv6 as a cost burden that should be avoided or at least delayed as long as possible, rather than a Next Generation IT enabler or a strategic upgrade that can leverage competitiveness (Dell, 2010; Hovav & Schuff, 2005; Singh & Tan, 2013).

As an infrastructure technology, IPv6 does not provide any direct revenue, making it difficult to justify a business case for its deployment by many enterprises (Colitti, Gunderson, Kline, & Refice, 2010; Hovav, Hemmert, Kim, 2009). Significant transition and training costs, compatibility issues, lack of vendor support, and security concerns are some of the primary reasons organizations are reluctant to begin IPv6 migrations (Singh & Tan, 2013; Yadav, Abad, Shah, & Kaul, 2012). Nevertheless, IPv6 adoption is inevitable and the debate on whether it will happen, stopped on February, 3rd 2011.

There is concern within the Internet community that the lack of widespread IPv6 adoption could lead to a partitioning of the Internet into disconnected IPv6 and IPv4 “regions”, with the IPv4 regions relying increasingly on multiple layers of network address translation (NAT). In 2008, the Organization for Economic Co-operation and Development (OECD) voiced concern with a reproach that governments and business must work together to tackle the problem of Internet address shortages by encouraging IPv6 education and awareness (OECD, 2008). In a 2010 progress report pertaining toIPv6 deployment, the OECD again called on all stakeholders to "anticipate the impacts of the transition period and plan accordingly to gather momentum for the deployment of IPv6 to decrease the pressure on IPv4" (OECD, 2010, p.5). To increase awareness on the criticality of this issue, more scholarly research and empirical studies of organizational IPv6 readiness and adoption are needed (Kaur, Singh, & Tan, 2013). A thorough review of the literature revealed only one scholarly study investigating IPv6 readiness of end-user enterprise organizations. The study, conducted by Dell (2012), found that of the top 1000 Australian end-user enterprises, few had made any progress in IPv6 readiness.

This study sought to extend Dell's work through an empirical analysis of the level of IPv6 readiness of enterprise organizations in eastern North Carolina and the identification of the technology adoption variables associated with an organization's stage of IPv6 readiness. The importance of understanding the innovation adoption process within organizations is emphasized by Oliveira and Martins (2011), stating that "Information technology is universally regarded as an essential tool in enhancing the competitiveness and of the economy and a country" and that "It is crucial, therefore to understand the determinants of adoption and the theoretical models that have arisen to addressing adoption (p. 1)". Relating to Oliveira and Martins (2011), technological knowledge of adoption factors associated with IPv6 readiness, as well as, the current readiness level within organizations is key to the development of effective programs that are designed to help decision makers understand the technological, operational, business risks, and opportunities created by IPv6 adoption.

## Statement of the Problem

The problem addressed by this study pertains to the fact that the level of IPv6 readiness of end-user enterprise organizations in eastern North Carolina is unknown and the technology adoption factors that are associated with organizational IPv6 readiness are not yet well understood.

## Research Questions

The present study will address the following research questions:

1. What is the level of IPv6 readiness of end-user enterprise organizations in the North Carolina eastern region?
2. What steps toward IPv6 adoption readiness have organizations in eastern North Carolina taken?
3. What technology adoption factors are associated with the IPv6 adoption readiness of organizations in eastern North Carolina?
4. What correlations, if any, exist among the variables used in this study?

## Purpose of Study

The purpose of this study was three-fold. First, this study was conducted to investigate the level of IPv6 readiness of end-user enterprise organizations across five facets of IPv6 preparedness, where were: IPv6 training, high-level IPv6 planning, assessment of the current environment for IPv6, IPv6 policy, and IPv6 deployment. Second, the study was conducted to identify technology adoption factors significantly associated with IPv6 readiness. Third, the remaining purpose of this study was to provide a recommended course of action for IT decision makers to implement an IPv6 strategy.

## Significance of the Study

The implementation of this study is novel and will provide pertinent information that will greatly contribute to the technology management profession. More specifically, this study fills a literature gap by providing the first known empirical and scholarly study of the IPv6 readiness of end-user enterprise organizations conducted in United States. Second, this is the first known scholarly study known to apply diffusion theory and institutional theory to the study of IPv6 readiness using the technological-organizational-environmental (TOE) framework. Third, this is the first known empirical study to use a categorically distributed dependent variable based on a Guttman scale to operationalize IPv6 readiness. Therefore, the results from the aforementioned study contributions can be used to increase the awareness of organizational makers of the importance of having an IPv6 adoption strategy.

## Assumptions

The research associated with this study is conducted under the basis of multiple assumptions:

1. The IPv6 is the only feasible long term solution to IPv4 address exhaustion.
2. The Internet will continue to grow and the growth will require more IP addresses than are currently available with IPv4 and Network Address and Protocol Translation technologies combined.
3. The respondents in this study are IT decision makers in their organizations and respond truthfully and honestly to each survey item.
4. The survey questions accurately captured the level of IPv6 readiness levels of organizations in eastern North Carolina.

## Limitations

Some associated limitations of this study are:

1. The sample population of this study was limited to enterprise organizations within the geographic region of eastern North Carolina. Therefore, the results of this research cannot be generalized to the larger population of all enterprise organizations.
2. The constructs and survey instrument used in this study were adapted from previous studies on adoption of IPv6, cloud computing, radio frequency identification (RFID), and voice over IP (VoIP). As a result, other factors that explain, influence, or are associated with the adoption and assimilation of IPv6 may be absent from this study.
3. Data was collected from a single respondent within each organization surveyed. These responses might be subjective and distorted and thus may not be representative of the entire organization.

## Methodology

This study involved the use of a survey instrument distributed electronically to 463 enterprise organizations in eastern North Carolina to assess IPv6 readiness. The survey questions were adopted from previous technology adoption studies (Dell, 2012), cloud computing (Tweel, 2012), RFID (Wang, Wang, & Yang, 2010), and VoIP (Basaglia, Caporarello, Magni, & Pennarola, 2009). Prior to deployment, the survey was tested for both face and content validity by two panels of reviewers. The first panel was made up of reviewers from various professional backgrounds that assessed the face validity of the survey instrument. The second panel consisted of subject matter experts in the information technology field with extensive IPv6 knowledge that evaluated the content validity of the survey instrument.

The survey instrument and the methodologies used in distributing the survey were approved by the Institutional Review Boards (IRBs) at both Indiana State University and East Carolina University. Exemption letters from both IRBs are located in Appendix A.

The target population for this study was enterprise organizations in eastern North Carolina which were identified through two employer databases maintained at East Carolina University (ECU). Respondents to the survey were limited to IT decision makers within the organizations. The survey instrument was sent electronically using ECU's Qualtrics Web based survey tool to 463 organizations. Of the 121 responses that were received, 68 of these were identified as useable for a net response rate of 14.65%. All data in this study were analyzed using IBM's SPSS v22.0 statistical software program. Descriptive statistical analysis techniques were employed to describe demographic characteristics of the respondent organizations, to check key variables for violations of assumptions of statistical techniques, and to address research questions. Scale reliability was calculated using Cronbach's alpha coefficient and measurement model validity was evaluated using principle component analysis. Associations between variables were analyzed using Spearman's rank-order correlation coefficient and Fisher's exact test.

Definition of Terms:

1. IPv4 exhaustion - IPv4 exhaustion is the point when an Internet registry has no more general use allocations of IPv4 addresses available. This threshold will vary slightly based on the individual policies at each RIR but is typically a single /8 or /9.
2. Final /8 - The last /8 block of IPv4 addresses available for general use allocations. A /8 block contains 16,777,216 addresses.

3. IPv6 adoption - The process in which an organization decides to replace or upgrade its current hardware, software, and systems to support IPv6.
4. IPv6 assimilation - The process of organizations moving from initial awareness of IPv6 to full adoption and deployment.
5. Internet of things - Real-world everyday objects that are connected to the Internet.
6. Enterprise network - An organizational network which has more than one internal link, one or more WAN connections to at least one service provider, and that is actively managed by a network operations entity.
7. Non-native IPv4 services - Includes transition technologies such as NAT64, NAT444, and Dual-Stack Lite.
8. IPv6 readiness - The state of preparedness of an organization to adopt IPv6.
9. End-user organizations - Organizations that are not service providers and do not provide IP services to other organizations.
10. Innovation - An idea, a product, a program, or a technology that is new to the adopting unit.

# CHAPTER 2

## LITURATURE REVIEW

### The Internet Protocol (IP)

In 1974, Vinton Cerf and Robert Kahn published their seminal work "A Protocol for Packet Network Intercommunication". The paper presented a protocol that supported resource sharing between different packet switching networks. More specifically, Cerf and Kahn (1974) proposed the existence of a transmission control program (TCP) that performed many functions that would later be performed by the Transmission Control Protocol / Internet Protocol (TCP/IP). The TCP/IP is a uniform addressing scheme that includes procedures for fragmenting packets, segmenting and sequencing of packets, retransmission of dropped packets, and carries port addressing information. The TCP address scheme allows for up to 256 distinct networks (8 bits) and 65,536 nodes (16 bits) on each network, which was argued as being "sufficient for the foreseeable future" (Cerf & Kahn, 1974, p. 5). A series of Internet Experiment Notes (IENs) and several Requests for Comments (RFCs) were drafted by Jon Postel in 1979, 1980 and 1981 that proposed splitting TCP into the two protocols that are known today as TCP/IP version 4 (J. Postel, 1980, 1981). By August of 1980, 12 gateways were already established which ran IP that connected 10 networks, including the ARPANET, local area networks, packet radio networks, and satellite networks (J. B. Postel, Sunshine, & Cohen, 1981).

The US Department of Defense (DoD) adopted the TCP/IP suite in 1980, and by 1982 the protocol suite was considered to be robust and reliable enough to be the standard protocol for all DoD military computer networks. On January 1, 1983, the ARPANET transitioned from the network control process to TCP/IP (Waldrop, 2008). Because TCP/IP was part of the public domain, other non-governmental entities/individuals could use it to connect networks to the Internet, which by the mid-1980s was beginning to expand with various US and international government-funded activities and with interest from the commercial sector. One of the larger networks to be connected to the Internet was the National Science Foundation's NSFNet, launched in 1986. The NSFNet linked researchers on every university campus to a system of supercomputer systems and eventually grew to become the backbone of the Internet. Commercial networks were also beginning to be connected to the Internet and in 1989, the ARPANET was decommissioned (Waldrop, 2008). By 1990, the Internet had already grown far beyond its original role as an experimental research network. It was serving a rapidly growing user community and commercial activity was rapidly increasing.

The first RFC to define IP as a separate protocol from TCP was RFC 760 "DoD Standard Internet Protocol" (J. Postel, 1980). As a separate protocol, IP's scope was limited in function to delivering packets, called datagrams, from a source to a destination over an interconnected system of dissimilar networks (Waldrop, 2008). There were design tradeoffs that had to be made in designing the details of the Internet protocol. According to Cerf and Kahn (1974) the most difficult design decision was the size and structure of the IP address. An address field of 32-bits was chosen as a trade-off between having sufficient addresses to accommodate growth and not so large that it added excessive overhead. The IP address was designed for a two level addressing hierarchy that included an 8-bit network address and a 24-bit host address (Postel et al., 1981). This address hierarchy would allow for 256 IPv4 networks, each of which would support 16.7 million hosts (Fig. 1).

| | | | |
|---|---|---|---|
| Ver. | IHL | ToS | Length |
| ID | | | Fragment Offset |
| TTL | | Protocol | Checksum |
| 32-bit source IP | | | |
| 32-bit destination IP | | | |
| Options | | | |
| Data | | | |

Figure 1. The structure of an IPv4 header and the two 32-bit addressing fields.

*IPv4 Address Space Exhaustion*

The 32-bit address field in the IPv4 header allows for a theoretical maximum of approximately 4.3 billion unique IPv4 addresses. In practice, however, the number of available addresses is far less. This lack of availability is due to inefficient address allocations that were made prior to the establishment of the IANA and the regional Internet registry system, and to a large number of reserved and special purpose addresses. During the inception of the Internet, IPv4 network address allocations were made in large blocks to early adaptors by a single person, Jon Postel (Hughes, 2010). The IANA lists these as legacy allocations in its IPv4 Address Space Registry and they make up a significant portion of the IPv4 address space. Virtually, 13% of the entire IPv4 addressing space is owned by 35 very large organizations, such as IBM, Ford Motor Company, and the DoD. There is also a significant amount of the IPv4 address space reserved for special purposes, such as private IP addresses, bench marking, and multicast. Taken together with the legacy allocations, just over a billion addresses or 25% of the total IPv4 addressing space is unavailable for allocation (IANA, 2014).

By the early 1990s, the Internet community was well aware that 32-bits of addressing space were inadequate to support the exponential growth of the internet. In 1991, the Network Working Group of the Internet Engineering Task Force (IETF) predicted that "the Internet will run out of the 32-bit IP address space altogether, as the space is currently subdivided and managed" (Clark, Braden, Chapin, Hobby, & Cerf, 1991, p. 5). Furthermore, in 1992, the IETF called the pending address space exhaustion "one of the most serious and immediate problems that the Internet faces today" (Crowcroft & Wang, 1992; e.g. Fig. 2). While it was obvious to many in the early 1990s that the IPv4 address pool would eventually be depleted, predicting when exactly that event would occur was an inexact science and the subject of many debates.

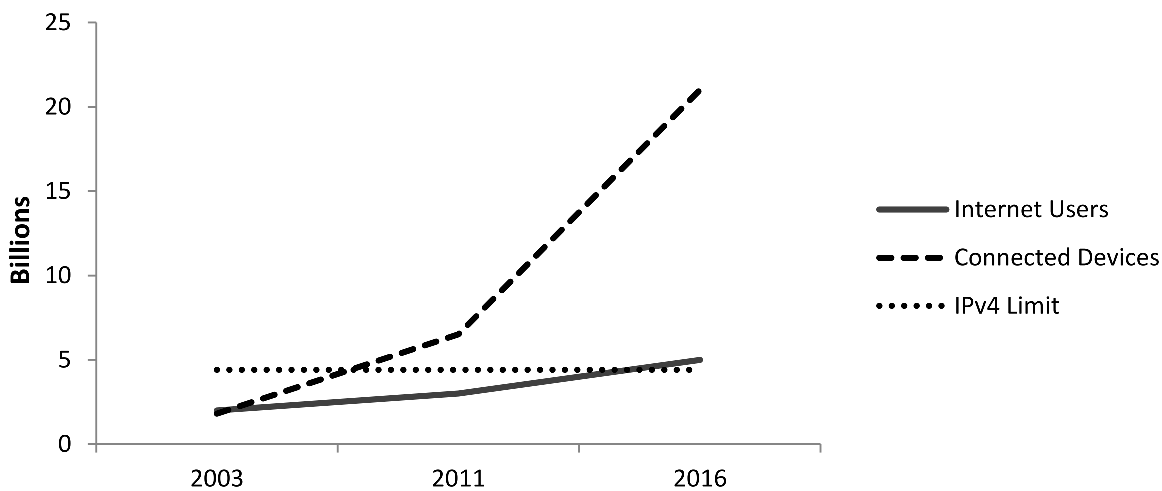


Figure 2. Represents the quantity of Internet connected devices in relation to time. More specifically, this figure shows how Internet connected devices (dashed line) and internet users (solid line) has exceeded the number of available IPv4 addresses (dotted line) (Google, 2014). The number of Internet users is represented by the solid line.

Table 1

Projected IPv4 exhaustion dates. The projected dates at which the Internet Addressing and Numbers Authority (IANA) and each of the Regional Internet Registry's (RIRs) will exhaust their available pools of IPv4 addresses. IANA and four RIRs have already exhausted their IPv4 address pools, where as the last remaining fragments of the /8 in each registry will be allocated according to individual registry final /8 policies.

| IPv4 Address Pool Exhaustion Projections | | |
|---|---|---|
| | Projected Exhaustion Date | Remaining /8s |
| IANA | 3 February 2011 (actual) | 0.00 |
| APNIC | 19 April 2011 (actual) | 0.82 |
| RIPE NCC | 14 September 2012 (actual) | 0.98 |
| LACNIC | 10 June 2014 (actual) | 0.22 |
| ARIN | 14 April 2014 (actual) | 0.66 |
| AFRINIC | 8 June 2020 (projected) | 3.01 |

*IPv4 Address Conservation*

To accommodate continued growth of the Internet, solutions were implemented by the Internet community to conserve and manage the remaining IPv4 address pool. Some solutions, such as the establishment of Private IP addresses and Network Address Translation (NAT) were designed to specifically slow down the rate of IPv4 address exhaustion until the permanent solution, IPv6 adoption, could be put in place. Other solutions, such as Classless Inter-Domain Routing (CIDR) and the establishment of the Regional Internet Registries (RIRs), were designed to help conserve and economically manage IP address space (Hughes, 2010).

To slow down the rate of IPv4 address exhaustion private IP addresses were defined by Request for Comment (RFC) 1597 "Address Allocation for Private Internets". The RFC set aside a range of addresses that organizations could use for internal use only. These addresses could be used and routed internally by the organization but were not intended for Internet connectivity. Previously, organizations had been allocated globally unique addresses for all devices, even when the devices being addressed had no need for Internet connectivity. Because these blocks of addresses are private and not routable on the public Internet, they can be used by many organizations (Rekhter, Karrenberg, Groot, & Moskowitz, 1994).

While not specifically intended to address the problem of IPv4 address space exhaustion, CIDR did help postpone the exhaustion problem by allowing address prefix allocations sized appropriately for mid-sized organizations. Prior to the use of CIDR allocations, an organization either received a class C address with a maximum of 254 host addresses, which is usually too small, or a class B with 65,534 host addresses, which is usually too large. The use of CIDR allowed the allocation of one or more blocks of Class C prefixes to network service providers who could then allocate subsets of theses blocks to organizations according to the organization's size and addressing needs. As a result of CIDR implementation, the life of the public IPv4 address space was extended and the growth rate of routing tables on Internet routers slowed considerably (Fuller, Li, Yu, & Varadhan, 1993).

The internet community realized that CIDR would probably not sustain Internet growth long enough for the long-term IPv6 solution to be implemented. To further delay the depletion of IPv4 addresses, IP Network Translators (NATs) were defined to allow for address reuse. NATs are placed at the boarder of a domain or autonomous system, such as a corporate network, and translate internal private IPv4 addresses into one or more public Internet routable IPv4 addresses. In this way, many internal hosts can all share a single (or a few) public IPv4 address (Egevang & Francis, 1994).

*The Internet Registries*

The need for a distributed Internet registry system was recognized in 1990. The motivation and the model for such a distributed system were presented in RFC 1366 "Guidelines for Management of IP Address Space" and the RFC 2050 "Internet Registry IP Allocation Guidelines". Under the RIR system and as defined by the RFC 2050, address space is distributed according to three goals:

- Conservation - Addresses are distributed fairly, according to the documented needs of end-users and Internet Service Providers.
- Routability - Addresses are distributed in a hierarchical manner allowing for routing scalability and aggregation.
- Registration - Addresses are documented in a public registry to ensure uniqueness.

RFC 2050 also defined the Internet Registry (IR) hierarchy into the following levels from the top down: IANA, RIRs, and Local IRs. Each RIR operates in a large continent-sized geographic region (Hubbard, Kosters, Conrad, Karrenberg, & Postel, 1996). The fire internet registries are: American Registry for Internet Numbers (ARIN) - serving North America, the Reseaux IP Europeans Network Coordination Centre (RIPE NCC) - serving Europe and western Asia, the Asia Pacific Network Information Centre (APNIC) - serving Asia and the Pacific region, the Latin America and Caribbean Network Information Centre (LACNIC) - serving Latin America and the Caribbean, and the African Network Information Center (AFRINIC) - serving Africa.

Under the Internet Registry (IR) system, the Internet Corporation for Assigned Names and Numbers (ICAAN) fulfills the IANA role of managing the top of the IP address and AS number allocation hierarchies. IANA's function is to allocate IP addresses from the pools of unallocated addresses to the RIRs according to their needs per ICANNs Global Addressing Policies (ICANN, 2014). On February 3rd, 2011, the Internet Addressing and Numbers Authority (IANA) assigned the last remaining five, /8 address blocks to each of the five RIRs officially exhausting the world's pool of global IPv4 (ARIN, 2011). While it is expected that some IPv4 addresses will be returned to IANA from organizations that no longer need them, IANA will place these addresses into a recovered IPv4 pool. These addresses will only be allocated to the RIRs once the RIR declares it has fewer than an /9 (i.e. 8.3 million addresses) remaining in its inventory (ICANN, 2012).

Immediately after receiving the final distribution of /8 blocks from IANA in 2011, each RIR enacted its own plan for managing their remaining IPv4 address pools. All but the AFRINIC are now operating under final /8 IPv4 depletion policies (see Table 2).

Table 2

Regional Internet Registry's (RIRs) IPv4 depletion policies. This table summarizes the IPv4 depletion policies, or "soft-landing" policies, of each of the five RIRs. The five RIRs are: the American Registry for Internet Numbers (ARIN), the Reseaux IP Europeans Network Coordination Centre (RIPE NCC), the Asia Pacific Network Information Centre (APNIC), the Latin America and Caribbean Network Information Centre (LACNIC), and the African Network Information Center (AFRINIC) - serving Africa.

| Registry | IPv4 Depletion Policies |
|---|---|
| APNIC | Reached final /8 on 15 April 2011. Operating under final /8 policy. Members (LIRs or XP) can obtain a maximum of a /22, which is1024 IPv4 addresses. This is a onetime allocation. Once a member has received a /22 delegation they will not be eligible for any additional IPv4 addresses from APNIC (APNIC, 2014a). |
| RIPE NCC | Reached final /8 on 14 September 2012. Operating under final /8 policy. Members (LIRs) can obtain a maximum of a /22, which is1024 IPv4 addresses. This is a onetime allocation. This allocation is only available if the member has also received and IPv6 allocation. Members receiving a /22 will not be eligible for additional IPv4 addresses from RIPNCC.<br>No new IPv4 Provider Independent (PI) space will be assigned (RIPENCC, 2014). |
| LACNIC | Reached final /10 June 2014.<br>Currently only assignments from /22 - /24 are made.<br>Phase 3 – begins when the reserved final /11 block is exhausted. Only /22 - /24 assignments will be made until this block is exhausted (LACNIC, 2014). |
| ARIN | Reached final /8 April 2014.<br>A /10 is reserved to facilitate IPv6 deployment.<br>All requests of any allocation is subject to team review (ARIN, 2011). |
| AFRINIC | Projected to reach final /8 in 2019.<br>Phase 1 – Maximum allocation reduced from /10 to /13<br>Phase 2 – begins when AFRINIC has no more than a /11 equivalent. Maximum allocation becomes /22<br>A /12 block will be reserved from the final /8 for unforeseen future use (AFRINIC, 2013). |

*The IPv6 Specification*

The Internet Engineering Task Force (IETF) began working to find a successor to IPv4 in late 1990. In 1993 the IETF formed the IP Next Generation (IPng) Area to begin reviewing various proposed solutions for the next generation IP protocol. Three finalist IPng proposals were evaluated by the IPng Area, which were the Common Architecture for the Internet (CATNIP), Simple Internet Protocol Plus (SIPP), and TCP/UDP Over CLNP-Addressed Networks (TUBA). Each proposal had merits and each proposal addressed the goals of the IETF; however, it was SIPP that was adopted as the IPng and was assigned the protocol version number 6 to become IPv6 (Bradner & Mankin, 1995).

IPv6 was designed as an evolutionary successor to IPv4. Features that worked well in IPv4 were retained and features that were inefficient, or used infrequently, were either removed or made optional in IPv6. The most obvious difference between the two protocols is the size of the addressing space. The 32-bit address field in IPv4 allows for 4.3 billion addresses while IP version 6 (IPv6) has a 128-bit address field allowing for 340 undecillion addresses. While both protocols are still IP and have many similarities, they are very different and are not backward compatible (Khan & Sindi, 2012).

The headers associated with the two protocols are distinctly different. IPv4 was designed with a variable length header consisting of 13 fields while IPv6 has a fixed length header of only 8 fields (Fig. 3). The fixed length of the IPv6 header permits greater routing efficiency and performance (Deering & Hinden, 1998).

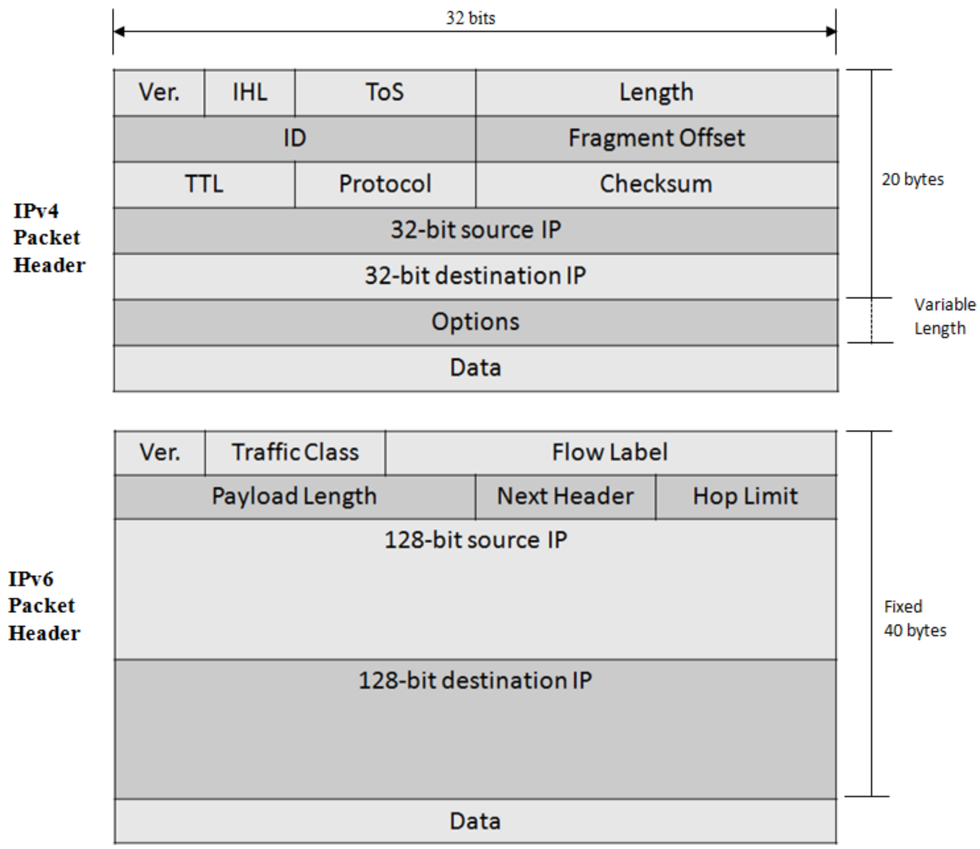


Figure 3. IPv6 and IPv4 headers comparisons. RFC 791 "Internet Protocol" defines the fields included in the IPv4 header and RFC 2460 "Internet Protocol, Version 6 (IPv6) specification" defines the fields included in the IPv6 header (Deering & Hinden, 1998; Postel, 1990).

The following seven fields in the IPv4 header were considered obsolete and were not retained for use in the IPv6 header (Hagen, 2006):

- IHL (Header Length) - Unlike IPv4, which has a variable length header, IPv6 has a fixed length header of 40 bytes. Since the length is fixed, a header length field is not required.
- Identification - Used to identify fragments of a fragmented datagram. With IPv6, fragmentation is only performed by the source of the packet and not by IPv6 headers, therefore, this field is removed from the header.

- Flags - Used to control whether routers are allowed to fragment a packet. With IPv6, fragmentation is only performed by the source of the packet and not by IPv6 headers, therefore, this field is removed from the header.
- Fragment Offset - Used to IP packet fragmentation. With IPv6, fragmentation is only performed by the source of the packet and not by IPv6 headers, therefore, this field is removed from the header.
- Header Checksum - Used to check the integrity of the packet header. In IPv4 this has to be performed at every hop due to Time to Live (TTL) value changes, which degrades router performance. To increase performance, this field and its function are removed from IPv6 and left to upper layer protocols.
- Options - A variable length field used as a placeholder for information relevant to how the data carried by the packet should be handled. This field is rarely used in IPv4, but if it is, the IPv4 header length will be greater than 20 bytes, which impacts router performance. This field is removed from IPv6 and its functionality is moved to IPv6 extension headers.
- Padding - Used to align the variable-length options field with the 32-bit boundary. Because the IPv6 header is a fixed 40-byte length, this field is not needed.

Four fields in the IPv4 header were retained; however, their position and names in the IPv6 header were changed (Hagen, 2006):

- Type of Service - Carries information enabling routers to classify and forward packets according to quality of services (QoS) policies. In the IPv6 header, this field is renamed Traffic Class.

- Total Length - Indicates the length in octets of the entire packet, header plus payload. In IPv4, this field is 16 bits so the maximum length of an IPv4 packet is 65,535 octets. In the IPv6 header, this field is renamed Payload Length to reflect the fact that it is only the payload length indicated, because the header length is always 40 bytes.
- TTL (Time to Live) - Used to count down the number of "hops" (routers) that switch the packet. The packet is discarded when the value reaches zero. In the IPv6 header, the name is more appropriately changed to Hop Limit.
- Protocol - Lists the upper layer protocol (TCP, UDP, ICMP, etc.) that is present in the packet payload. In the IPv6 header, this field is renamed Next Header and its function is expanded to indicate the information type that immediately follows the basic IPv6 header. This could be an upper-layer protocol or an extension header in the payload.

Three fields in the IPv4 header where retained in the IPv6 header along with their functionality (Hagen, 2006):

- Version - Indicates the IP protocol version. In the case of IPv4, the bit value of this field is set to 4. In IPv6, the bit value is set to 6.
- Source / Destination Address - The IP address (32-bits in IPv4 or 128-bits in IPv6 header) of the node that sourced the packet and of the packet destination.

There is one new field in the IPv6 header which is the Flow Label field. This field indicates a packet flow and is intended to enable routers to identify packets in a flow that should receive "special" treatment.

The engineers of IPv6 took the opportunity when designing the protocol to add new features and functionality based on the lessons of 30 years of experiences with IPv4 (Bradner, Mankin, 1995)The improvements made to IPv6 can be found in RFC 2460, "Internet Protocol, Version 6 (IPv6) Specification" (Deering & Hinden, 1998). These improvements include:

- Expanded addressing capabilities. The address fields in IPv6 are increased to 128-bits which will support many more addresses than IPv4 and makes the addressing space much more scalable. Additionally, the size and scalability of the multicast addressing space is greatly improved and a simpler mechanism for the auto-configuration of addresses through Stateless Address Auto Configuration (SLAAC) is added.
- Header format simplification. Unlike the IPv4 header which has a variable length, the IPv6 header has a fixed length of 40 bytes which allows for reduced router processing and bandwidth resources. Six fields that exist in the IPv4 header; Length (IHL), Identification, Flags, Fragment Offset, Header Checksum, and the Options and Padding, are removed from the IPv6 header, making the protocol more efficient.
- Flow labeling. This is a new capability added to IPv6 that was not part of IPv4. The flow label allows packets belonging to a specific traffic flow to be identified by routers for special handling. This new IPv6 field gives nodes the ability to identify packets that need non-default quality of service.
- Authentication and privacy capabilities. The IPv6 specifications mandate support for IPsec. Extension headers provide authentication, data integrity, and data confidentiality.
- Improved support for extensions and options. Optional information is moved from the main IP header to extension headers where it is only processed by nodes that need

the information. Flexibility is given for introducing new extension headers and in the future.

*IPv6 Adoption*

Although IPv6 has many technical improvements over IPv4, in the absence of a killer application that takes advantage of these improvements, the main driver for adoption of IPv6 becomes the exhaustion of IPv4 addresses. However, lack of any real perceived value of IPv6 means that organizations do not see IPv4 address exhaustion as a critical issue and are therefore reluctant to invest in IPv6 adoption. White, Shah, and Cook (2005) conducted a survey of ISP and non-ISP organizations in the United States to collect empirical data on the progress organizations are making in the area of IPv6 adoption. The results of the survey revealed that companies had not taken steps to upgrade their networks to support IPv6. Few companies, only about 7%, responding to the survey indicated making any progress towards deploying IPv6 services. More than half the respondents, 55%, indicated they did not know if IPv6 based services would benefit their company.

White et al. (2005) attributed organizational indifference to IPv6 to several factors. First, because of the huge investments made by companies in IPv4 infrastructure, the transition to IPv6 will require significant investments in learning, training and restructuring. Second, the shortage of IPv4 addresses has not had severe consequences due to the success of short-term solutions, such as NAT, CIDR, and DHCP. Finally, the decentralized nature of the Internet means that there is no set date in which all companies must migrate to IPv6. All of these factors add up to a "wait-and-see" approach by IT managers before committing to IPv6 adoption.

The findings of White et al. (2005) are similar to the later findings of Dell (2012) who surveyed 1000 of Australia's largest end-user organizations to determine their state of IPv6 adoption readiness. In Dell's study, more than 50% of the chief information officers (CIOs) responding to the survey indicated that their organizations had not begun any IPv6 planning. Furthermore, 52% did not believe that IPv6 was an urgent issue, due to sufficient IPv4 address space and irrelevance of IPv6 to their circumstances. Further analysis of the survey data showed that few organizations had made any progress in five areas identified by Grossettete (2008) as key to IPv6 readiness. These areas were: training, high-level planning, assessment of the current environment, policy frameworks, and IPv6 deployment (Dell, 2012).

The apparent widespread complacency among organizations is concerning, especially since the RIRs are already restricting their allocations of IPv4 addresses to Internet Service Providers (ISPs) and Local Internet Registries (LIRs) as part of their IPv4 depletion policies. This means that ISPs and LIRs, including wireless mobile providers and cable operators, are running out of IPv4 address space from which to make allocations. Once these pools are exhausted, the providers will only be able to offer customers native IPv6 service or non-native IPv4 services, such as Carrier Grade NAT (CGN). While CGN provides a temporary solution, it does not offer the network performance and reliability, and thus the user experience that native services provide. Companies conducting business in parts of the world that are more rapidly deploying IPv6, risk losing potential new customers and trading partners if they are using applications that do not work well through CGN. In addition, the CGN solutions provided by ISPs are becoming more complex to manage and troubleshoot and thus, the associated costs are passed down to the customers (Chittimaneni et al., 2013).

The exhaustion of IPv4 addresses has also become an issue for large organizations that use RFC 1918 private IPv4 addresses. IP based service, smart devices, mobile devices, and virtual machines are consuming vast numbers of IP addresses. Large service provider and enterprise organizations that must interconnect a significant numbers of devices are finding themselves constrained by the limited size of the private (RFC 1918) address space (Popoviciu & Dini, 2006). Comcast for example, exhausted its entire pool of private IPv4 addresses (i.e. ~17 million addresses) by 2005. A typical subscriber needs a Cable Modem (CM) and two or three Set-Top Boxes (STBs) each of which require 2 IP addresses. Having more than 23.3 million subscribers, Comcast consumes more than 116.5 million IP address. Comcast resolved the problem by migrating their device management network to IPv6. (Hovav & Popoviciu, 2009).

Facebook is another example of an organization which ran out of RFC 1918 addresses and has implemented an IPv6 solution. Facebook used private IPv4 addresses to assign a /24 subnet to each data center rack. This allowed for 254 addresses per rack; however, there are only 80 addresses needed per rack to meet equipment demands, so 174 addresses per rack were wasted. Addressing needs were such that even re-addressing their data center racks to /25 subnets would not provide sufficient addresses to meet the demand. The solution for Facebook was to deploy IPv6 and give each data center rack a /64 subnet (Saab, 2014).

The dilemma faced by Comcast and Facebook was the exhaustion of private IPv4 address space inside their organizations. The limitations of private IPv4 address space can also be an issue for smaller organizations that still have plenty of private IP addresses if they are part of mergers or acquisition. When organizations merge, there is a very high likelihood that their internal address space will overlap. This requires the organizations to undergo a readdressing of the network, the implementation of translation solution, or tunneling solutions between network resources (Chittimaneni et al., 2013).

Not only do organizations need to have an IPv6 strategy in place to address future growth but also to limit the exposure to unplanned IPv6 deployments. All modern operating systems have IPv6 enabled by default. This means that even IPv4-associated organizations have unplanned IPv6 traffic on parts of the network. This unplanned IPv6 traffic opens a second attack vector that internal or external attackers could leverage for illegitimate and malicious purposes. Additionally, many end operating systems come with automatic transition mechanisms that could cause internal hosts to become globally reachable over IPv6 (Gont, 2013). Existing Network Intrusion Detection Systems (NIDSs) may be able to detect attack patterns for IPv4 traffic, but might be incapable of detecting the same patterns for IPv6 traffic. Similarly, an organization's firewalls used to enforce IPv4 security policies may not be capable of enforcing the same policies on IPv6 traffic (Hagen, 2011).

As software vendor support for IPv6 increases, more applications will support IPv6 by default, and in the not too distant future, new applications can be expected to support IPv6 only. Organizations should prepare by ensuring the readiness of the network to securely and reliably support applications running over IPv6. For most organizations, deploying IPv6 will involve significant investment of time and resources, but, the longer organization delays, the more expensive the migration will become and the more risk it will involve. Waiting until the last minute to develop and IPv6 migration strategy, increases the likelihood that an organization will likely lose the opportunity to upgrade equipment during existing upgrade cycles and that migration take place reactively. RIPENCC (2013) warns that a poorly planned and rushed migration will increase the cost of IPv6 deployment significantly.

*Measuring IPv6 Adoption*

Alain Fiocco, Senior Director, and Head of IPv6 High Impact Program at Cisco Systems states that "Having clear metrics to measure on-going IPv6 adoption is the best way to foster deployment, monitor success and spot trouble areas, and in the end, make better business decisions" (Fiocco, 2012, par. 4). Getting the clear metrics on each phase of IPv6 adoption is what Fiocco and his team at the IPv6 High Impact Program have accomplished with 6Lab, a website that contains daily consolidated and updated statistics on IPv6 adoption. Publically available data and data compiled by special tools built by 6lab are used to analyze the IPv6 adoption data. The 6Lab program segments world IPv6 adoption into four phases: planning, core network, content, and users, and further presents metrics on the measurements for each phase (Fiocco, 2012).

- Planning - Measured by looking at the number of IPv6 prefix allocations from the RIRs and how many of these allocated prefixes show up in Internet routing tables. Planning is the first step in IPv6 adoption and one of the first steps in the plan should be to obtain and IPv6 prefix. By measuring the number of allocated IPv6 prefixes it is possible to get a leading indicator of future IPv6 deployments (Fig. 4).

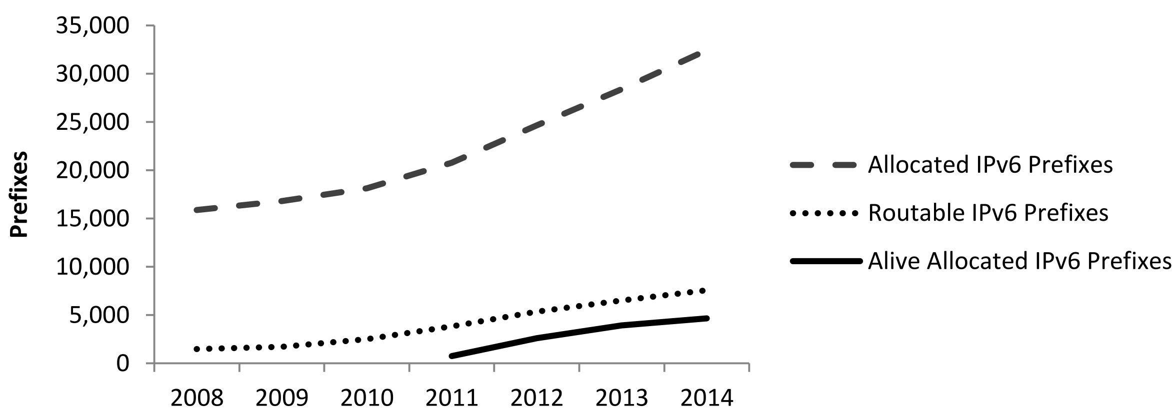


Figure 4. World IPv6 prefix allocation data (6lab, 2014). All three prefixes (Allocated IPv6 Prefixes – dashed line, Routable IPv6 Prefixes – dotted line, and Alive Allocated IPv6 Prefixes – solid line) exhibit an increasing trend.

- Core Network - Measured by looking at the percent of IPv6 transit Autonomous Systems (AS). This is accomplished by digging the BGP Routing Table and computing a weight and rank for each Autonomous System based on the number of times it show up in the AS path for all IPv4 and IPv6 prefixes. Currently, all Tier1 providers have enabled IPv6 transit service (6lab, 2014).

- Content - Measured by looking at the number of websites reachable over IPv6. 6Lab looks into the DNS system to find how many domain names have a bounded AAAA record and checks that the site is actually reachable over IPv6 by opening an HTTP session to the home page over IPv6. There are currently about 5,630 websites reachable over IPv6 versus 56,580 which are not, or about 10% (6lab, 2014).
- Users - Both Google (Google, 2014) and APNIC (APNIC, 2014b) measure and publish IPv6 end-user adoption on the web which are presented on the 6lab site. Google's IPv6 statistics sight measures and displays in graphical form the availability of IPv6 connectivity among Google users (Fig. 5).

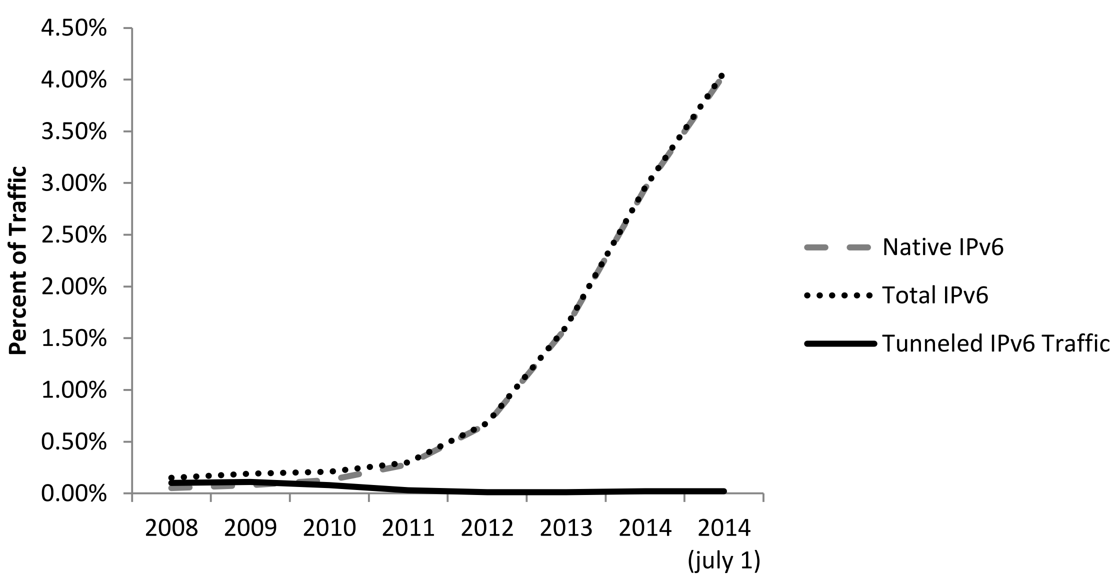


Figure 5. Percentage of users accessing Google over IPv6 (6lab, 2014). More specifically, represents the percentage of users that access Google over IPv6. Native IPv6 traffic is

represented by the dashed line, tunneled IPv6 traffic is represented by the solid line, and total IPv6 traffic is represented by the dotted line.

IPv6 deployment statistics are also maintained by the National Institute of Standards and Technology (NIST). NIST monitors the Domain Name System (DNS), Mail, and Web external core network services of private industry enterprises, federal government agencies, and universities in the United States for IPv6 deployment progress. The private industry domains monitored by NIST are from companies on the Fortune 1,000 list and on the Alexa (2014) list of top 100 sites in the US. The list is comprised of 1,070 companies. The NIST monitoring tool examined the IPv6 and IPv4 status of DNS, Mail, and Web services for each of the company domains on a daily or weekly basis (Fig. 6). Research illustrates that only (1%) of private industry domains have their services fully operational over IPv6. Those that had only one or two services operational are shown as in progress (37%), and those that have no services operational over IPv6 are shown as no progress (62%) (Fig. 6).

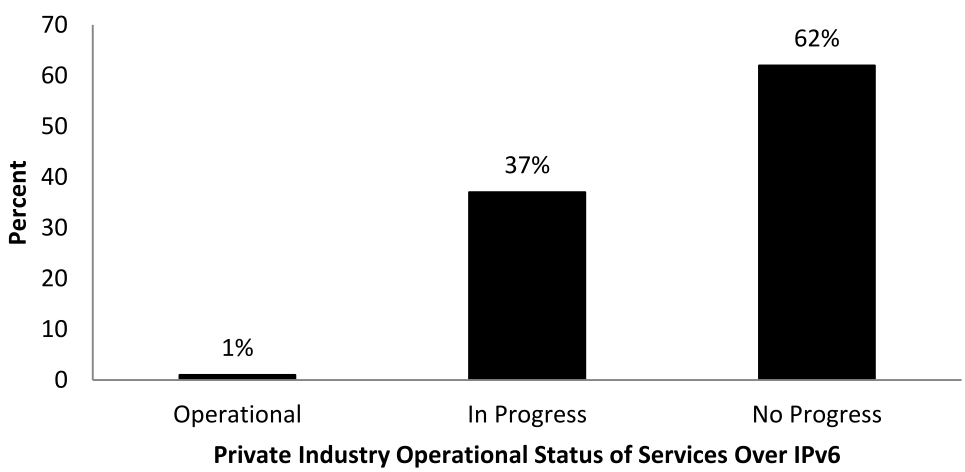


Figure 6. Industry IPv6 enabled domains as of July 26, 2014 (NIST, 2014). More specifically, this figure shows the percentage of private industry domains that have all three services (Domain Name System, Mail, and Web) operational over IPv6.

For US government agency IPv6 operational status, the test monitored 1,265 US government agency domains. Again, the NIST monitoring tool examined the IPv6 and IPv4 status of DNS, Mail, and Web services for each agency on a daily or weekly basis (Fig. 7). Research demonstrates that the percentage of domains that have all three services (DNS, Mail, Web) operational over IPv6 is 34%, those that have only one or two services operational is 42%, and that those that have made no progress is 24% (Fig. 7).

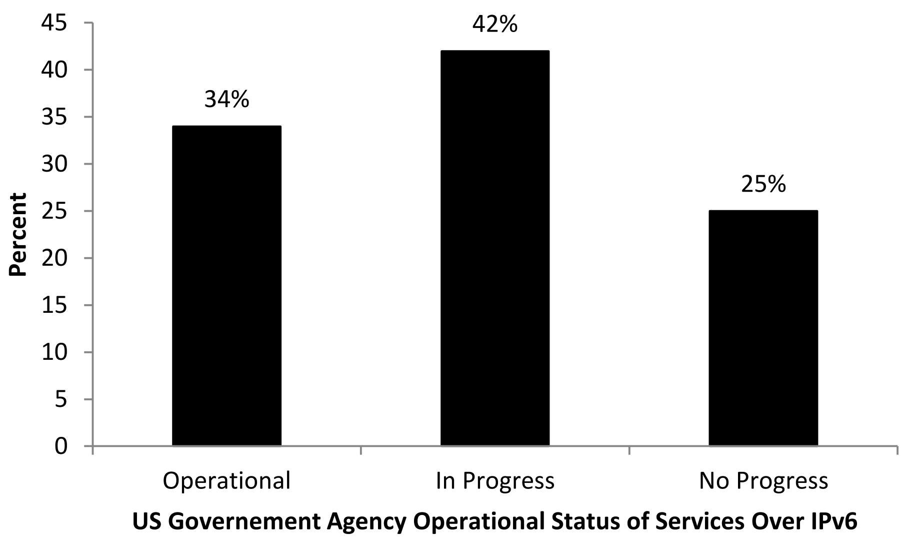


Figure 7. US Government IPv6 enabled domains as of July 26, 2014 (NIST, 2014).

To measure university domain operational status a total of 346 university domains were monitored by NIST. The list of universities came from the NCAA member's web site. Of the universities surveyed, those that have all three services (DNS, Mail, and Web) operational over IPv6 is 1%, those in progress is 16% and those that have made no progress is 83% (Fig. 8).

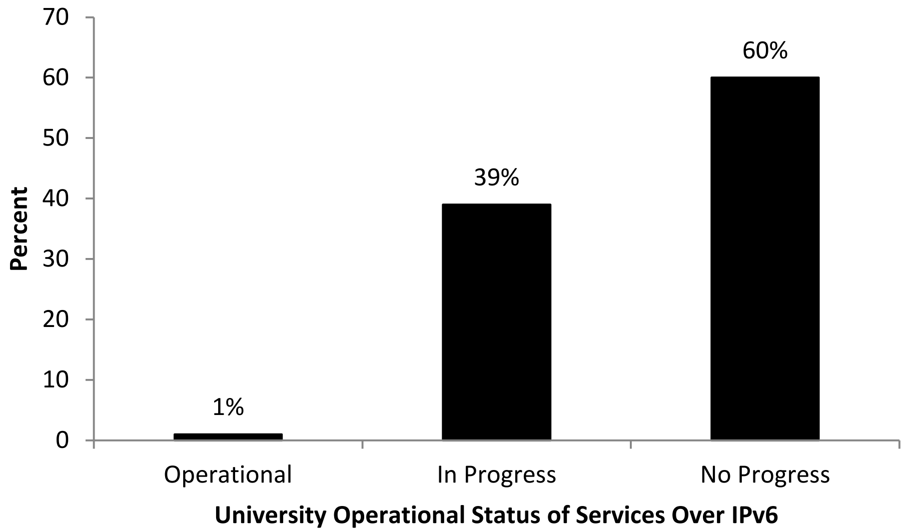


Figure 8. University IPv6 enabled domains as of July 26, 2014 (NIST, 2014).

## Innovation Adoption Theories

Hameed, Counsell, and Swift (2012) define an innovation as “an idea, a product, a program or a technology that is new to the adoption unit” (p. 1). Since IT is considered a form of technological innovation, theories of technological innovation can also be applied to studies of IT adoption. A review of the literature revealed numerous theories, frameworks, and models that attempt to explain innovation adoption at both the individual unit and the organizational unit.

No single or definitive theory of adoption was found to fully explain the process of innovation adoption for all technologies and units of adoption (Fichman, 1999; Oliveira & Martins, 2011). A review and comparison of widely applied innovation adoption models was conducted by Oliveira and Martins (2011) and Hameed et al. (2012). Both studies found the Diffusion of Innovation theory and the Technological, Organizational, and Environmental framework as the most widely used in the literature of organizational IT adoption.

In an effort to develop a conceptual model for organizational IT innovation adoption processes, Hameed et al. (2012) conducted a literature review of 151 published studies of technology adoption and identified the most common theoretical models used for technology adoption analysis as: Diffusion of Innovation (DOI) (Rogers, 1983), Technology Acceptance Model (TAM) ( Davis, 1989), Theory of Planned Behavior (TPB) (Ajzen, 1991), Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), the Technological, Organizational, Environmental (TOE) framework (Tornatzky & Fleischer, 1990) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Gordon, & Davis, 2003). e DOI was found mostly in studies focusing on organizational adoption, while studies using TRA, TAM, and TPB focused on the individual level. The TOE framework was used in the greatest number of studies involving organizational level analysis (Hameed et al., 2012; Table 3).

Table 3

Widely used theories in the innovation adoption literature.

| Theory/Model | Number of Studies | |
|---|---|---|
| | Organizational Level | Individual Level |
| Diffusion of Innovation (DOI) | 28 | 3 |
| Theory of Reasoned Action (TRA) | 5 | 14 |
| Technology Acceptance Model (TAM) | 11 | 26 |
| Theory of Planned Behavior (TPB) | 4 | 12 |
| Technology Organization Environmental (TOE) | 35 | 0 |
| Unified Theory of Acceptance and Use of Technology (UTAUT) | 0 | 1 |

*Theory of Reasoned Action*

The Theory of Reasoned Action (TRA; Fig. 9) was one of the first theories to explain user acceptance behavior (Hameed et al., 2012; Venkatesh et al., 2003). The TRA proposes that the behavior of an individual is determined by their intention to perform the behavior which is in turn determined jointly by their attitude toward the behavior and their subjective norm concerning the behavior. The person's attitude is determined by their beliefs about the results of performing the behavior and the evaluation of those results. The person's subjective norm is their perception of social pressure for them to perform the behavior (Ajzen & Fishbein, 1975).

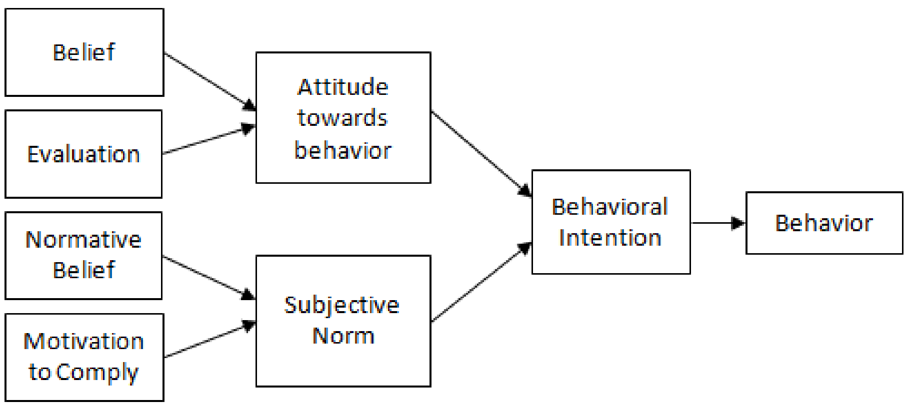


Figure 9. Theory of Reasoned Action (Fishbein & Ajzen, 1975).

*Technology Acceptance Model*

The Technology Acceptance Model (TAM; Fig. 10) is an adaptation of the TRA by Davis, Jr. (1986) to explain computer usage behavior by end-users. TAM was specifically designed as a model of user acceptance of information systems but has since been applied to a wide range of technologies (Venkatesh et al., 2003). The TAM uses two constructs, perceived usefulness (U) and perceived ease of use (E), as the determinants of user acceptance of a new technology (Fig. 11). Perceived usefulness is defined as the degree to which a person believes a particular system would enhance his or her job performance within an organization and perceived ease of use is defined as the degree to which a person believes that using a particular technology is free of effort. Although Davis, Jr. (1986) developed the TAM to explain technology adoption of end-users within organizations, other studies have confirmed that the

TAM model can successfully explain technology adoption behavior of organizations (Hernández, Jiménez, & Martín, 2008; Yu & Tao, 2009). For example, Hernández et al. (2008) used the TAM to analyze the acceptance of business management software (CRM, financial accounting, and budgeting) of the firm's technology decision-makers. The study concluded that the TAM can be applied to decision-makers to adequately explain the acceptance of business management software by an organization. Yu and Tao (2009) extended the TAM to explain business-level innovation technology adoption of electronic marketplace technology by Taiwanese firms. Their study also concluded that the TAM can be used successfully to explain the adoption of new technology by organizations. While both studies support using the TAM at the organizational decision-maker level, both studies focused on a single technology and caution making generalizations to other technologies.

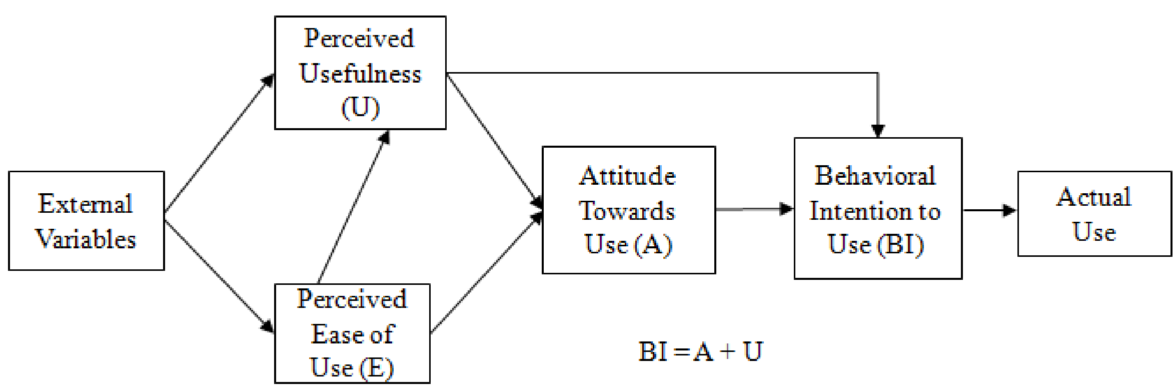


Figure 10. Technology Acceptance Model (F. D. Davis, Bagozzi, & Warshaw, 1989).

*Theory of Planned Behavior*

Ajzen (1991) extended the TRA in the Theory of Planned Behavior (TPB; Fig. 11) by adding an additional variable called Perceived Behavioral Control (PBC) that affects the intention to perform a behavior (Hameed et al., 2012). The construct of Perceived Behavioral

Control represents a person's actual control over performing, or not performing, a behavior due to availability of opportunities and resources (Ajzen, 1991).

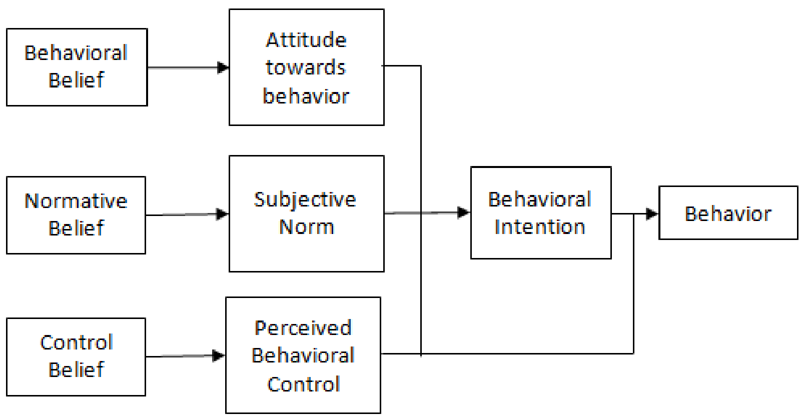


Figure 11. Theory of Planned Behavior (Ajzen, 1991).

*Unified Theory of Acceptance and Usage of Technology*

The Unified Theory of Acceptance and Usage of Technology (UTAUT; Fig. 12) integrates the elements from eight prominent adoption models: the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Motivational Model (MM), the Theory of Planned Behavior (TPB), the Combined TAM and TPB (TAM-TPB), the Model of PC Utilization (MPCU), the Diffusion of Innovation Theory (DOI), and the Social Cognitive Theory (SCT) (Venkatesh et al., 2003). From the eight theoretical models, four core determinants of technology acceptance and usage were found to be significant: (1) performance expectancy is the degree to which an individual believes that using the system improves job performance, (2) effort expectancy is the ease of use associated with the technology, (3) social influence is to what degree the user believes they should use the system, and (4) facilitating conditions are levels of support and infrastructure the individual perceives to be available to support the technology (Venkatesh et al., 2003).

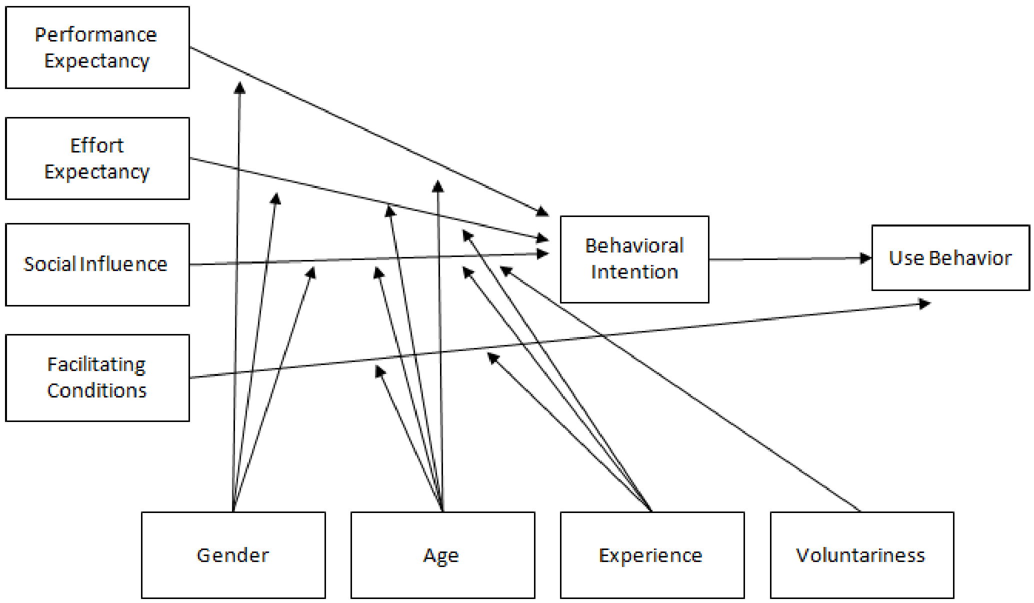


Figure 12. Unified Theory of Acceptance and Usage of Technology (Venkatesh et al., 2003).

*Diffusion of Innovation*

Diffusion of Innovation (DOI) theory was introduced by Rogers (1983) and is one of the most widely used models for the study of innovation adoption (Pervan, Bajwa, & Lewis, 2005). Rogers (2003) defined diffusion as "the process by which an innovation is communicated through certain channels over a period of time among members of a social system". Furthermore, the four main elements of diffusion are: (1) the innovation, (2) communication channels, (3) time, and (4) a social system (Rogers, 2003).

The first element of diffusion is the innovation itself. According DOI theory, there are five perceived attributes of an innovation which play a central role in shaping the attitude of potential adopters towards adopting the innovation. These are the innovation's perceived relative advantage, compatibility, complexity, trialability and observability (Rogers, 2003; Table 4).

Table 4

Rogers' innovation attributes.

| Innovation Attribute | Definition | Effect on Adoption Attitude and Rate |
|---|---|---|
| Relative Advantage | The degree to which an innovation is perceived to be better than its predecessor. Rogers notes that the level of "objective" advantage is not as important as the level of perceived advantage. | Positive |
| Compatibility | The degree to which an innovation is perceived as being with existing values, experiences, and needs. An incompatible innovation will not be adopted as readily. | Positive |
| Complexity | The degree to which an innovation is perceived as difficult to understand. Innovations that are simpler to understand are adopted faster than those that require learning new skills. | Negative |
| Trialability | The degree to which an innovation can be used on a trial or limited basis. An innovation that can be sampled "experimentally" is likely to be adopted more quickly. | Positive |
| Observability | The degree to which an innovation is visible to others. Innovations are more likely to be adopted if their results are easily observed. | Positive |

The second element of diffusion is communication channels. According to Rogers (2003), "diffusion is a very social process that involves communication of a new idea or innovation to others over a communication channel". Studies have shown that most individuals do not evaluate innovations based on objective analysis but rather on the subjective evaluations of other individuals who have already adopted the innovation. This leads to modeling and imitation by potential adopters of those in the social system that have previously adopted (Rogers, 2003).

The third element of diffusion is time. Rogers (2003) proposed that the time dimension impacts the diffusion process in three ways: (1) the innovation-decision process in which the potential adopter moves from first knowledge of an innovation to a decision to adopt or reject the innovation, (2) the innovativeness of the potential adopter which is the degree that a potential adopter is earlier in adopting new ideas compared to other potential adopters in a system, and (3) the rate of adoption which is the time required for a certain percentage of members of a system (Rogers, 2003).

A social system is the fourth element of diffusion. The social system is defined by Rogers (2003) as "the set of interrelated units that are engaged in joint problem solving to accomplish a common goal". The units that make a social system can be individuals, organizations, or groups. Diffusion of the innovation or new technology will take place within the boundaries of the social system. According to Rogers (2003), there are several factors that have influence on the diffusion process, which include the structure of the social system, its norms, the influence of its opinion leaders, the type of innovation decisions that are made, and the consequences of the innovation.

Although DOI is widely used in technology adoption studies, the model focuses primarily on the technology adoption behaviors of individuals rather than those of organizations (Lee & Cheung, 2004). When used for organizational adoption behaviors, DOI has several limitations. First, the model does not account for the influence of organizational and environmental factors and therefore, does not fully explain the technology adoption within organizations. Secondly DOI does not address whether the innovation is put into use by the adopter (Brancheau & Wetherbe, 1990; Fichman & Kemerer, 1997; Hameed et al., 2012; Lee & Cheung, 2004).

*Technological-Organizational-Environmental framework*

The Technological-Organizational-Environmental (TOE) framework proposed by Tornatzky and Fleischer (1990) is a frequently used theoretical model for examining technology adoption in organizations and provides three contexts that influence an organization's decision to adopt a new technology; technological factors, organizational factors, and environmental factors (Hameed et al., 2012; Henderson, Sheetz, & Trinkle, 2012; Fig. 13). The technological factors context includes technologies that are relevant to the firm. These can be internal or external to the organization and can also be existing or emerging technologies (Wang et al., 2010). The organizational factors context includes the organization's size, management structure, top management support, technology competence, and the availability and quality of human resources (Tweel, 2012; Wang et al., 2010). Environmental factors context includes the organization's industry, its competitors, access to resources, and trading partners (Tweel, 2012). Figure 13 shows the technological-organizational-environmental framework proposed by Tornatzky and Fleischer (1990).

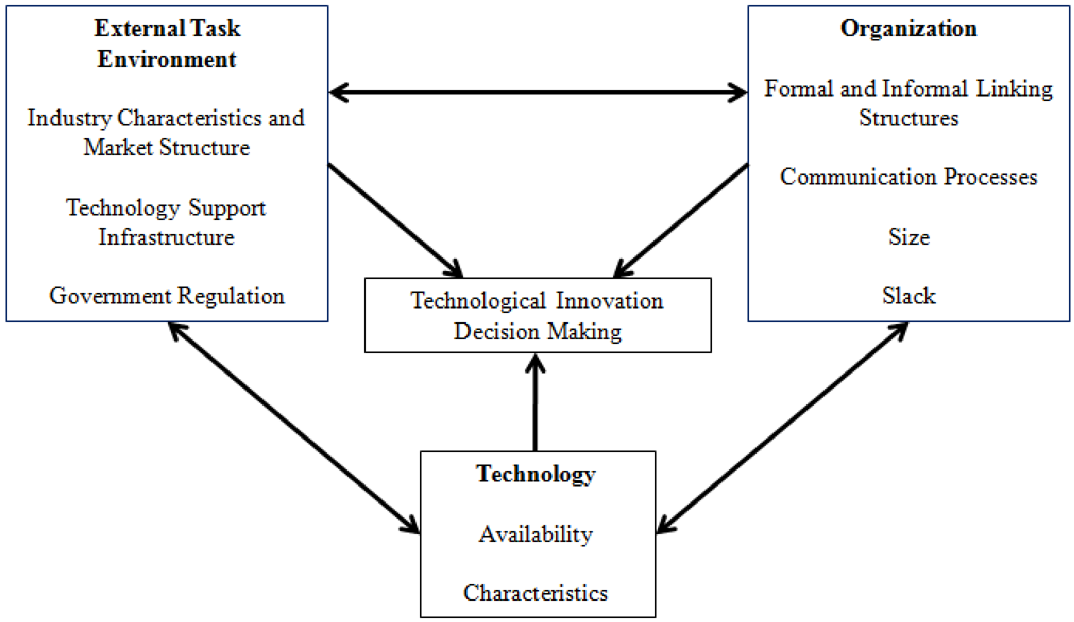


Figure 13. The technological-organizational-environmental (TOE) framework (Tornatzky & Fleischer, 1990).

*Internet Standards Adoption (ISA) model*

The Internet Standards Adoption (ISA) model combines features of innovation with economics of adoption to examine and predict adoption of new Internet standards (Hovav, Patnayakuni, & Schuff, 2004). The ISA model combines adoption factors into two contexts, which are usefulness of features and conduciveness of the environment. The factors within the usefulness of features context are adopted from DOI theory and include relative advantage, compatibility, complexity, trialability, and observability (Hovav et al., 2004; Rogers, 1983). Relative advantage is the competitive advantage offered by a new standard over the existing technology in creating new opportunities, new markets, and products and services for early adopters. Compatibility is the amount of backward compatibility the new standard has with existing technologies and infrastructure. Complexity is the amount of effort required to implement the new standard and can negatively impact the number of adopters. Trialability is the measure of the ability of an adopter to verify and quantify the benefits of a new standard.

Observability is the organization's ability to observe the benefits of adoption of the new technology (Hovav et al., 2004; Rogers, 1983).

In an empirical study that focused on the factors that influence an ISPs decisions to adopt IPv6, Hovav, Patnayakuni, and Schuff (2001) proposed that adoption is influenced by factors from two theoretical perspectives on innovation diffusion: (1) traditional diffusion theory and (2) economic theory. In the perspective of the traditional diffusion theory, Hovav et al. (2001) included the five innovation characteristics as defined by Rogers (1983) that influence innovation adoption: relative advantage, compatibility, complexity, trialability and observability. In the economic theory of diffusion, the adoption of the innovation is dependent on the economic returns and benefits of adoption and the expectation that adoption will reach a point of critical mass, such as positive network externalities, economies of scale, and prior technology drag. . Hovav et al. (2001) further proposed that the identified adoption factors can influence the time it takes an organization to adopt IPv6. Potential adopters are categorized into four categories, similar to those proposed by (Rogers, 1983), based on how early they adopt the innovation: (1) leaders, (2) initial adopters, (3) late adopters, and (4) laggards. Each category of adopter is influenced to a greater or lesser extent by each of the adoption factors. (Hovav et al., 2001).

Hovav et al. (2004) expanded on their study of IPv6 adoption by introducing an integrative model of internet standards adoption (ISA) which combined diffusion of innovation theory and economics of adoption. The model proposes that adoption of Internet standards (e.g. IPv6) is dependent on the usefulness of the features (UF) provided by the standard and the conduciveness of the environment (EC) to the adoption of the standard. Their ISA model also takes into account the concept of partial adoption where both standards co-exist for a period of time. The model proposes four modalities of adoption (Table 5):

1. Status quo - Non-adoption of the new standard.
2. Replacement - Adoption of the new standard through replacement. In this partial mode of adoption, the new standard is deployed in the organization as a replacement of the old standard; however, its new features are not fully utilized. Therefore, the new standard is used in the same manner as the old standard.
3. Co-existence - Adoption of the new standard through coexistence. In this second possible partial mode of adoption, the new standard is deployed alongside the old standard and the two coexist within the organization. In this type of situation the new features of the new standard are utilized to serve niche markets.
4. Full implementation - Full adoption of the new standard.

Table 5

Modes of adoption in ISA model (Hovav et al., 2004). Each quadrant corresponds to the level of perceived usefulness of features and the conduciveness of the environment. Potential adopters are placed into one of the four quadrants based on the adoption stage of the organization beginning in quadrant I, status-quo, and moving towards quadrant IV, full implementation, along either the path through quadrant II or quadrant III.

| | | Conduciveness of environment to adoption of the new standard (EC) | |
|---|---|---|---|
| | | Low | High |
| Usefulness/need of features of the new standard (UF) | Low | I. Status quo<br><br>*Unlikely to adopt* | III. Replacement<br><br>*Implement new standard but without taking advantage of new features – use same as old standard* |
| | High | II. Co-existence<br><br>*Implement new standard and take advantage of some of the new features. Support both standards while in transition* | IV. Full implementation<br><br>*Implement new standard with all the new features* |

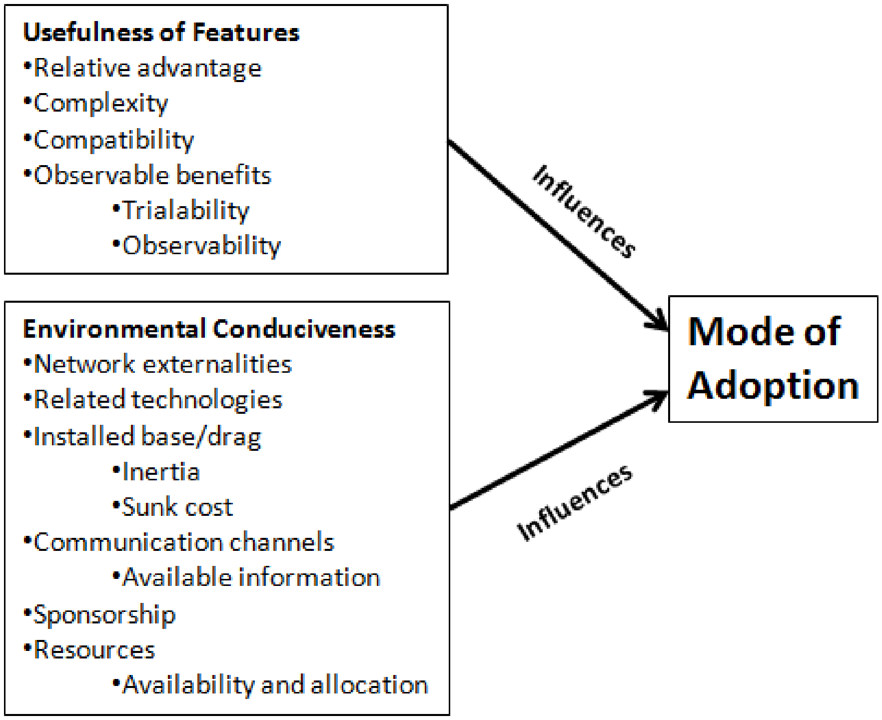


Figure 14. Internet Standards Adoption (ISA) model (Hovav et al., 2004).

The ISA model, as proposed by Hovav et al. (2004; Fig. 14), illustrates how both the usefulness of features and environmental conduciveness influences the mode of adoption. The factors within the environmental conduciveness context include: network externalities, related technologies, the current standard's installed base (sunk costs), communication channels, and government and private sponsorship. Network externalities are effects of the adoption of a standard by other organizations. If there is widespread adoption of a standard by other organizations then network effects can lead to reduced cost and risk, and increased opportunities for interactions (Hovav et al., 2004). Technologies that are related can promote adoption by creating a foundation of products and services that are compatible. The installed base is a measure of the current standard's infrastructure. A large installed base can have a negative effect on adoption due to the associated high sunk costs and inertia. Communication channels refer to the voluntary flow of information between existing and potential adopters and can create a positive environment for the diffusion of the standard. Finally, sponsorship can refer to government or private support of the new standard. This can be through government mandates or tax incentives and private consortia, monetary incentives, and the development of transition technologies (Hovav et al., 2004).

From their analysis, Hovav et al. (2004) concluded that DoI theory is insufficient to explain the adoption of Internet standards, and that economic theory must also be applied to fully understand adoption. Additionally, adoption is not a dichotomous event, rather there are modes of partial adoption which are dependent on the perceived levels of feature usefulness and the environmental conduciveness. An unexpected study finding was that geographic boundaries have an influence on the adoption of Internet standards by ISPs. Because the Internet is decentralized, the adoption of Internet standards may rely on government or private sponsorship and on the availability of resources. In the context of IPv6, geographic boundaries are influential for the following reasons: (1) In many countries the ISPs are owned or tightly controlled by governmental telecommunications agencies. (2) Governments that view the Internet as a tool for achieving economic and strategic advantage tend to fund projects that support IPv6 adoption, (3) Because the Internet originated in North America and Western Europe, most IPv4 addresses are allocated in these regions thus leaving other regions no alternative but to move to IPv6, and (4) ISPs in North America and Europe tend to have heavy IPv4 investments and sunk costs creating more drag and inertia to adoption.

Hovav et al. (2004) applied the ISA model to IPv6 adoption in a theoretical study indicating that future empirical research would be required to determine the level of significance of each of the factors on IPv6 adoption.

## Institutional Theory

Institutional theory attempts to explain the process of institutional isomorphic change that causes organizations sharing the same environmental conditions to adopt similar structures and processes (Braunscheidel, Hamister, Suresh, & Star, 2011). According to Scott and Christensen (as cited by Oliveira & Martins, 2011), "institutional environments are crucial in shaping organizational structure and actions" and "organization are in part driven by social and cultural factors and concerns for legitimacy" (p. 7). Oliveira and Martins (2011) go on to posit that "Organizations in the same industry environment tend to become homologous over time as competitive and customer pressures motivate them to copy industry leaders" (p. 7). These external isomorphic pressures on organizations come from many sources, which include customers, trading partners, competitors, governments, and professional organizations (DiMaggio & Powell, 1983; Oliveira & Martins, 2011).

In their study of institutional isomorphism, DiMaggio and Powell (1983) identify three factors attributed to institutional isomorphic change: 1) coercive pressure, 2) mimetic pressure, and 3) normative pressure. The first factor, coercive pressure is defined as the formal or informal pressures exerted on an organization by either other organizations on which it is dependent or by cultural expectations of society (DiMaggio & Powell, 1983). The sources of coercive pressures on an organization include customer or trading partner requirements, contracts, government mandates, and in some cases it can originate from the parent corporation (Basaglia et al., 2009; DiMaggio & Powell, 1983). The second factor, mimetic pressure, can influence an organization to change over time to become more similar to other organizations operating in the same industry or environment (DiMaggio & Powell, 1983). According to Haveman (as cited by Teo, Wei, & Benbasat, 2003), mimetic pressures manifest themselves in two ways, one is "the prevalence of a practice in an organization's industry and the other is the "perceived success of organizations within the organization's industry that have adopted the practice" (p. 21). The third factor of isomorphic pressure is normative pressure which, according to DiMaggio and Powell (1983), is heavily influenced by professionalism. Professionalism is defined as "the collective struggle of members of an occupation to define the conditions and methods of their work" (DiMaggio and Powell, 1983, p. 6). According to DiMaggio and Powel (1983), the normative forces of professionalism stem from two principal sources. This first source is universities and professional training centers that impart the same knowledge and organizational norms on the professional managers of the range of organizations. The second source is the professional trade associations that define and promulgate normative rules about organizational behavior. As a result, organizational behavior with respect to IT adoption is significantly influenced by the shared norms and values disseminated through an organization's relationship with other organizations and with professional organizations (Henderson et al., 2012; King et al., 1994).

## Innovation Assimilation and the Innovation-Decision Process

Technology innovations are not adopted instantly by organizations but rather they are assimilated into an organization by passing through the phases of an innovation-decision process (Meyer & Goes, 1988). The innovation-decision process is the actual process by which innovation adoption decisions are made. Many studies have attempted to describe this process, in which individuals and organizations initially learn about and ultimately decide to adopt or reject an innovation, through the use of distinct stages. These stages make up a progression of decisions and behaviors by the potential adopter that moves it closer to a final adoption decision (Ettlie, 1980).

*The Innovation-Decision Process*

Rogers (2003) states that adoption of an innovation is not an "instantaneous act", but is rather "a process that occurs over time". Rogers (2003) called this process the "innovation-decision process" in which decision makers go through the steps from learning of an innovation, making a decision to adopt or reject the innovation, and finally confirming that decision (Fig. 15).

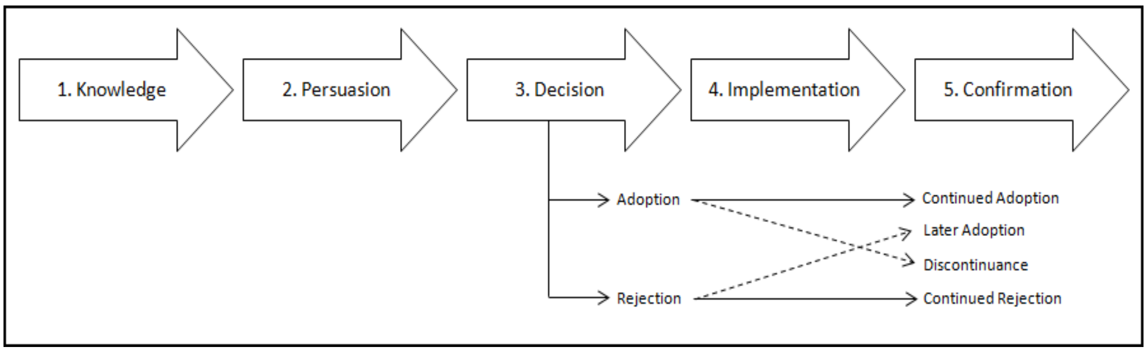


Figure 15. Model of five stages in the innovation-decision process (Rogers, 2003).

During the innovation-decision process, potential adopters are seeking and processing information in order to decrease uncertainty about the innovation and understand its advantages and disadvantages for their particular circumstance. The process will lead a potential adopter to the decision to adopt (e.g. make full use of) or to not adopt (e.g. reject) the innovation. This decision is not final and can be reversed through a later adoption or rejection decision in the final confirmation stage. The five stages proposed by Rogers (2003) are:

1. Knowledge - In this stage the potential adopter becomes aware of the innovation and gains some level of knowledge on how to use it and how it works. Having knowledge of the innovation does not guarantee that it will become adopted. A potential adopter who does not believe the innovation to be relevant to their need or

who has inadequate (or inaccurate) knowledge of the innovation may not progress further in the decision process.

2. Persuasion - It is in the persuasion stage that a potential adopter develops a favorable or unfavorable attitude toward an innovation. In this stage the potential adopter will actively seek to learn more information about the innovation in order to better understand potential consequences of adopting the innovation, as well as, its advantages and disadvantages.
3. Decision - In the decision stage, a potential adopter makes the choice to adopt or reject the innovation. The innovation may be tested or deployed in a trial basis, perhaps in an isolated test environment during this stage.
4. Implementation - In the implementation stage, the innovation actually gets deployed and used. This phase may span a long period of time. During implementation, the innovation often is changed or modified by the adopter. Over time, most innovations tend to eventually become "institutionalized" and are no longer considered new. Institutionalization marks the end of the implementation phase and in many cases, also the end of the decision process.
5. Confirmation - In some cases there is a confirmation stage. In the confirmation stage, an adopter continues to seek feedback that supports the innovation decision that was made the previous stages. This feedback can either support the decision or cause the adopter to reverse the decision.

The amount required to progress through the five stage innovation-decision process is known as the innovation-decision period and varies with potential adopters. Rogers (2003) argued that the innovativeness of a potential adapter is a relative measure of how rapidly the individual or organization adopts new ideas compared to other members of the same social system. Rogers (2003) placed potential adopters of a social system into five categories on the basis of their innovativeness; innovators, early adopters, early majority, late majority and laggards (Fig. 16).

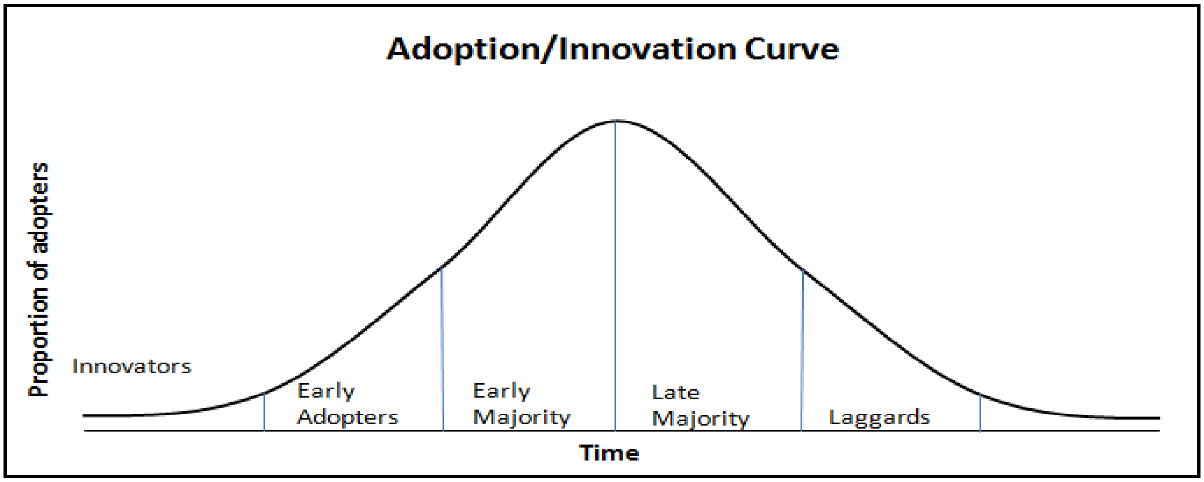


Figure 16. Adoption and Innovation Curve (Rogers, 1983).

Ettlie (1980) adapted Rogers' five stage model with slight modifications to investigate the process by which decisions on innovation adoption are made within organizations. Ettlie (1980) proposed a six stage model: (1) awareness - the adopter is aware of the innovation, but does not yet have enough information to make an adoption decision; (2) interest - the adopter is interested in the innovation and begins to actively seek out information; (3) evaluation - the advantages and disadvantages of adopting the innovation by the organization are weighed and considered; (4) trial - the innovation is tested on a limited basis to better understand its potential usefulness if fully adopted; (5) adoption - results from the trial phase are considered to determine if the innovation should be full adopted; and (6) implementation - in the final phase the innovation is fully adopted.

To test the model, Ettlie (1980) investigated 34 innovations at six transportation firms that were each known for their innovativeness. Ettlie (1980) had the respondents from each firm identify the current innovation-decision stage of each innovation and then indicate if the sequence of the stages were truly representative to the actual decision making process that took place in the firm. The findings from the study demonstrated that the proposed six stage model accurately represented the actual decision making process in 61.8% of the cases. In the remaining cases, the primary deviation from the actual decision making process was the absence of a trial stage. This absence was due to the fact that some innovations do not lend themselves well to limited test or trial deployments. Ettlie (1980) concluded that "it is surprising how well the six-stage model describes the innovation and decision-making process in these six firms" (p. 994).

Fichman and Kemerer (1997) adapted Ettlie's six stage model for a study assessing the assimilation of Software Process Innovations (SPIs) in 608 medium to large size U.S enterprises. For the study, Fichman and Kemerer (1997) made two changes to Ettlie's six stages. First, the "*evaluation*" and "*trial*" stages were combined into a single third stage (evaluation/trial) because, it was suggested that these two stages typically occur simultaneously. Second, the stage of "*implementation*" was divided into two separate stages which were limited deployment and general deployment, since some innovations may be deployed in only a limited manner.

Table 6

Six stage model of assimilation and Guttman scale as employed in Fichman and Kemerer (1997).

| Stage | Criteria to Enter the Stage |
|---|---|
| 0. Awareness | Key decision makers are aware of Software Process Innovations (SPIs) |
| 1. Interest | The organization is committed to learning more about SPI |
| 2. Evaluation/Trial | The organization has acquired specific innovation related products and has initiated an evaluation or trial of SPI |
| 3. Commitment | The organization has committed to SPI in a significant way for one or more production projects |
| 4. Limited Deployment | The organization has established a regular, but limited use of SPI |
| 5. General Deployment | The organization has reached a state where SPI is used in a substantial way – at least one mission critical system |

Fichman and Kemerer (1997) also accounted for the rejection and discontinuance of an innovation by an organization in their model. They posit that an organization may evaluate an innovation, such as SPI, and decide to reject it. In such a case, the innovation may never reach the later stages of commitment and deployment. An organization might also have been committed to using an innovation in the past but has discontinued using it and has no plans to use it in the future (Fichman & Kemerer, 1997; Table 7).

Table 7

Rejection and discontinuance of an innovation (Fichman & Kemerer, 1997).

| Category | Criteria |
|---|---|
| Rejection | The organization has evaluated and rejected the Software Process Innovation (SPI) |
| Discontinuance | The organization was committed to using SPI in the past but is not using it currently and has no plans to use it in the future |

In the results of their study, Fichman and Kemerer (1997) confirmed the value of using assimilation stages to measure the innovativeness of organizations in adopting innovations – especially the technological innovations that are not yet widely adopted.

Another study often cited in the innovation-decision and assimilation literature is that of Meyer and Goes (1988), who examined the assimilation of medical innovations in community hospitals. Meyer and Goes (1988) adapted the prior frameworks of previous studies (Ettlie & Vellenga, 1979; Rogers, 1983; Zaltman, Duncan, & Holbek, 1973) into a decision-stage model that included three primary decision-making stages and nine sub-stages. The researchers then used a nine-point Guttman scale to operationalize the decision making stages to serve as the dependent variable in the study (Table 8).

Table 8

Decision-making stages in the assimilation of medical innovations (Meyer & Goes, 1988).

| Stage / Sub-stage | Description |
|---|---|
| Knowledge-Awareness Stage | |
| 1. Apprehension | Individual organization members learn of an innovation's existence |
| 2. Consideration | Individuals consider the innovation's suitability for their organization |
| 3. Discussion | Individuals engage in conversations concerning adoption |
| Evaluation-Choice Stage | |
| 4. Acquisition proposal | Adoption of equipment embodying the innovation is proposed formally |
| 5. Medical-fiscal evaluation | The proposed investment is evaluated according to medical and financial criteria |
| 6. Political-strategic evaluation | The proposed investment is evaluated according to political and strategic criteria |
| Adoption-Implementation Stage | |
| 7. Trial | The equipment is purchased but still under trial evaluation |
| 8. Acceptance | The equipment becomes well accepted and frequently used |
| 9. Expansion | The equipment is expanded, upgraded, or replaced with a second-generation model |

The aforementioned model was demonstrated to give reasonably good predictions of the extent a hospital will assimilate an innovation (Meyer & Goes, 1988).

## Addressing a Gap in the Literature

Despite the critical nature of the IPv4 address exhaustion and the lack of significant progress in IPv6 adoption, there is surprisingly little literature available on the adoption readiness of enterprise organizations. Most of the extant studies in the IPv6 adoption literature are conceptual and theoretical in nature, conducting analysis at the Internet service provider level, or making inferences to IPv6 adoption rates through the use of Internet traffic analysis. More empirical research is required to understand the IPv6 readiness of organizations. Furthermore, research is required to identify the technology adoption factors that are associated with organizations that have, and have not, made any IPv6 preparations.

While many technology innovation adoption studies exist which combine diffusion of innovation theory and the TOE framework with other theories to examine a broader range of factors (Fig. 17), it is uncertain if any studies combine these models to study the IPv6 readiness of organizations. According to the empirical findings of Wang et al. (2010), the TOE framework "provides a good starting point for analyzing and considering suitable factors that can influence business innovation-adoption decisions" (p. 813).

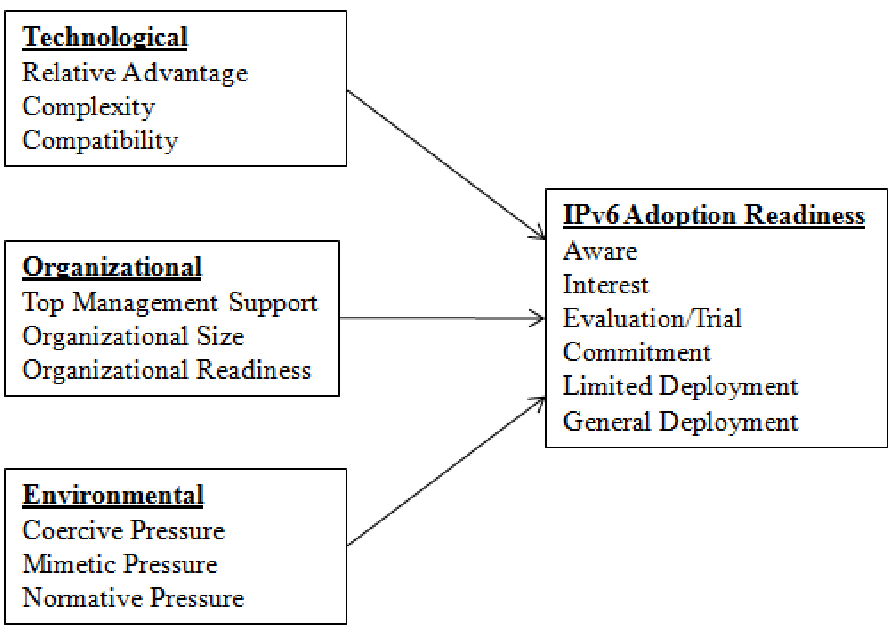


Figure 17. IPv6 adoption readiness model. This model identifies adoption factors that were viewed as significant in other technology adoption studies and applies them to IPv6 readiness.

The IPv6 adoption readiness model (Fig. 17) contains nine constructs taken from adoption studies of cloud computing, radio frequency identification (RFID), extensible business reporting language (XBRL), electronic data interchange (EDI), and voice over IP (VoIP) technologies and integrates them into the three contexts of the TOE model (Table 9).

Table 9

Significant factors from prior adoption studies. An "S" in the columns indicates that the particular study found a construct to be a statistically significant factor in organizational adoption of the technology under investigation.

| | Prior Adoption Studies | | | |
|---|---|---|---|---|
| Constructs | Low (2011) Cloud | Wang (2010) RFID | Basaglia (2009) VoIP | Henderson (2012) XBRL |
| Relative Advantage | S | - | S | S |
| Complexity | - | S | - | S |
| Compatibility | - | S | - | S |
| Top Management Support | S | - | - | - |
| Organizational Size | S | S | - | - |
| Org. Readiness | S | - | - | - |
| Coercive Pressure | - | S | S | - |
| Mimetic Pressure | S | S | - | - |
| Normative Pressure | - | - | S | S |

The technological context refers to the characteristics of IPv6 that influence adoption by the organization. In the present study, the technological context includes three constructs adapted from Diffusion of Innovation Theory which are relative advantage, complexity, and compatibility. Of the five perceived attributes of innovations posited by DOI theory to explain rates of innovation adoption, relative advantage, complexity, and compatibility were cited most often as significant variables in studies of technology innovation adoption (Alshamaila, Papagiannidis, & Li, 2013; Hovav et al., 2004; Low, Chen, & Wu, 2011; Rogers, 1983; Tweel, 2012; Wang et al., 2010).

The organizational context refers to the descriptive characteristics of the organization that influence IPv6 adoption readiness. For the present study, the constructs of top management support, organization size, organization readiness, and technology readiness were used. These three were shown in a meta-analyses conducted by Hameed et al. (2012) and Oliveira and Martins (2011) to be significant contributors in technology innovation adoption studies.

The environmental construct refers to factors external to the organization that can influence IPv6 adoption decisions. This is the external environment in which the organization operates and includes pressures from customers, business partners, competitors and government. This present study draws upon institutional theory using the constructs of coercive, mimetic, and normative pressures (DiMaggio & Powell, 1983; Henderson et al., 2012; Table 10).

Table 10

Model constructs and sources. Illustrates the theoretical basis for each of the constructs in the IPv6 adoption readiness model and studies in which the construct was found significant.

| Constructs | Definition | Reference | Source |
|---|---|---|---|
| Relative Advantage | The degree to which IPv6 offers benefits over IPv4 | Rogers (1983) | Henderson et al. (2012); Low et al. (2011) |
| Complexity | The degree to which IPv6 is perceived as more difficult to deploy than IPv4 | Rogers (1983) | Henderson et al. (2012); Wang et al. (2010) |
| Compatibility | The degree to which IPv6 is compatible with existing IT infrastructure and vendors' products | Rogers (1983) | Henderson et al. (2012); Wang et al. (2010) |
| Top Management Support | The extent of support from the organization's top management for adopting IPv6 and for investing in technology | Grover (1993) | Low et al. (2011) |
| Size<br>• Employees<br>• IT staff | The number of employees in the organization and the size of the IT staff | Fichman and Kemerer (1997) and Damanpour (1992) | Low et al. (2011); Wang et al. (2010) |
| Organizational Readiness<br>• Financial | The level of financial and technical resources available to undertake IPv6 adoption | Iacovou, Benbasat, and Dexter (1995) | Low et al. (2011) |
| Coercive Pressure | The degree to which the organization perceives pressure from trading partners and customers to adopt IPv6 | DiMaggio and Powell (1983) | Low et al. (2011); Wang et al. (2010) |
| Mimetic Pressure | The degree to which the organization perceives pressure to mimic competitors who have adopted IPv6 | DiMaggio and Powell (1983) | Low et al. (2011); Wang et al. (2010) |
| Normative Pressure | The degree to which the organization perceives pressure from professional associations to adopt IPv6 | DiMaggio and Powell (1983) | Low et al. (2011); Wang et al. (2010) |

# CHAPTER 3

# METHODOLOGY

The research method presented investigates the level of IPv6 readiness of end-user enterprise organizations across five facets of IPv6 preparedness: training, high-level planning, assessment of the current environment, IPv6 policy, and IPv6 deployment. The IPv6 readiness model was adapted from prior research on the adoption and assimilation of information technology assimilation (Rogers, 1983). Finally, the data used in this study was collected using a web-based survey instrument delivered electronically to 463 enterprise organizations within eastern North Carolina.

## Research Model

Building on the findings of prior technology adoption research, the model developed for this study uses factors and input variables adapted from diffusion of innovation theory (Rogers, 1983), institutional theory (DiMaggio & Powell, 1983), innovation assimilation theory (Fichman & Kemerer, 1997; Iacovou et al., 1995) and integrates them into the three contexts of the technological, environmental, organizational framework (Tornatzky & Fleischer, 1990; Fig. 18).

Multiple theories were combined into the IPv6 readiness model because, as Brancheau and Wetherbe (cited in Hameed et al., 2012) argues, “no single theory alone can fully explain the process of innovation adoption by organizations” and “research studies of innovation adoption are likely to use a combination of adoption theories and frameworks from different contexts to examine innovation adoption" (p. 362). Examples of technology adoption studies that combine the factors of multiple theories are common. A meta-analysis conducted by Hameed et al. (2012) involving the review of 151 prior studies of IT adoption, found 40 studies combining multiple innovation adoption models, with DOI and TOE used together most often. The same observation was made by Oliveira and Martins (2011) who found that "for more complex new technology adoption, it is important to combine more than one theoretical model to achieve a better understanding of the IT adoption phenomenon" (p. 120).

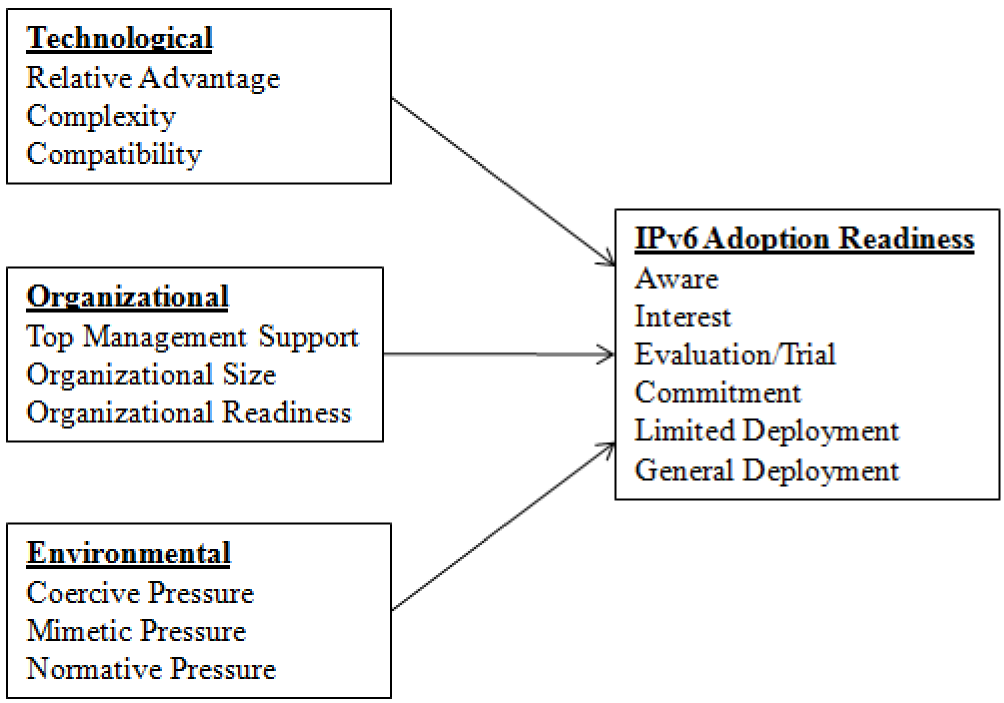


Figure 18. IPv6 readiness model. This model is employed in the present study and contains nine constructs adopted from multiple adoption theories.

Variables

The dependent variable of IPv6 readiness was measured using a 6-stage Guttman-type scale adapted from Fichman and Kemerer (1997) and Ettlie (1980; Table 11). Since the innovation process of adoption within an organization is not an instantaneous and dichotomous event, but rather a process that occurs over time", a sequence of adoption-decision stages was used (Rogers, 2003). Adoption-decision, or assimilation stages, "measure the earliness of initiation of assimilation activities, speed of assimilation activities, and an absence of rejection, stalling, or discontinuance" (Rogers, 2003, p. 21).

Table 11

Operationalization of the dependent variable. Illustrates the operationalization of the six stage dependent variable in which organizations were classified according to the highest stage achieved at the time the survey was administered in the present study.

| Stage of Readiness | Criteria | Survey Item used to Classify |
|---|---|---|
| 0. Not Aware | Key IT decision makers in the organization are not aware of IPv6. | Have you heard of IPv6 prior to receiving this survey? |
| 1. Awareness | Key IT decision makers in the organization are aware and have knowledge of IPv6. | Have you heard of IPv6 prior to receiving this survey? |
| 2. Interest | Key IT decision makers in the organization are actively learning more about IPv6 for possible deployment within 12 months. | Does your organization have plans to investigate IPv6 for possible production use within next 12 months? |
| 3. Evaluation/Trial | The organization has initiated an evaluation or trial of IPv6 in a test environment. | Has your organization conducted a trail or evaluation of IPv6 in a test environment or non-production environment? |
| 4. Commitment | The organization has committed to adopt IPv6 though establishment of a formal deployment plan. | Has your organization developed a formal IPv6 deployment plan? |
| 5. Limited Deployment | The organization has initiated an IPv6 project and has completed deployment in at least one area of the production environment. | Has your organization performed a limited deployment of IPv6 in at least one area of the production environment? |
| 6. General Deployment | The organization is using IPv6 in a substantial portion of the production environment. | Has your organization deployed IPv6 in a significant portion of the production environment? |
| Rejecters | Key IT decision makers are aware of IPv6 however the organization has no plans to adopt at time of survey. | Indicate how soon your organization plans to deploy IPv6 – No plans to deploy IPv6- |

Nine independent variables were categorized into the three contexts of the TOE framework:

1. Relative advantage - Relative advantage is the degree to which potential adopters of IPv6 perceive it to be superior to the existing IPv4. Higher levels of perceived relative advantage can positively influence an organization's intent to adopt IPv6 (Hovav et al., 2004). To capture relative advantage, respondents were asked to indicate on a five-point Likert scale their level of agreement or disagreement with the following potential benefits of IPv6 adoption as they pertain to their organization: (1) increased competitiveness, (2) enter new businesses or markets, (3) reach new customers, and (4) support new products and services.
2. Complexity - Complexity refers to the degree to which IPv6 is perceived as difficult to understand and use by the organization. High levels of perceived complexity can negatively impact an organization's intent to deploy IPv6 (Hovav et al., 2004). This study measured complexity through two 5-point Likert scale items in which respondents indicated their level of agreement or disagreement with the following statements: (1) IPv6 is more difficult to understand than IPv4, and (2) IPv6 adoption is a more complex process compared to IPv4.
3. Compatibility - Compatibility is the degree of perceived compatibility of IPv6 with the existing technologies and infrastructure in the organization. High levels of compatibility can positively influence an organization's level of IPv6 deployment readiness (Hovav et al., 2004). This study measured compatibility through five 5-point Likert scale items in which respondents indicated their level of agreement or disagreement with the following statements concerning IPv6 adoption in their organizations: (1) IPv6 is compatible with the organization's IT infrastructure, (2)

IPv6 is compatible with the organization's current software applications, (3) the organization's hardware vendors support IPv6, (4) the organization's software vendors support IPv6, and (5) the organization's network management systems support IPv6.

4. Top management support - Top management support is the degree to which leaders within an organization are perceived to support for IPv6 adoption. Prior studies on technology adoption indicate that support from top management is critical to the adoption of a new innovation (Low et al., 2011). Top management support was measured on three 5-point Likert scale items concerning the respondent's level of agreement or disagreement with the following statements about the organization's top management: (1) top management is interested in adopting IPv6, (2) top management considers adoption of IPv6 strategically important, and (3) top management has shown support for IPv6 adoption.
5. Organization size - Organizational size was measured in two ways: (1) the size of the workforce employed by the organization and (2) the number of personnel assigned to the organization's information technology department. Larger organizations tend to have the resources that allow greater flexibility and the ability to take more risks with new technological innovations (Alshamaila et al., 2013; Low et al., 2011). Additionally the size of an organization's IT resources was shown by Fichman and Kemerer (1997) to be a significant indicator of assimilation of innovation in an organization.
6. Organizational readiness - Organizational readiness in this study was examined in two dimensions: (1) IT resources and (2) financial resources. Organizations with

high levels of organizational readiness are better prepared for the adoption of IPv6. Organizations adopting IPv6 will require significant expertise, technological infrastructure, financial and IT human resources for successful deployments. Respondents were asked to rate on a 5-point Likert scale how much they agreed or disagreed with the following statements concerning their organization's readiness: (1) there is an operational budget committed to IPv6 adoption and (2) the organization has the technical expertise in-house to adopt IPv6.

7. Coercive pressure - Coercive pressure is the perceived pressure on an organization from dominant trading partners, such as customers and suppliers which have already adopted IPv6 and from government mandates (Singh & Tan, 2013). Higher levels of coercive pressure can positively affect IPv6 adoption decisions of an organization. Eight items were used to evaluate coercive pressure in this study. Respondents were asked to rate on a 5-point Likert scale how much they agreed or disagreed with the following statements concerning IPv6 adoption pressure on their organization: (1) key customers are encouraging IPv6 adoption, (2) the organization risks losing important customers if IPv6 is not adopted, (3) key suppliers are encouraging IPv6 adoption, (4) the organization risks losing important suppliers if IPv6 is not adopted, (5) key trading partners are encouraging IPv6 adoption, (6) the organization risks losing important trading partners if IPv6 is not adopted, (7) parent company is pressuring the organization to adopt IPv6, and (8) government mandates or regulations are pressuring the organization to adopt IPv6.
8. Mimetic pressure - Mimetic pressure is the perceived pressure on an organization from its peers to adopt IPv6. Mimetic pressures can encourage an organization to

adopt a new technological innovation through initiation of its peers (DiMaggio & Powell, 1983). Because organizations intending to deploy IPv6 may lack the necessary skills and knowledge, they may choose to follow the example of successful organizations (Singh & Tan, 2013). Higher levels of mimetic pressure can encourage an organization to adopt IPv6. To measure the influence of mimetic pressure on an organization to adopt IPv6, respondents were asked to rate on a 5-point Likert scale how much they agreed or disagreed with the following two statements concerning IPv6 adoption in their organization: (1) key competitors are currently adopting IPv6 and (2) our organization will use IPv6 to remain competitive.

9. Normative pressure - Normative pressure is the perceived pressure on an organization to adopt IPv6 from various forums, associations, and professional organizations associated with raising awareness of and encouraging IPv6 adoption globally. Through these forums, associations, and organizations, employees can become socialized about the importance of IPv6 and exert normative pressure from within the organization (Singh & Tan, 2013). Higher levels of normative pressure can positively affect IPv6 deployment readiness. Respondents were asked to rate how much they agree or disagree with two items to measure the influence of normative pressures to adopt IPv6 using a 5-point Likert scale: (1) Industry sources are pressuring the organization to adopt IPv6 and (2) our organization actively participates in industry, trade, or professional associations that promote IPv6 adoption.

Target Population and Sampling Procedures

The target population of this study was enterprise organizations located in 45 counties found in eastern North Carolina. The geographic boundary was chosen because East Carolina University serves the businesses and communities of the three economic development commissions that make up eastern North Carolina (Fig. 19). Respondents within the target population of organizations were limited to senior IT managers and decision makers to ensure that the responses received were from individuals who were well informed and influential in the IT decision making process of their organizations.

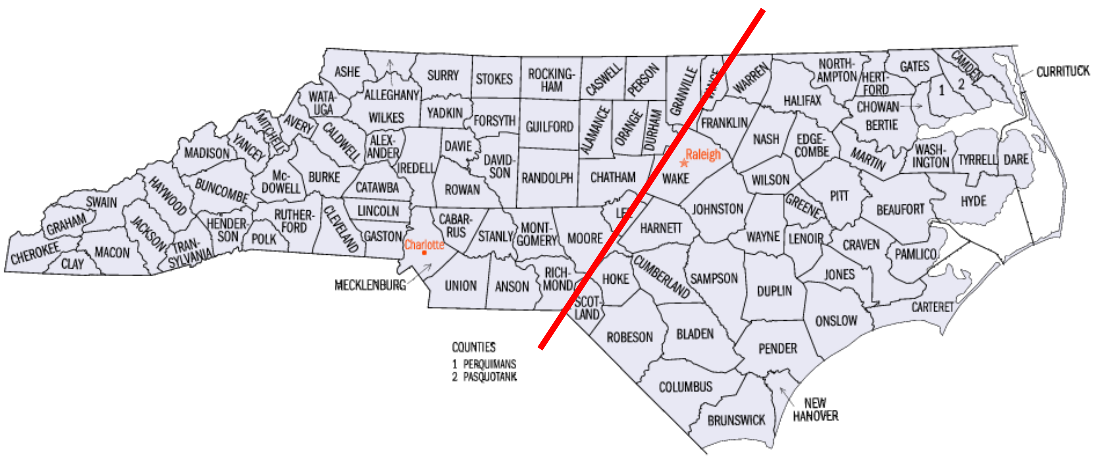


Figure 19. Eastern North Carolina (United States Census Bureau Map, 2014). Illustrates the counties found within North Carolina.

Two employer databases maintained at ECU were mined to obtain a list of target organizations within the North Carolina eastern region. The first database mined was the ECU Career Center CareerNET database which contained 419 contact email addresses. The second database mined was obtained from the ECU Center for Innovation in Technology and Engineering (CITE) and contained email addresses of an additional 262 contacts. The two combined lists contained 681 email addresses. Because some organizations had multiple contact email addresses listed in the databases, the actual number of companies represented in the combined list was 463. The combined lists of 681email addresses were uploaded into ECU's Qualtrics Web based survey tool. From Qualtrics, an email containing the recruitment letter (appendix A), instructions, and a link to the survey was sent to all 681 email addresses. The instructions included in the email asked the recipient to forward the survey link to the senior IT manager within the organization.

## Data Analysis Procedures

All data in this study were analyzed using IBM's SPSS v22.0 statistical software program. The response data received from the questionnaire was downloaded from the Qualtrics survey tool as an SPSS file (.sav) which was then imported directly into SPSS v22.0, requiring no manual data entry. A codebook, located in appendix C, was created listing all the variables in the questionnaire, the abbreviated variable name as it was used in SPSS, and the way in which the variable was coded in SPSS. Once the data was imported into SPSS, it was parsed for duplicate cases from a single company, cases from non-IT professionals, and cases which contained no useable variable values. Once these cases were identified, they were removed from analysis. In all instances of duplicate cases from a single organization, the case that was retained for analysis was the case with the most number of complete responses. After the data was sorted and organized, the data analysis procedures were performed in three stages: (1) descriptive statistics to explore frequencies, correlations, and to check assumptions, (2) analysis of the measurement model for internal consistency and to assess convergent and discriminant validity, and (3) exploration of variable associations.

Descriptive statistical procedures were used to describe the characteristics of the sample, inspect for missing data, check variables for any violation of the assumptions underlying statistical techniques used to address research questions, and to address specific research questions. Frequency distributions were analyzed and bar graphs were generated for the demographic characteristics of the organizations, respondent perceptions of IPv6 urgency and necessity, organizational level of IPv6 readiness, and for each of the five facets of IPv6 preparedness.

Next, the measurement model was evaluated for reliability, convergent validity, and discriminate validity. The internal consistency, as a measure of construct reliability, was calculated and assessed for each of the eight scales used in this study and further evaluated using Cronbach's alpha coefficient. A minimum Cronbach's alpha score of .70 was used to determine of survey items making up the scales measured the same latent variable or underlying construct. Convergent validity and discriminant validity were assessed by performing factor analysis using principle component extraction and Oblimin rotation. Principle component analysis was also used to reduce groups of highly correlated independent variables into the least number of factors and to establish the underlying dimensions between the measured variables and the factors.

Finally, analysis of variable associations was conducted using Spearman's rank-order correlation coefficient and Chi-square test with Fisher's exact test. The correlation analysis was used to determine whether there was a linear relationship between variables and to describe the strength and direction of the relationship. Fisher's exact test were used to test for significant association and the strength of relationships between the categorical independent variables and the dependent variable of IPv6 readiness.

# CHAPTER 4

## SURVEY INSTRUMENT

This chapter discusses the development and validity testing of the survey instrument which was adapted from previous technology adoption studies. The survey instrument was approved by the Institutional Review Boards (IRBs) of both Indiana State University and East Carolina University and was tested for both face and content validity by two independent reviewer panel who provided feedback for modifications. Once modifications were complete, the survey was delivered via email to 463 organizations via ECU's Qualtrics Web-based survey tool. Of the 463 organizations that received the survey, 68 useable responses were obtained, thus giving an overall response rate of 14.65%.

### Instrument Approval

IRB approval was obtained from both Indiana State University and East Carolina University for the use of human participants in this study. The researcher submitted a Human Research Subjects Proposal to the IRBs at both Indiana State University and East Carolina University prior to administrating the survey instrument. Exemption letters from both IRBs are located in Appendix A.

### Instrument Validity

The survey questions used were adapted from previous technology innovation adoption studies and modified as necessary to fit the context of IPv6 adoption. The survey questionnaire was reviewed by experts in questionnaire design at ECU's Center for Survey Research to ensure the most positive impression on respondents and to maximize instrument effectiveness. Face and content validity reviews were also conducted prior to survey deployment. The final survey instrument consisted of total of 22 questions with some questions containing multiple response components giving a total of 84 data points per survey. Also included were two "write-in" open-ended response items to capture qualitative information from the respondents. The first survey question was used to identify respondents who did not meet the requirement of being an IT decision maker within their organization. Respondents who selected "no" to this first question were automatically redirected to the end of the survey.

The survey instrument used in this study was checked for both face and content validity by two panels of reviewers. The Standards for Educational and Psychological Testing (as cited in Sartori and Pasini (2007), state that "validity is the most important consideration in test evaluation (p. 361)". An instrument's validity is whether or not it truly measures what a researcher intends it to measure (Angoff, 1988; Lynn,1986; Sartori & Pasini, 2007). Evaluating test validity begins with a qualitative review of the test items and of the test as a whole to determine if they appear suitable, comprehensive, and representative for the purpose of the study (Sartori & Pasini, 2007; Yaghmale, 2009). This initial qualitative review is done to check the face validity and the content validity of the test.

*Face Validity*

Face validity is concerned with how a test appears to those who take it. It is a simple subjective examination of a test by individuals who may or may not have technical knowledge of the subject under study or knowledge of test measurement (Lynn, 1986; Roberts, 2000). While there is some disagreement in the literature on the merits of face validity, Nevo (1985) states that "face validity (FV) is an important feature of any psychological or educational test intended for practical use" (p. 288). The view that face validity has value in test validity is also expressed by Roberts (2000, p. 6), who states that "face validity has a legitimate place in assessment, and making decisional about potential use or non-use of instruments for particular purposes" and by Sartori and Pasini (2007, p. 365) who argue that "face validity keeps its own utility."

Face validity in this study was appraised and rated by six reviewers on a 5-point scale of suitability that was adapted from Nevo (1985): (1) irrelevant, (2) inadequate, (3) adequate, (4) suitable, and (5) highly suitable. The six reviewers had various levels of technical knowledge, came from various professional backgrounds, but were not considered experts in the area of IPv6. Each reviewer received a soft copy of the survey questionnaire in Microsoft Word and a link to the Web-based version of the survey hosted in Qualtrics. The reviewers were also provided a copy of the objectives, purpose statement, and research questions of the study. The reviewers were asked to rate each survey item, as well as, the overall survey on the 5-point scale of suitability ranging from irrelevant to highly suitable. The reviewers were also asked to give written feedback and suggested revisions to items they found difficult to understand or to answer. Using the guidelines for assessing content validity proposed by Lynn (1986), a content validity index (CVI) rating of at least 0.83 for six reviewers is required. The CVI rating is the proportion of reviewers that are in agreement that an item is suitable or highly suitable. Six items received a rating of (3) "adequate" or lower by at least one reviewer. These six items were reviewed, edited and modified as necessary based on the reviewer's comments and suggestions then re-evaluated (Table 12).

Table 12

Face validity results. This table shows the items that were rated as either (4) suitable or (5) highly suitable marked with an “x”. Items that were rated as (3) “adequate” or lower are marked with an “-“. The table also shows the number of reviewers who rate an item as suitable or highly suitable and the proportion of reviewers rating an item as suitable or highly suitable.

| Item | Reviewer 1 | Reviewer 2 | Reviewer 3 | Reviewer 4 | Reviewer 5 | Reviewer 6 | Reviewers in agreement | Item CVI |
|---|---|---|---|---|---|---|---|---|
| 1 | x | x | x | x | - | x | 5 | 0.83 |
| 2 | x | x | x | x | x | - | 5 | 0.83 |
| 3 | x | x | x | x | x | x | 6 | 1.00 |
| 4 | x | x | x | x | x | x | 6 | 1.00 |
| 5 | x | x | x | x | x | x | 6 | 1.00 |
| 6 | x | x | x | x | x | x | 6 | 1.00 |
| 7 | x | x | x | x | x | x | 6 | 1.00 |
| 8 | x | x | x | x | x | x | 6 | 1.00 |
| 9 | x | x | - | x | x | x | 5 | 0.83 |
| 10 | x | x | x | x | - | x | 5 | 0.83 |
| 11 | x | x | x | x | x | x | 6 | 1.00 |
| 12 | x | x | x | x | x | x | 6 | 1.00 |
| 13 | - | x | x | x | x | x | 5 | 0.83 |
| 14 | x | x | x | x | x | x | 6 | 1.00 |
| 15 | x | x | x | x | - | x | 5 | 0.83 |
| 16 | x | x | x | x | x | x | 6 | 1.00 |
| 17 | x | x | x | x | x | x | 6 | 1.00 |
| Over all | x | x | x | x | x | x | 6 | 1.00 |

*Content Validity*

Yaghmale (2009) defines content validity as “the degree that the instrument covers the content that it is supposed to measure and the comprehensiveness and representativeness of the content” (p. 25). The purpose of content validity is to review the survey instrument to ensure it includes all that it should and does not contain unnecessary or irrelevant content (Litwin, 1995). In contrast to face validity, which relies on the subjective opinions of laypersons, content validity is evaluated based on the subjective judgment of experts in the field of study (Lynn, 1986; Polit & Beck, 2006; Yaghmale, 2009).

This study used a two stage process adapted from research conducted by Lynn (1986) and Yaghmale (2009) to establish content validity. The first stage, the development stage, involved three steps: (1) constructs were identified through a thorough review of literature, (2) survey items adapted from previous literature were generated for each construct, and (3) the items generated were edited and arranged in a logical sequence. Once the items were finalized and the survey instrument constructed, the development stage was complete and the second stage (i.e. the judgment stage) began. In the judgment stage, experts in the networking field with extensive knowledge of IPv6 reviewed the instrument to assess the validity of each item individually and as a whole.

The number of experts used for content validity should be between five and ten when practical (Lynn, 1986; Polit, Beck, & Owen, 2007; Yaghmale, 2009). However, Lynn (1986) also states that in cases where there are limited numbers of experts available, less than five is acceptable as long as a minimum CVI of 1.00 is used to represent valid survey items.

The survey instrument in this study was sent to six subject matter experts (SMEs) that had extensive industry experience with IPv6 deployment and who were not part of the targeted study population. The reviewers were given a soft copy of the survey questionnaire, as well as, the link to the Web-based survey hosted in Qualtrics, and were asked to rate each item on a frequently used scale advocated by L. L. Davis (1992): (1) = not relevant, (2) = somewhat relevant, (3) = quite relevant, and (4) = highly relevant. The CVI was then computed as the number of experts giving a rating of either 3 or 4 divided by the total number of experts. With four reviewers, an item is considered to have content validity if it had an item CVI of 1.00.

Items that do not score the required minimum of 1.00 must be eliminated or revised (Lynn, 1986). The reviewers were also asked to identify areas of omission and to make suggestions to improve or modify items and the questionnaire as a whole.

Of the six SMEs, four returned the survey with completed reviews (Table 11). In the reviews, only two items, number 12 and number 13, received a CVI of less than 1.00. These two items were rated as a (1) “not relevant” and a (2) “somewhat relevant”, respectively by expert reviewer #2. Based on comments made by the reviewer, the reasoning for the low ratings was attributed to poorly written instructions for these two items. The two items were revised based on the reviewer’s comments before inclusion in the final version of the survey. Also, based on feedback from the SMEs, several multipart questions were broken up into multiple individual questions bringing the total number of questions to 22.

Table 13

Content validity results. An ‘x’ in the table indicates the item received a rating of either (3) relevant or (4) irrelevant by the expert reviewer.

| Item | Expert Reviewer 1 | Expert Reviewer 2 | Expert Reviewer 3 | Expert Reviewer 4 | Reviewers in agreement | Item CVI |
|---|---|---|---|---|---|---|
| 1 | x | x | x | x | 4 | 1.00 |
| 2 | x | x | x | x | 4 | 1.00 |
| 3 | x | x | x | x | 4 | 1.00 |
| 4 | x | x | x | x | 4 | 1.00 |
| 5 | x | x | x | x | 4 | 1.00 |
| 6 | x | x | x | x | 4 | 1.00 |
| 7 | x | x | x | x | 4 | 1.00 |
| 8 | x | x | x | x | 4 | 1.00 |
| 9 | x | x | x | x | 4 | 1.00 |
| 10 | x | x | x | x | 4 | 1.00 |
| 11 | x | x | x | x | 4 | 1.00 |
| 12 | x | - | x | x | 3 | 0.75 |
| 13 | x | - | x | x | 3 | 0.75 |
| 14 | x | x | x | x | 4 | 1.00 |
| 15 | x | x | x | x | 4 | 1.00 |
| 16 | x | x | x | x | 4 | 1.00 |
| 17 | x | x | x | x | 4 | 1.00 |
| Overall | x | x | x | x | 4 | 1.00 |

## Survey Response Rate

The electronic survey instrument was emailed to 463 companies using East Carolina University’s Qualtrics Web-based survey tool. Emails contained the recruitment letter (see appendix B), instructions, and a link to the survey. The email included instructions asking the recipient to forward the survey link to the senior IT manager or decision maker in the organization. The Qualtrics survey tool recorded all survey responses and kept a log of the start time, end time, and duration of each survey response.

Data collection was conducted for a period of 21 days. Pre-programmed reminder emails were sent out by Qualtrics on day 7, day 9, and day 16 to recipients who had not yet opened the survey link. At the end of the sampling period a raw number of 121 survey responses were recorded as returned by Qualtrics. These responses were downloaded from Qualtrics as a SPSS readable file format (.sav) which was then opened in SPSS. The data was then filtered for duplicate responses from any single organization. The filter identified 20 duplicate responses which were eliminated from data analysis. In all 20 cases, the duplicate responses that were eliminated contained no data. This would indicate that the surveys had been opened and then immediately closed with no responses recorded. Next, the data was searched for responses from non-IT decision makers. Twenty-three responses were eliminated from respondents who indicated they were not IT decision makers within their organization. Finally, 11 responses were eliminated for being incomplete and containing no useable data. In total, of the 121 initial responses, 54 were eliminated leaving a net of 68 responses from 464 organizations. This gave a net response rate of 14.65% which is consistent with similar studies of IT technology adoption (Table 14). It should also be noted that the response rates from senior executives of an organization are typically lower than those from populations of individuals (Baruch, 1999).

Table 14

Response rates from similar studies.

| Author | Study | Sample size/Response | Response rate |
|---|---|---|---|
| Dell (2012) | IPv6 Readiness in Australia | 971/180 | 18.5% |
| Henderson et al. (2012) | XBRL Adoption | 344/65 | 18.8% |
| Tweel (2012) | Cloud Adoption | 4000/221 | 5.5% |
| Low et al. (2011) | Cloud Adoption | 500/111 | 22.22% |
| Yoon (2009) | Virtual World Adoption | 2289/130 | 5.6% |
| White et al. (2005) | IPv6 Adoption | 1000/74 | 7.4% |

Note: The true response rate for Henderson's study is unknown as the link to the survey was posted on XBRL user group sites, the Information Systems Audit and Control Association (ISACA) web site, and the discussion forum of CIO magazine. The same size listed is the reported number of survey links which were actually opened.

## Non-Response Bias

Non-response bias was determined to not be a concern in this study. Non-response bias is defined by Taris and Schreurs (as cited by Halbersleben and Whitman, 2013) as "a systematic difference between those who respond and those who do not respond on a substantive construct measured by a survey" (p. 915). As shown in the formula below, nonresponse rate and none response bias are not necessarily positively correlated (Halbesleben & Whitman, 2013).

The non-response bias of a variable of interest is equal to the proportion of the non-respondents multiplied by the difference of the mean of the respondents to the mean of the non-respondents. In other words, the greater the difference between the two means, the greater the nonresponse bias. In research conducted by Rogelberg et al. (as cited by Halbesleben and Whitman, 2013) it was found that there are meaningful differences between active non-participants and passive non-participants. The attitudes of passive non-participants were found to be very similar to respondents suggesting there are fewer differences between passive non-respondents and respondents compared to active non-respondents. The exception is the areas of personality or in surveys dealing with work demands.

Non-response bias was determined to not be a concern in this study for two reasons: (1) this study did not test personality nor personal attitudes towards work demands and (2) the rate of active non-participants was low (Halbesleben & Whitman, 2013). Of the 463 companies receiving the survey, only 18 (3.8%) actively opted out by choice of the recipient.

## Common Method Bias

Due to the fact that all survey data was self-reported through the same questionnaire, variance in the factors could be attributed to the measurement method rather than the constructs of interest which can bias the estimates of the true relationship among the constructs. According to Podsakoff, MacKenzie, Lee, and Podsakoff (2003), several common method bias factors exist, including common rater effects, item characteristic effects, item context effects, and measurement context effects. Several techniques were used for controlling common method bias in this study. Common rater effects were controlled for by methodologically and proximally separating the measures by using different response formats and scale endpoints for the predictor and criterion variables and by having the variables measured in different blocks of the survey. According toPodsakoff et al. (2003), this method reduces the ability of the respondent to use prior responses to answer subsequent questions. Item characteristic effects were controlled for by allowing respondents to answer questions anonymously thus making them less likely to answer questions the way they perceive is desired by the researcher (Podsakoff et al., 2003). Finally, proactive steps were taken when designing the survey items to avoid item ambiguity through two rounds of validity testing.

# CHAPTER 5

# DESCRIPTIVE STATISTICS

This chapter presents the findings and statistical analysis of the survey data collected from 68 enterprise organizations located within the North Carolina eastern region. Descriptive statistical analyses were used to describe characteristics of the respondents, to check key variables for violations of assumptions of statistical techniques, and to address research questions. Frequencies were used to obtain the descriptive statistics for the categorical variables.

## Demographic Data

Demographic data were collected from respondents concerning the size of the organization in both number of employees and number of IT staff, the organization's industry sector, and the geographic regions in which the organization operates.

Respondents were asked to report the size of their organizations in two ways, the number of employees and the number of IT staff. The largest percentage (48%) of the organizations responding to the survey was small-to-medium sized (SME) organizations of less than 500 employees with the largest group represented by organizations of 50 or fewer employees (Fig. 20).

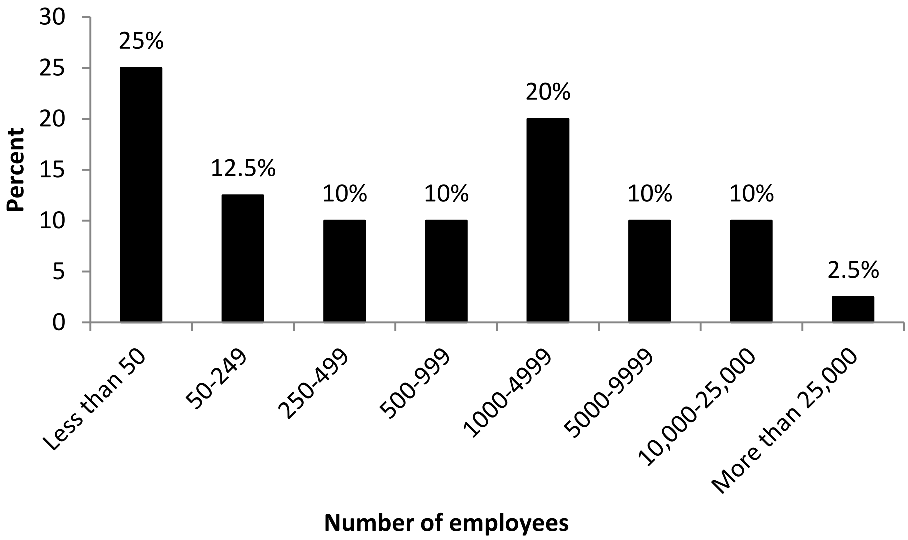


Figure 20. Percentage of organizations by number of employees.

As would be expected in SMEs, the size of the IT staff in most of the organizations (50%) was fewer than 10, which characterizes 50% of the surveyed organizations (Fig. 21).

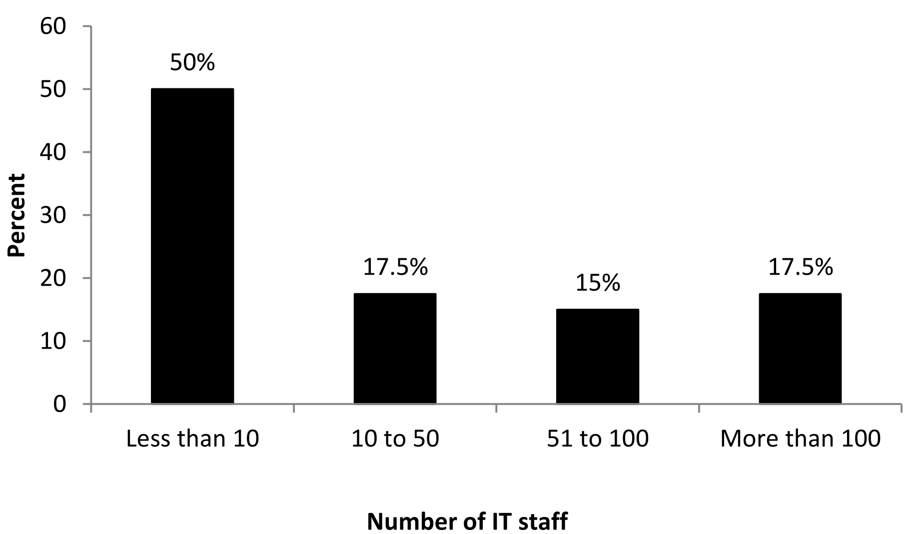


Figure 21. Percentage of organizations by number of IT staff.

There were respondent organizations representing each of the thirteen industry segments listed in eastern North Carolina (Fig. 22). The largest industry segment represented was manufacturing (36.5%) with construction, the second largest, at 17%.

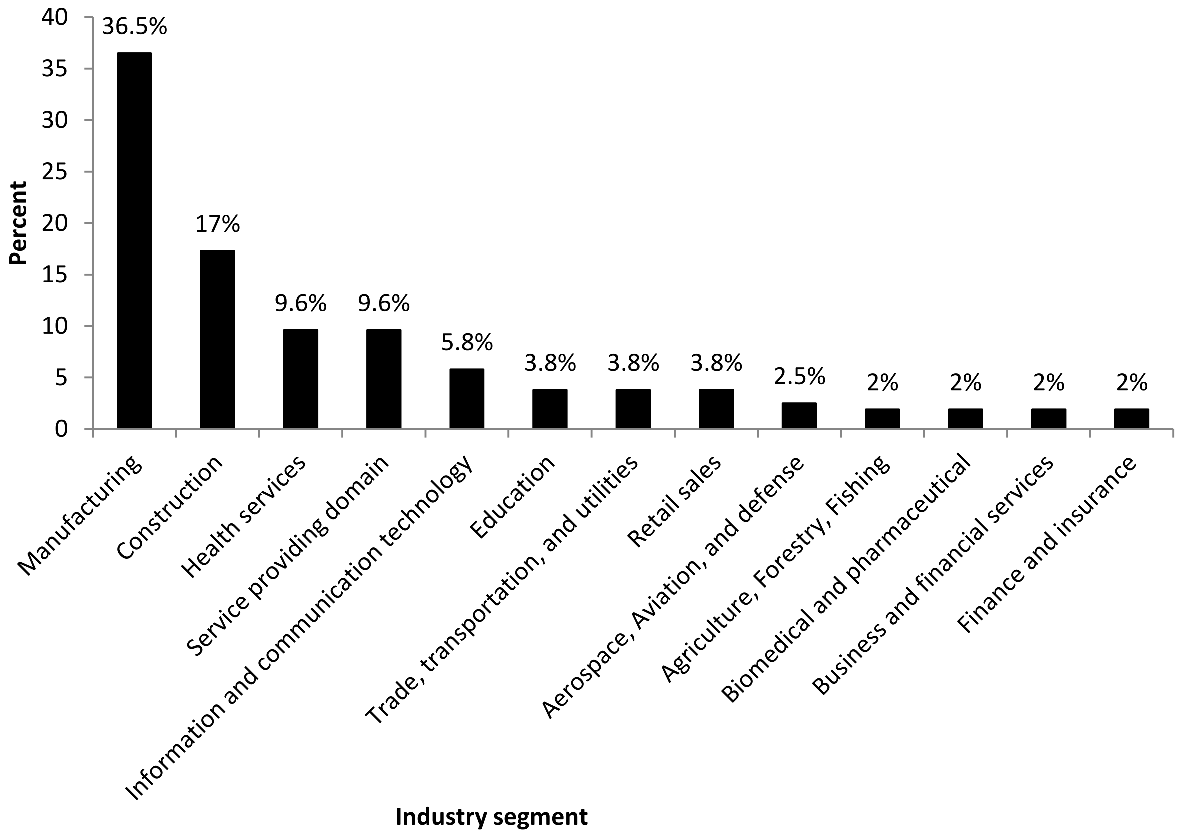


Figure 22. Respondent organization industry categories. The largest proportions of respondents were from manufacturing (36.5%) and construction (17%).

Thirty-eight percent of the respondent organizations were multinationals, having operations in at least one geographic region in addition to North America (Fig. 23). Ten percent of the organizations had operations in all five geographic regions (Fig. 23).

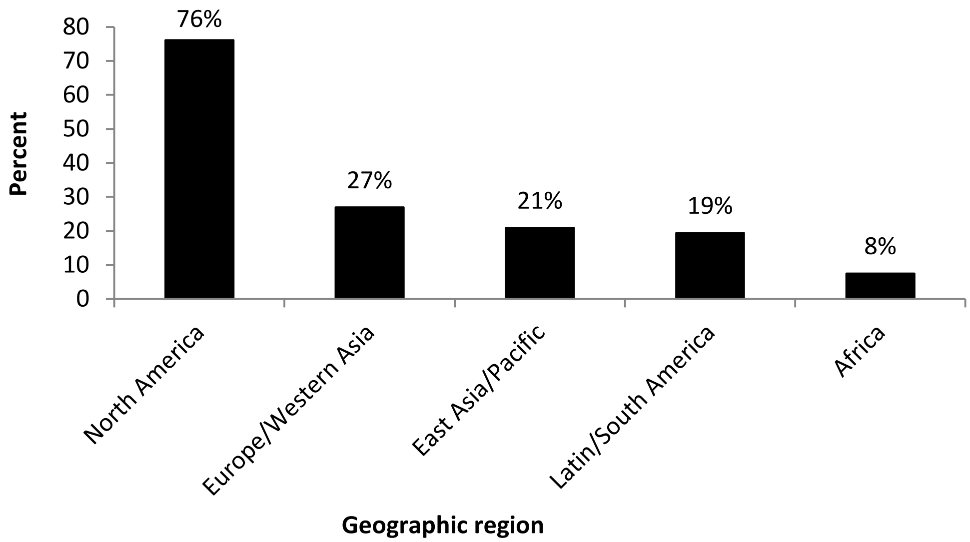


Figure 23. Geographic regions of operation. Note that because some organizations had operations in more than one geographic region, the percentages add up to more than 100%.

Most (84%) of the responding organizations were headquartered in the United States, though there were a few headquartered outside the United States, 5% in Canada, 5% in Japan, 4% in Germany, and 2% in Australia.

## IPv6 Awareness

The first question asked of respondents who indicated they were IT decision makers was if they were aware of IPv6 prior to receiving the survey (Fig. 24).

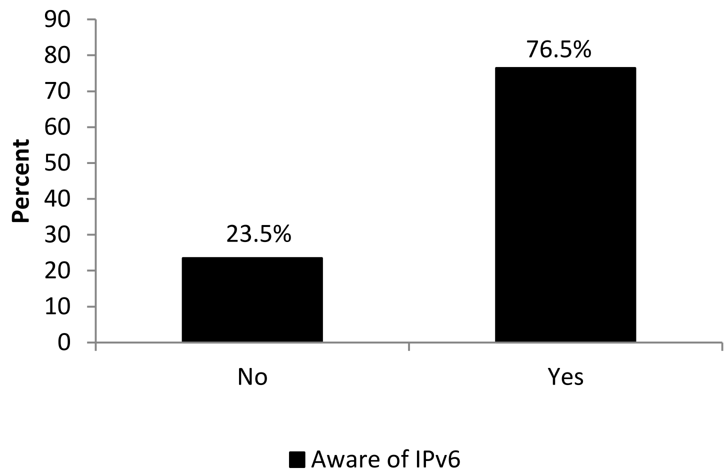


Figure 24. IPv6 awareness. Responses by IT decision makers to determine if they were aware of IPv6 prior to receiving the survey.

## Organization IPv6 Readiness

Respondents were asked a series of questions to discern the highest stage of IPv6 readiness achieved by their organization (Fig. 25). Each of the six stages of IPv6 readiness, ranging from stage 1 to stage 6 or awareness to general deployment, respectively, is shown with the percentage of respondents that indicated that their organization had progressed to that particular stage. Multiple responses from a single respondent were consolidated so that only the highest level response is shown.

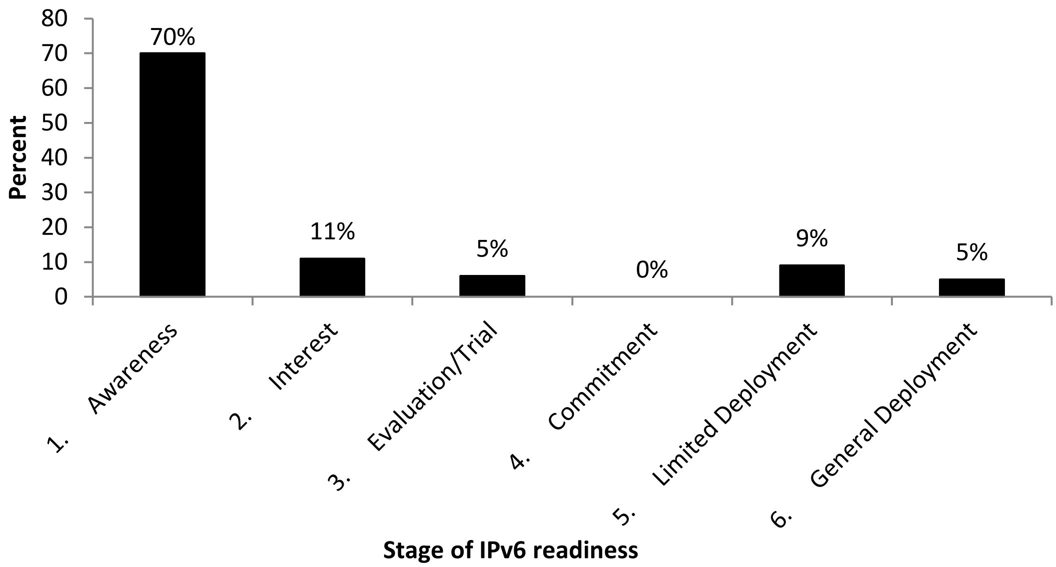


Figure 25. Highest achieved stage of IPv6 readiness. The data reflect the responses made by respondents regarding the highest achieved stage of organizational IPv6 readiness.

A dichotomized version of IPv6 readiness was made by transforming the variable of highest stage of readiness into a binary variable of awareness and beyond awareness, which is defined as level 2, interest, and above (Fig. 26).

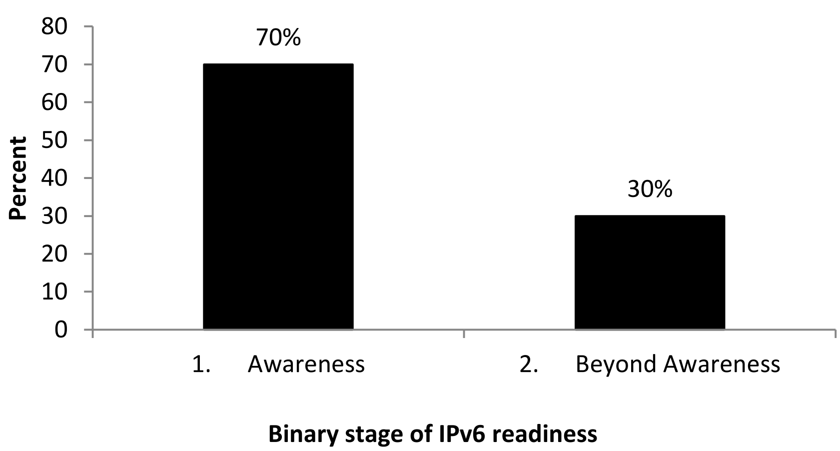


Figure 26. Two stage representation of IPv6 readiness of organizations. The data further examine how respondents feel regarding their organizational IPv6 readiness when already achieving the highest stage of readiness.

Of the respondents who indicated they were aware of IPv6, only 25% believed that IPv6 adoption was an urgent issue and a few more than half (57%) believed it was a necessary upgrade (Fig. 27).

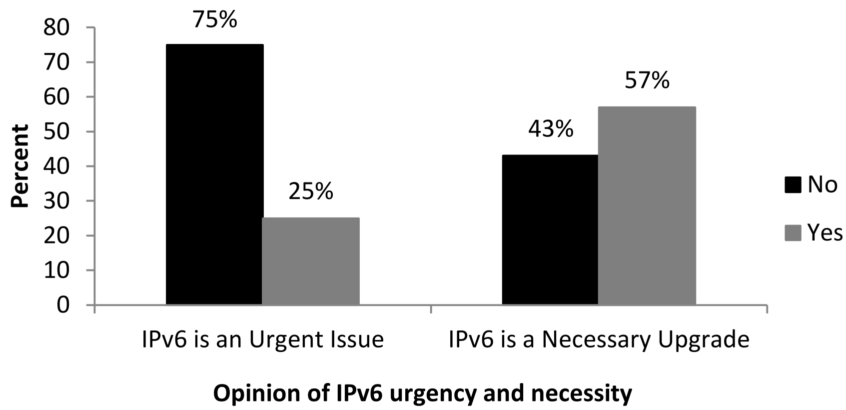


Figure 27. Response IPv6 as an urgent issue or necessary upgrade. These responses were obtained from respondents who indicated that they were aware of IPv6.

Two open-ended questions were provided to assess the reasons why respondents did or did not believe IPv6 adoption was an urgent issue or a necessary upgrade. Thirty-three respondents replied for the question of urgency and twenty seven replied for the question of necessity. Responses to the open-ended questions were reviewed for major themes which were then coded into categories. The cited reasons given by respondents for no urgency were: lack of industry pressure (38%), NAT and ISP provided solutions (29%), the adequacy of IPv4 (29%), and lack of vendor product support (4%; Table 15). The cited reasons in support of urgency were: the depletion of IPv4 address (50%), proliferation of IP based mobile devices (25%), and the Internet of Things (25%; Table 15).

Table 15 Responses to IPv6 urgency open-ended question.

| No Urgency | Percent |
|---|---|
| No Industry or Organizational Pressure | 38 |
| NAT/ISP Solutions | 29 |
| IPv4 is Meeting Our Needs | 29 |
| Lack of Vendor Product Support | 4 |

| Urgency | Percent |
|---|---|
| Depletion of IPv4 Addresses | 50 |
| Growth in Number of Mobile Devices | 25 |
| Growth of IP Enabled Devices/Internet of Things | 25 |

On the question of necessity of IPv6, the majority of respondents (57%) began their answer with "eventually", suggesting that they believe necessity of IPv6 adoption is a future concern. The prevalent answers given for not believing IPv6 adoption to be a necessary upgrade were: no current pressures on the organization to adopt (31%), a belief that the organization had adequate IPv4 addresses (46%), and the availability of NAT (23%; Table 16). The cited reasons given by respondents for necessity of upgrading to IPv6 were: standardization will make it necessary (57%), the depletion of IPv4 addresses (29%), growth in the number of IP enabled mobile devices 7%), and growth of IP enabled smart devices and IoT (7%; Table 16).

Table 16

Responses to IPv6 necessity open-ended question.

| Upgrade is not Necessary | Percent |
|---|---|
| IPv4 is Meeting Our Needs | 46 |
| No Industry or Organizational Pressure | 31 |
| NAT/ISP Solutions | 23 |
| **Upgrade is Necessary** | **Percent** |
| Eventually for Standardization | 57 |
| Depletion of IPv4 Addresses | 29 |
| Growth in Number of Mobile Devices | 7 |
| Growth of IP Enabled Devices/Internet of Things | 7 |

## IPv6 Planning and Preparation

Respondents were next asked a series of questions concerning the planning and preparations their organizations had made toward IPv6 adoption. One of the first steps in planning an IPv6 deployment is obtaining IPv6 addressing space; however, the majority of respondents (58%) did not know if their organization's service provider offered IPv6 connectivity (Fig. 28). Further, 64% indicated their organization had not obtained global IPv6 addressing space (Fig. 28). Further, few organizations (2%) have undertaken initial IPv6 address planning steps by obtaining public IPv6 address space (Fig. 28).

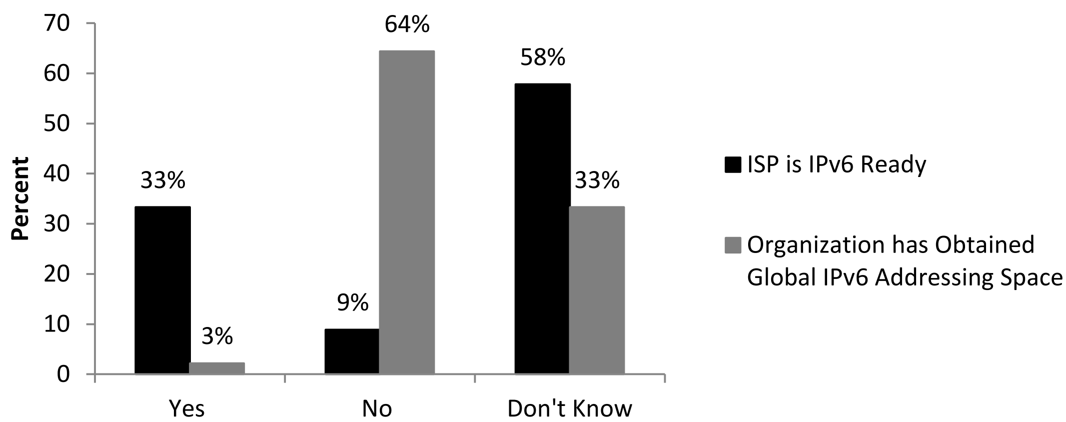


Figure 28. Readiness of ISP and IPv6 address space allocation.

Respondents were asked if their organization had plans to deploy IPv6 and if so how soon those plans would be completed. Most respondents (59%) indicated their organization had no plans to deploy IPv6, and only about 15% had plans to do so within the next two years (Fig. 29).

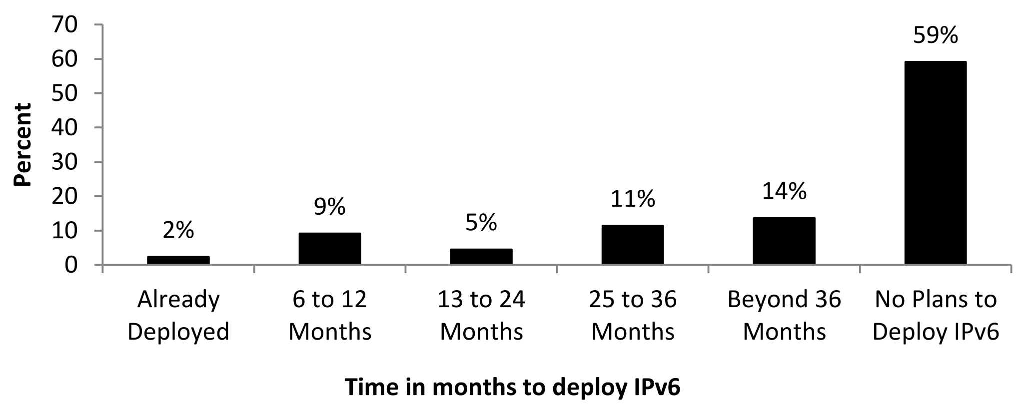


Figure 29. Timeframe to deploy IPv6. Respondent organizations responses to when IPv6 would be deployed within their organization.

IPv6 planning and preparation by organizations was also evaluated against five facets of organizational IPv6 preparedness recommended by Dell (2012) and Grossettete (2008): training, high level planning, assessment of the current environment, updated policy framework, and IPv6 deployment.

Because the majority of respondents indicated their organizations had no plans to deploy IPv6, it was not surprising that the majority of organizations had conducted little to no training on IPv6. Respondents were asked to provide information on how much training their organization has conducted in each of six areas: IPv6 technology, IPv6 deployment, IPv6 security, IPv6 configuration on network equipment, IPv6 configuration on host operating systems, and IPv6 applications. For every IPv6 training category, the majority of organizations had conducted no IPv6 training. The percentages indicating no IPv6 training at all in the given categories were: 56% on IPv6 technology, 80% on IPv6 deployment, 75% on configuring IPv6 on network equipment, 73% on configuring IPv6 on host operating systems, and 89% on development of IPv6 applications. On the positive side, with the exception of training on developing IPv6 applications, more than 20% of organizations had conducted some level of IPv6 training in each training area. The area that showed the highest level organizational training was IPv6 technology with 43% of organizations indicating some level of training in this area (Fig. 30).

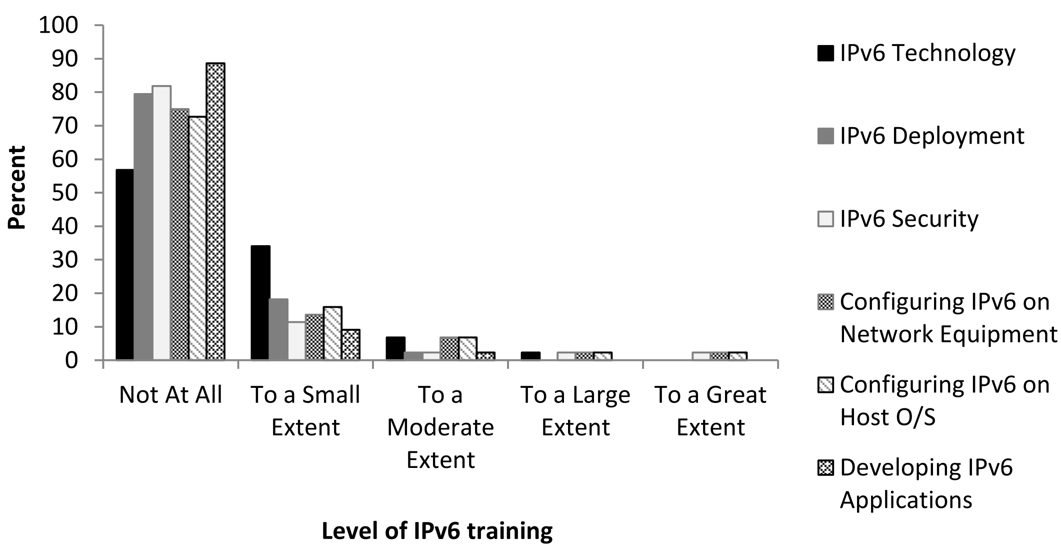


Figure 30. Levels of IPv6 training.

As with IPv6 training, very few of organizations had conducted any high-level IPv6 planning, such as commenced planning for IPv6 (58% - not at all), developed an IPv6 strategy (79% - not at all), or created IPv6 projects (84% - not at all; Fig. 31). However, when combining those that indicated small, moderate, large and great extent, almost 41% indicated they had begun some level of IPv6 planning.

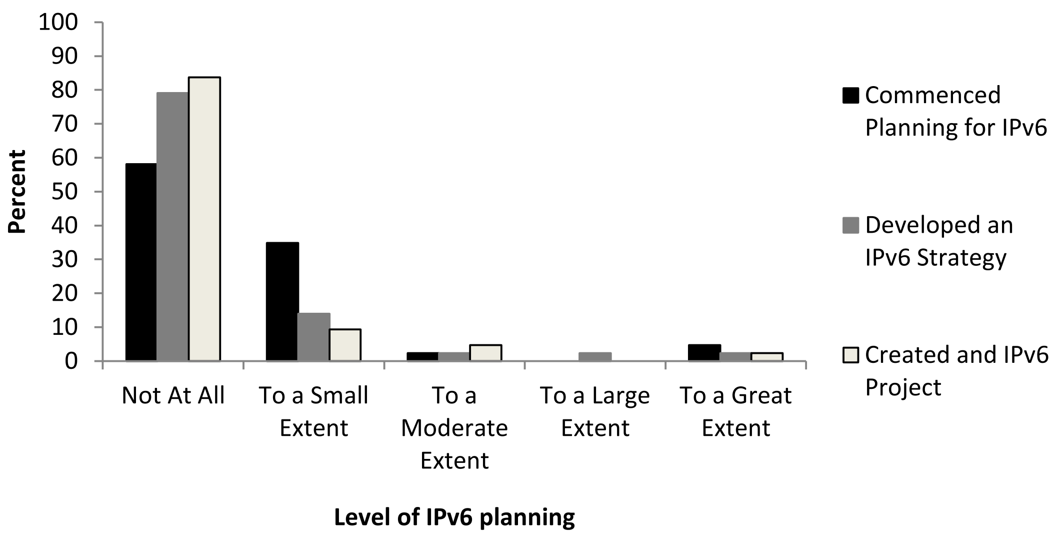


Figure 31. Levels of IPv6 planning.

Assessing the current environment is a critical part, and usually one of the first steps of any IPv6 adoption plan. Further, this assessment takes into consideration the human resources, in the form of training and skills, and the hard assets that make up the network infrastructure and applications. Each area must be assessed for IPv6 readiness; however, the majority of organizations (71%) had not assessed their IT assets, their applications portfolio (82%), nor assessed their training requirements (84%) for IPv6 readiness (Fig. 32). In comparison, approximately 20% of organizations had conducted some level of assessment in each area, with assessing IT assets leading with almost 30% of organizations conducting some level of assessment.

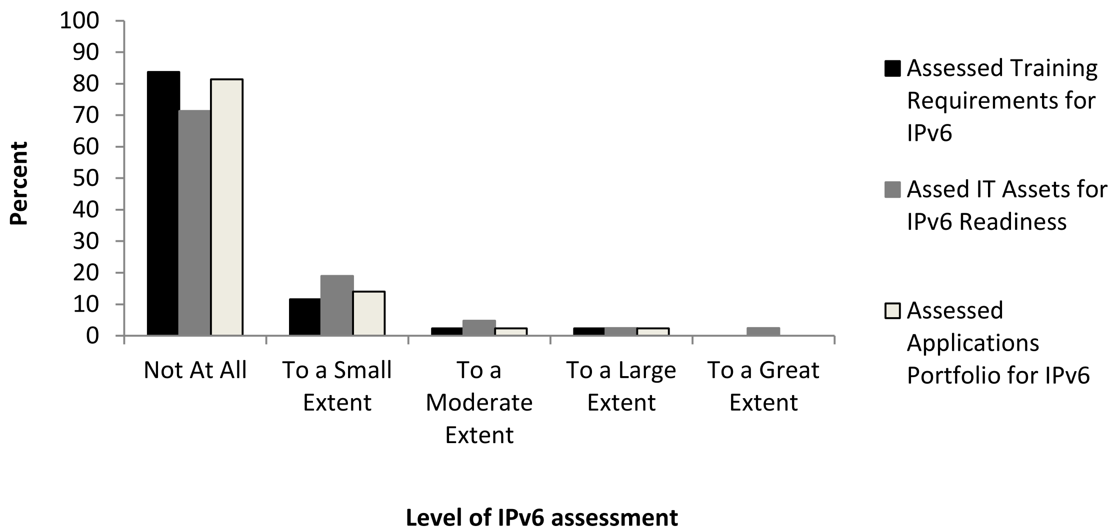


Figure 32. Levels of IT environment assessment for IPv6.

Consistent with the other facets of IPv6 preparedness, few organizations have made progress in updating policies for IPv6. Approximately 90% of organizations indicated that they have not updated their policies in any of the following policy framework areas, including: purchasing policies, application development policies, and security policies (Fig. 33). Not updating IT policies to include IPv6 puts organizations at risk of having to replace equipment and applications outside of normal upgrade cycles.

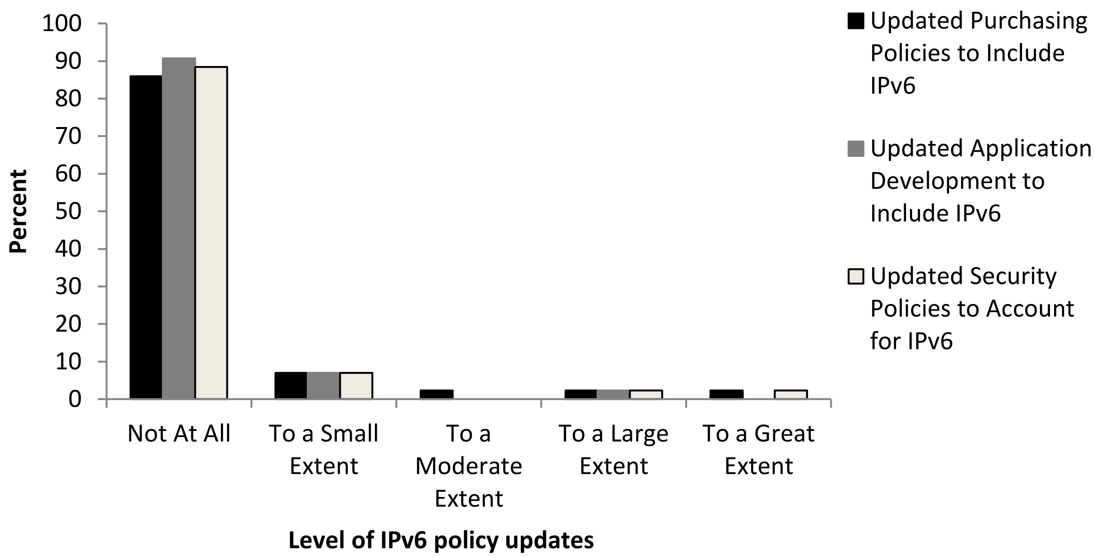


Figure 33. Levels of IPv6 readiness in policy frameworks.

The last facet of IPv6 preparedness concerns deployment steps of conducting an address plan and actual deploying of IPv6. In fact, 86% of organizations had not yet conducted an IPv6 addressing plan and 84% have not begun to deploy IPv6 (Fig. 34).

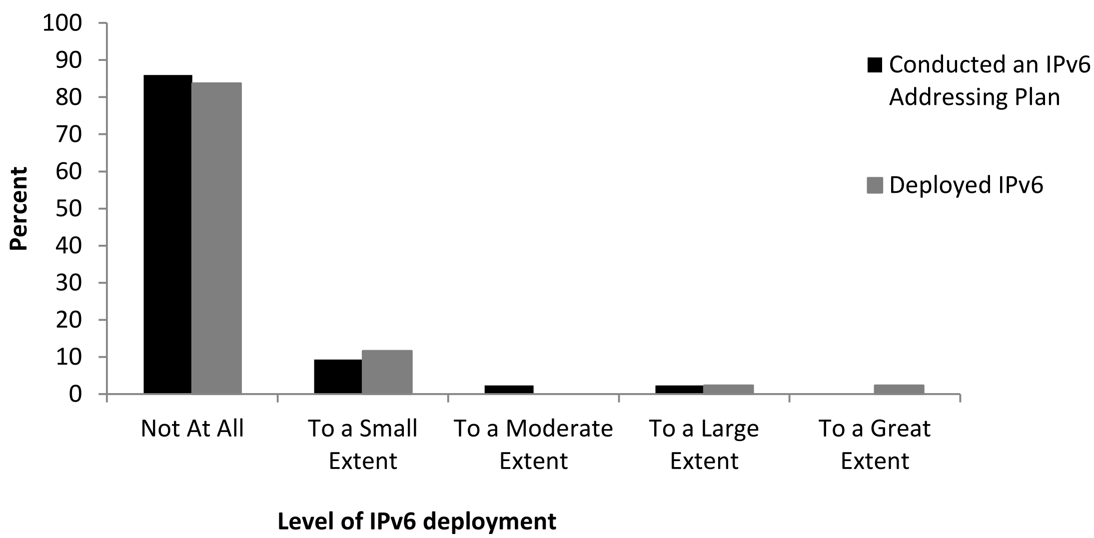


Figure 34. Levels of IPv6 deployment.

This chapter presented descriptive statistical analysis and findings of the survey data collected from 68 enterprise organizations located within eastern North Carolina. Demographic data revealed good cross representation of organizations varying in size, industry, and geographic operations. Organizations ranged in size from fewer than 50 employees to more than 25,000 employees. All industry categories were represented in the data with manufacturing, construction, health services, and service providing organization making up the majority of sectors represented. While most organizations had operations in North America, there was some representation from all five geographic regions.

The results of the IPv6 readiness data showed that only 30% of organizations had advance beyond the first stage of IPv6 readiness (awareness) and that the majority of respondents (75%) did not believe IPv6 was an urgent issue. An assessment of the IPv6 planning in the areas of training, high level planning, assessment of the current environment, updated policy framework, and IPv6 deployment revealed that the majority of organizations had made little to no progress in these areas. It is not surprising that so few organizations had made progress toward IPv6 adoption, since the majority (73%) of respondents indicated their organizations do not have any plans to deploy IPv6 within 36 months.

# CHAPTER 6

# MEASUREMENT RELIABILITY AND VALIDITY

The measurement model was evaluated for reliability, convergent validity, and discriminate validity. Construct reliability, or internal consistency, was assessed by calculating Cronbach's alpha coefficient for each of the eight scales used in this study with a minimum Cronbach's alpha score of 0.70. Convergent validity and discriminant validity were assessed by performing factor analysis using principle component extraction with Oblimin rotation on 23 questionnaire items capturing the eight factors in the IPv6 readiness model. Items with Kaiser-Meyer-Olkin (KMO) values below 0.50 and with cross loadings on multiple factors were removed from analysis. Only factors with minimum eigenvalues of 1.0 and minimum contributions of 5% to the cumulative variance were considered for extraction. A scree test was conducted to further confirm factor extraction.

## Internal Consistency Reliability

The reliability of a scale is an indicator of its internal consistency. This consistency is the degree to which the survey items that make up a scale are measuring the same underlying latent variable or construct. Multiple Likert questions were used in this study to form eight scales, with each scale representing a construct in the IPv6 readiness model: relative advantage, complexity, compatibility, top management support, organizational readiness, coercive pressure, mimetic pressure, and normative pressure. It was expected that if the scales used in this study were reliable, then the Likert items making up each scale should be measuring the same underlying construct. The most commonly applied estimate of scale reliability is Cronbach's Coefficient alpha (α) (Pallant, 2010) and was the method used in this study.

To evaluate model reliability in this study, Cronbach's alpha coefficient was calculated (Formula 2) for each of the eight scales used in this study.

Cronbach's alpha (α) is expressed as a number between 0 and 1. The higher the correlation between scale items, the higher the value of Cronbach's alpha. The literature gives mixed acceptable values for Cronbach's alpha, ranging from 0.70 to 0.95; however, George and Mallery (2003, as cited in Gliem & Gliem, 2003) provide the rules for interpretation of Cronbach's alpha values (Table 17). There is also disagreement on maximum Cronbach alpha levels and a previous study argues that Cronbach's alpha levels which exceed 0.90 suggests that there are redundant items in the scale that should be considered for removal (Tavakol & Dennick, 2011).

Table 17

Cronbach's alpha values (α). These values are categorized in relation to their acceptability in determining the inter-relationships of factors.

| Alpha Value | Scale |
|---|---|
| >0.90 | Excellent |
| >0.80 | Good |
| >0.70 | Acceptable |
| >0.60 | Questionable |
| >0.50 | Poor |
| Less than 0.50 | Unacceptable |

The minimum Cronbach's alpha score considered acceptable was $\alpha \geq 0.70$. The minimum corrected item-total correlation, or the degree in which each item correlates with the total scale score, was $> 0.30$. If the corrected item-total correlation is low ($< 0.30$), it indicates that the item is measuring something different than the scale as a whole.

The impact of removing an item from the scale is given in the "Cronbach's alpha if deleted column" (Table 18). If the value in this column is higher than the final Cronbach's alpha value, then consideration should be given to removing the item to increase the Cronbach's alpha score. In the present study, with the exception of the organizational readiness scale, all scales achieved a Cronbach's alpha score well above the minimum acceptable value ($\alpha \geq 0.70$; Table 18).

Table 18

Results of reliability analysis. Note that scales with only two items have a dash in the "Cronbach's alpha if deleted" column since a scale must have a minimum of two items.

| Factor | Number of Items | Cronbach's Alpha | Cronbach's Alpha if Deleted | Corrected Item-Total Correlation |
|---|---|---|---|---|
| Relative Advantage | 4 items | .95 | | |
| RA1 | | | .94 | .88 |
| RA2 | | | .93 | .92 |
| RA3 | | | .93 | .92 |
| RA4 | | | .96 | .84 |
| Complexity | 2 items | .87 | | |
| CPX1 | | | - | .77 |
| CPX2 | | | - | .77 |
| Compatibility | 5 items | .75 | | |
| CMP1 | | | .72 | .51 |
| CMP2 | | | .68 | .58 |
| CMP3 | | | .73 | .44 |
| CMP4 | | | .72 | .50 |
| CMP5 | | | .67 | .60 |
| Top Management Support | 3 items | .97 | | |
| TM1 | | | .93 | .95 |
| TM2 | | | .97 | .90 |
| TM3 | | | .94 | .93 |
| Organizational Readiness | 2 items | .59 | | |
| ORD1 | | | - | .43 |
| ORD2 | | | - | .43 |
| Coercive Pressure | 8 items | .98 | | |
| CP1 | | | .99 | .78 |
| CP2 | | | .98 | .99 |
| CP3 | | | .98 | .99 |
| CP4 | | | .98 | .98 |
| CP5 | | | .98 | .98 |
| CP6 | | | .98 | .99 |
| CP7 | | | .98 | .93 |
| CP8 | | | .99 | .86 |
| Mimetic Pressure | 2 items | .76 | | |
| MP1 | | | - | .61 |
| MP2 | | | - | .61 |
| Normative Pressure | 2 items | .80 | | |
| NP1 | | | - | .69 |
| NP2 | | | - | .69 |

The findings from the reliability analysis for each scale are discussed next.

1. Relative advantage - The scale of relative advantage consisted of four items. The scale had a high internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.95$. Only one item, RA4, had a "Cronbach's alpha if deleted" score higher than .95 ($\alpha > 0.95$), but since this was not considered a significant increase in α, the item was retained. All items had a correct item-total correlation well above the minimum acceptable value of 0.30 ($\alpha > 0.30$). All items were considered to reliably measure the construct of relative advantage and were retained in the scale.
2. Complexity - The scale of complexity consisted of two items. The scale had a high internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.87$. Since no items would significantly increase α if deleted and since all items had a correct item-total correlation well above 0.30 ($\alpha > 0.30$), all items were considered to reliably measure the construct of complexity and were retained in the scale.
3. Compatibility - The scale of compatibility consisted of five items. The scale had an acceptable level of internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.75$. Since no items would significantly increase α if deleted and since all items had a correct item-total correlation above 0.30 ($\alpha > 0.30$), all items were considered to reliably measure the construct of compatibility and were retained in the scale.
4. Top management support - The scale of top management support consisted of three items. The scale had a high internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.97$. Since no items would significantly increase α if deleted and since all items had a correct item-total correlation well above 0.30 ($\alpha > 0.30$), all

items were considered to reliably measure the construct of top management support and were retained in the scale.

5. Organizational readiness - The scale of organizational readiness consisted of two items. The scale had a low and unacceptable internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.59$. Since no items would significantly increase $\alpha$ to above acceptable levels if deleted, the items were considered to not reliably measure the construct of organizational readiness but were rather stand-alone items.
6. Coercive pressure - The scale of coercive pressure consisted of eight items. The scale had a high internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.98$. Two items did have slightly higher alpha if deleted scores (CP1 and CP8 with 0.99) but since this was not considered a significant increase in $\alpha$, the two items were retained. All items had a correct item-total correlation well above 0.30 ($\alpha > 0.30$). All items were considered to reliably measure the construct of coercive pressure and were retained in the scale.
7. Mimetic pressure: The scale of mimetic pressure consisted of two items. The scale had an acceptable internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.76$. Since no items would significantly increase $\alpha$ if deleted and since all items had a correct item-total correlation well above 0.30 ($\alpha > 0.30$), all items were considered to reliably measure the construct of mimetic pressure and were retained in the scale.
8. Normative pressure: The scale of normative pressure consisted of two items. The scale had good internal consistency, with a Cronbach alpha coefficient reported of $\alpha = 0.80$. Since no items would significantly increase $\alpha$ if deleted and since all items had

a correct item-total correlation well above 0.30 (α > 0.30), all items were considered to reliably measure the construct of normative pressure and were retained in the scale.

The results of the reliability analysis showed that of the eight scales used in the model, seven had high internal consistency as measured by a Cronbach's alpha and high corrected total-item correlations, suggesting strong relationships among the items in the scales. The scale of organizational readiness was determined to measure two different underlying constructs with one measuring the financial readiness of an organization and the other, the technical readiness of an organization. By measuring internal consistency of a scale, Cronbach's alpha can be used to assess to what extent the items on the scale are measuring the same underlying dimension or latent variable. However, Cronbach's alpha cannot detect if scale items are also reflecting some other underlying dimension and thus for this assessment, factor analysis will be performed.

## Construct Validity

Two subtypes of construct validity, convergent validity and discriminant validity, were evaluated using exploratory factor analysis (EFA). Convergent validity occurs when items that measure the same factor correlate highly with items they theoretically should be similar to. Discriminant validity is achieved if an item correlates more highly with items intended to measure the same factor than with items it theoretically should not be similar to (Chau & Tam, 1997). Although the survey items used in this study were adapted from previous studies, parts of the survey included new items. Additionally, the adapted survey had not previously been applied to the context of IPv6 adoption. Because there was no expectation of the number or nature of the variables, EFA was appropriate for this study (Williams, Onsman, & Brown, 2010).

Prior to performing EFA, the suitability of data was assessed. The first consideration was sample size. There is little consistency in the literature concerning minimum sample size for reliable EFA and there are many published “rules-of-thumb”. MacCallum et al. (1999, as cited by Field 2000) argues that the importance of sample size diminishes as communalities increase, and suggests that small sample sizes of less than 100 may be adequate with all communalities measured above 0.6, which is how much variance is explained by each item. Another measure of sample adequacy is the Kaiser-Meyer-Olkin measure of sampling adequacy, or (KMO-test). This test considers the sample adequate if the test gives a KMO value of > 0.60 (Pallant, 2010). The next consideration was the presence of inter-correlations between variables. Variables measuring the same underlying factors were expected to correlate with each other with a minimum correlation value $r \geq 0.30$. In addition, because factor analysis is sensitive to singularity, variables that display perfect correlation ($r = 1.0$) with other variables should be excluded from analysis (Field, 2000). A review of the correlation table (Appendix E) revealed singularity between the variables CP2, which is the perception of risk of losing important customers if the organization does not adopt IPv6, and CP6, which is the perception of risk of losing important trading partners if the organization does not adopt IPv6. As a result it was decided to remove item CP6 from the analysis.

After data suitability was determined, 27 items were subjected to Principal Component Analysis (PCA) extraction using SPSS version 22.0. According to Gorsuch ( 1983, as cited by Williams et al. 2010), PCA is the recommended extraction method when there is no prior theory or model. Additionally, Tabachnick and Fidell (2007, as cited by Pallant, 2010), conclude that PCA is the preferred choice for obtaining an empirical summary of the data. A review of the anti-image correlation matrix, shown in Appendix F, was used to identify any variables with KMO measures below acceptable levels (< 0.05). Field (2000) offers the following guidelines for KMO measures: values less than 0.5 are unacceptable, between 0.5 and 0.7 are mediocre, between 0.7 and 0.8 are good, between 0.8 and 0.9 are great, and values above 0.9 are superb. The anti-image matrix contained two items with KMO values below the minimum acceptable level of 0.50; CMP3 with a KMO value of .40 and CMP4 with a KMO value of .30. These two items were removed from analysis and PCA was run a second time with the 25 remaining items. A review of the results of the second run of PCA revealed two items in the pattern matrix (ORD1 and ORD2) with crossloadings on multiple factors. Crossloading is when an item loads strongly (> 0.32) on two or more factors (Yong & Pearce, 2013). To achieve a simpler factor structure and eliminate crossloading, these two items were removed from analysis and the PCA was run for a third time with the remaining 23 items.

The third run of PCA produced a simple four factor structure. A simple structure is obtained "when each factor has large loadings for only some of the variables, making it easier to identify" (Norusis, 2012, p. 426). The resulting Kaiser-Meyer-Olkin value was 0.80, exceeding the recommended value of 0.60 (Pallant, 2010) for sample adequacy, and Bartlet's Test of Sphericity reached statistical significance ($p < 0.001$) (Williams et al., 2010), supporting the factorability of the correlation matrix of the 23 items (Table 19).

Table 19

KMO and Bartlett's test results.

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .800 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1100.665 |
| | df | 253 |
| | Sig. | .000 |

PCA revealed the presence of five factors (components in SPSS) with eigenvalues exceeding 1, explaining 52.48%, 13.67%, 8.23%, 6.59% and 4.55% of the variance, respectively, for a cumulative 85.51% of the variance explained (Table 20).

Table 20

Total variance explained. Note this table has been truncated to show only factors with eigenvalues above 1.0.

| | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings |
|---|---|---|---|---|---|---|---|
| Component | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total |
| 1 | 12.07 | 52.477 | 52.477 | 12.07 | 52.477 | 52.477 | 9.046 |
| 2 | 3.143 | 13.666 | 66.143 | 3.143 | 13.666 | 66.143 | 9.365 |
| 3 | 1.892 | 8.227 | 74.370 | 1.892 | 8.227 | 74.370 | 2.888 |
| 4 | 1.516 | 6.589 | 80.959 | 1.516 | 6.589 | 80.959 | 3.033 |
| 5 | 1.047 | 4.551 | 85.510 | 1.047 | 4.551 | 85.510 | 5.864 |

Not all factors are retained in factor analysis, therefore it must be decided which factors are retained or extracted (Field, 2000). Yong and Pearce (2013) state that extracting too many factors can “present undesirable error variance” but, extracting too few may “leave out valuable common variance” (p. 85). Therefore, it is suggested that multiple criteria should be used to determine which factors are extracted (Pallant, 2010; Williams et al., 2010). Three criteria were used in this study to determine the number of factors to retain from the extraction. First, the Guttman-Kaiser rule was used to eliminate factors from analysis with eigenvalues smaller than 1.0 (Field, 2000; Williams et al., 2010). Eigenvalues associated with a factor indicate the substantive importance of the factor. By eliminating all factors with eigenvalues less than 1.0, five factors remained for analysis. Second, only factors explaining more than 5% of the variance were considered for extraction, as suggested by Lund (2010), which resulted in retaining four factors for analysis. Finally, to confirm a factor solution, a scree test was conducted using the scree plot (Fig. 35). In the scree test, the scree plot is inspected to find a point at which the shape or slope of the curve breaks and becomes horizontal. This is a subjective test and is open to interpretation by the researcher (Pallant, 2010). The scree plot for the present study shows the first break and leveling off after the forth factor (Fig. 35). This, combined with only four factors explaining more than 5% of the variance, was used to confirm a four factor solution.

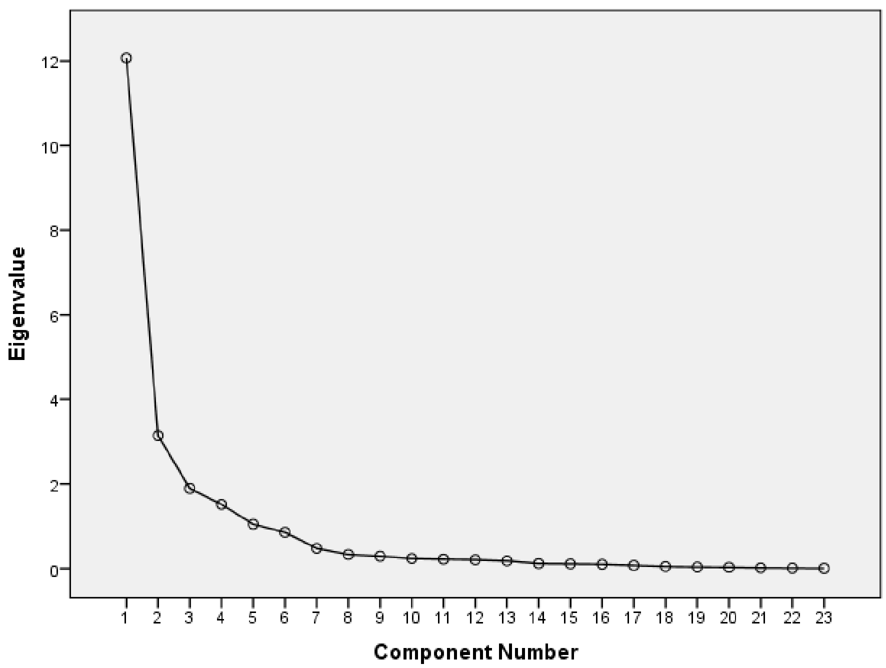


Figure 35. Scree plot.

Factor analysis was run a fourth time using Oblimin rotation and the fixed number of factors to extract set to 4. The goal of rotation is to arrive at a simple structure with each variable loading on as few factors as possible and at the same time maximize the number of high loadings on each variable (Yong & Pearce, 2013). Oblimin rotation was chosen as it is an oblique rotation method that may produce more accurate results for research involving human behaviors (Williams et al., 2010). Oblimin rotation gives two tables of loadings, the pattern matrix and the structure matrix (Table 21). The pattern matrix shows the factor loadings of each variable on each of the four factors. According to Stevens (1979, as cited by Field, 2000, p. 440), for a small sample size of 50, factor loadings of > 0.722 are considered significant. Also, at least two or three variables in the pattern matrix should load on a factor (Lund, 2010). The structure matrix shows the correlation between variables and factors (Table 21).

Table 21

Four factor solution results. The third column in Table 21, communalities, shows how much of the variance in each item is explained. Low values of < 0.30 may indicate that the item does not fit well with the other items in the factor.

| Item | Pattern Matrix | | | | Structure Matrix | | | | Communalities |
|---|---|---|---|---|---|---|---|---|---|
| | Factor | | | | Factor | | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| RA2 | .93 | .03 | .17 | .05 | .91 | .54 | -.05 | .19 | .86 |
| TM1 | .87 | .05 | -.10 | -.18 | .90 | .47 | -.31 | -.05 | .85 |
| MP2 | .87 | -.05 | .00 | .05 | .85 | .44 | -.20 | .15 | .72 |
| NP2 | .87 | -.06 | -.03 | .16 | .84 | .43 | -.23 | .24 | .73 |
| RA3 | .86 | .05 | .05 | .05 | .88 | .54 | -.16 | .18 | .79 |
| RA1 | .84 | .09 | -.08 | -.12 | .89 | .51 | -.29 | .01 | .81 |
| RA4 | .83 | .04 | -.01 | -.07 | .85 | .48 | -.21 | .05 | .72 |
| TM3 | .80 | .12 | -.23 | -.17 | .89 | .51 | -.42 | -.04 | .88 |
| TM2 | .78 | .14 | -.19 | -.15 | .89 | .54 | -.38 | -.01 | .84 |
| NP1 | .69 | .14 | .25 | .29 | .74 | .60 | .09 | .43 | .74 |
| MP1 | .57 | .16 | .02 | .16 | .67 | .52 | -.12 | .28 | .50 |
| CP1 | -.14 | .96 | -.01 | -.10 | .37 | .85 | -.02 | .19 | .75 |
| CP2 | .07 | .90 | .01 | .09 | .58 | .99 | -.05 | .39 | .98 |
| CP5 | .10 | .91 | .06 | .05 | .59 | .98 | -.01 | .35 | .97 |
| CP3 | .04 | .90 | .00 | .12 | .55 | .97 | -.05 | .41 | .95 |
| CP7 | .08 | .90 | -.09 | .02 | .59 | .95 | -.15 | .31 | .92 |
| CP4 | .11 | .90 | -.01 | .07 | .61 | .98 | -.08 | .36 | .96 |
| CP8 | .09 | .85 | .00 | -.06 | .55 | .88 | -.06 | .23 | .78 |
| CPX1 | .01 | .02 | .94 | .03 | -.20 | -.01 | .94 | .07 | .88 |
| CPX2 | -.01 | -.07 | .91 | -.22 | -.30 | -.20 | .91 | -.22 | .90 |
| CMP1 | .20 | -.03 | -.09 | .87 | .32 | .36 | -.11 | .88 | .83 |
| CMP2 | .06 | .02 | -.21 | .85 | .23 | .34 | -.20 | .86 | .79 |
| CMP5 | -.24 | .17 | .13 | .61 | -.10 | .23 | .19 | .64 | .48 |

Convergent validity is demonstrated if items have strong loadings on their associated factors and discriminant validity is demonstrated if items load stronger on their associated factors than on other factors (Kuan & Chau, 2001). Based on the results of the principle component analysis, both convergent and discriminant validity were demonstrated for the 4 factors extracted by PCA. The pattern matrix (see Table 21) shows that the variables within each single factor are highly correlated and that all variables are only loading on a single factor. However, the analysis also revealed that items from relative advantage (RA) and top management support (TM), as well as, items from mimetic pressure (MP) and normative pressure (NP) all loaded strongly on a single factor. This is not surprising since the survey instrument was composed of items adapted from adoption studies of other technologies as well as newly constructed items. This suggests that the items making up these constructs are actually measuring a single similar concept.

# CHAPTER 7

## ANALYSIS OF VARIABLE ASSOCIATIONS

Spearman's rank-order correlation and the Chi-square test for independence were used to test for associations between variables. Spearman's rank-order correlation is a non-parametric correlation test that is recommended when data violates parametric assumptions. Since data collected in this study are measured at the ordinal level, it is considered non-parametric and thus Spearman's rank-order correlation is appropriate (Field, 2000). A full correlation matrix is shown in appendix E. The Chi-square test for independence was used to further explore the relationship between the independent variables and the dependent variable of IPv6 readiness. When the assumption of expected frequencies of 5 in at least 80%of cells could not be met, the results of the Fisher's exact probability test results were presented.

### Correlation Analysis

The Spearman's rank-order correlation was used to investigate correlations between the six scale constructs of relative advantage (RA), complexity (CPX), compatibility (CMP), top management support (TM), mimetic pressure (MP), and normative pressure (NP), the two variables measuring organizational readiness (ORD1 and ORD2), and the two variables measuring organization size (SZ1 and SZ2) with the independent variable of IPv6 readiness (HS). The following guideline recommended by Cohen (1988, as cited in Pallent, 2010) was used for interpreting the strength of the correlation: small $r_s$ =.10 to .29, medium $r_s$ = .30 to .49, and large $r_s$ = .50 – 1.0.

The resulting correlation matrix revealed two constructs with significant correlations with the dependent variable IPv6 readiness (HS; Table 22). There was a significant positive relationship between the relative advantage (RA) construct and IPv6 readiness (HS) ($r_s$ = .40, $p$ < 0.01) and there was also a significant positive relationship between the coercive pressure (CP) construct and IPv6 readiness ($r_s$ = .37, $p$ < 0.05) with the dependent variable of IPv6 readiness (HS).

Table 22

Correlation results.

| Variables | RA | CPX | CMP | TM | ORD1 | ORD2 | SZ1 | SZ2 | CP |
|---|---|---|---|---|---|---|---|---|---|
| RA | 1.00 | -.21 | .15 | .86** | .51** | .35* | -.12 | -.03 | .60** |
| CPX | -.21 | 1.00 | .00 | -.40* | -.34* | -.31* | .36* | .51** | -.10 |
| CMP | .15 | .00 | 1.00 | -.01 | .16 | .44** | .22 | .21 | .30 |
| TM | .86** | -.40* | -.01 | 1.00 | .50** | .26 | -.15 | -.05 | .56** |
| ORD1 | .51** | -.34* | .16 | .50** | 1.00 | .40** | -.37* | -.31 | .42** |
| ORD2 | .35* | -.31* | .44** | .26 | .40** | 1.00 | -.07 | -.12 | .38* |
| SZ1 | -.12 | .36* | .22 | -.15 | -.37* | -.07 | 1.00 | .86** | .08 |
| SZ2 | -.03 | .51** | .21 | -.05 | -.31 | -.12 | .86** | 1.00 | .06 |
| CP | .60** | -.10 | .30 | .56** | .42** | .38* | .08 | .06 | 1.00 |
| MP | .67** | -.25 | .09 | .74** | .50** | .26 | -.32* | -.24 | .52** |
| NP | .73** | -.18 | .16 | .74** | .48** | .35* | -.36* | -.29 | .57** |
| HS | .40** | -.18 | .15 | .23 | .05 | .21 | .19 | .07 | .37* |

**Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 22

Continued

| Variables | MP | NP | HS |
|---|---|---|---|
| RA | .67** | .73** | .40** |
| CPX | -.25 | -.18 | -.18 |
| CMP | .09 | .16 | .15 |
| TM | .74** | .74** | .23 |
| ORD1 | .50** | .48** | .05 |
| ORD2 | .26 | .35* | .21 |
| SZ1 | -.32* | -.36* | .19 |
| SZ2 | -.24 | -.29 | .07 |
| CP | .52** | .57** | .37* |
| MP | 1.00 | .83** | .09 |
| NP | .83** | 1.00 | .23 |
| HS | .09 | .23 | 1.00 |

The correlation coefficients between the independent variables were less than 0.9 indicating that the data was not affected by a multicollinearity problem (Pallant, 2010). The results of the correlation analysis revealed that of the eleven constructs, relative advantage and coercive pressure had the strongest correlations with IPv6 readiness. This indicates that as the perception of the relative advantage of IPv6 and the perception of pressure on the organization to adopt IPv6 are associated with the organization's level of IPv6 readiness.

To further investigate associations between the independent and dependent variable, the chi-square test of independence was conducted on the constructs.

## Fishers Exact Test

Associations between the model constructs and the dependent variable were analyzed using Fisher's exact test. Fisher's exact test for independence is a non-parametric test that is appropriate for determining if two categorical variables are associated (Lund, 2010). To use the Fisher's exact test two assumptions must be met: (1) random samples, and (2) independent observations. Because this study has a relatively small sample size, the number of expected cell frequencies less than 5 exceeded 80%, therefore the Fisher's exact test results are reported (Pallant, 2010). Fisher's exact test statistic measures the divergence of the observed data (*o*) from the value that is expected (*e*), if the null hypothesis of no association were not rejected.

Each variable in the model was tested for association with the dependent variable, the stage of IPv6 adoption readiness. The Fisher's exact test revealed there was a significant association between relative advantage (RA) and IPv6 readiness with a significance of $p = 0.035$. Examination of the cell frequencies between relative advantage showed that 57% of respondents that disagree with IPv6 providing relative advantage were at stage 1 (awareness), while 100% of respondents that agreed with IPv6 providing relative advantage were at stage 6 (general deployment).

The Fisher's exact test also revealed there was a significant association between coercive pressure (CP) and IPv6 readiness with a significance of $p = 0.028$. Examination of the cell frequencies between relative advantage showed that 78% of respondents that disagree that there is coercive pressure on their organization to adopt IPv6 were at stage 1 (awareness) while 100% of respondents that were neutral to slightly agreeing indicated some level of deployment, either at stage 5 (limited deployment) or stage 6 (general deployment).

Finally, the Fisher's exact test revealed there was a significant association between normative pressure (NP) and IPv6 readiness with a significance of $p = 0.028$. Examination of the cell frequencies between relative advantage showed that 65% of respondents that disagree that there is normative pressure on their organization to adopt IPv6 were at stage 1 (awareness) while 50% of respondents that agreed were at stage 6 (general deployment; Fig. 36).

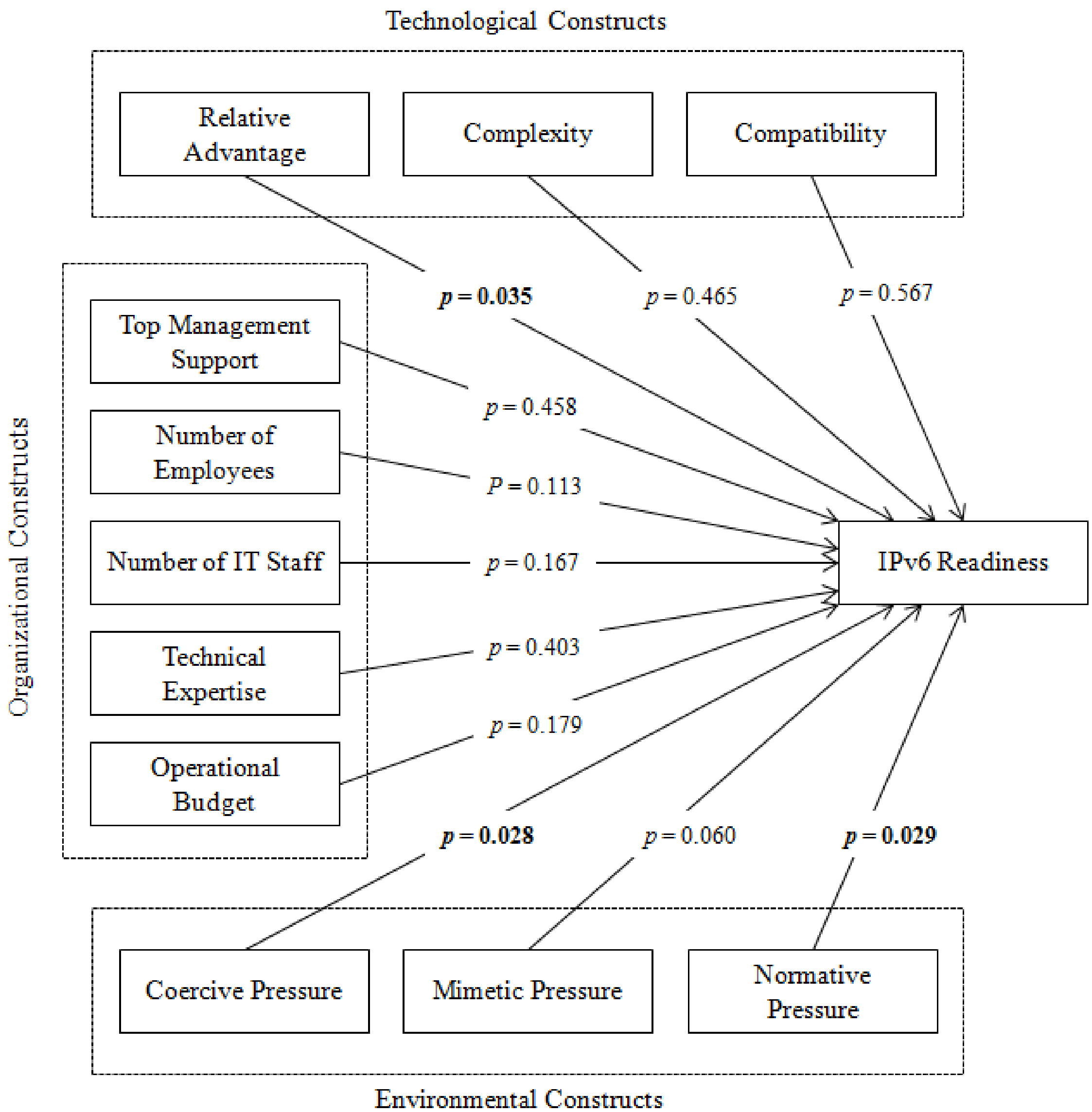


Figure 36. Results of Fisher's exact test. Significant levels ($p < 0.05$) are shown in bold.

The test for variable associations was assessed using Spearman's rank-order correlation and with the Fisher's exact test. The variables that showed significant associations from both tests were those from the constructs of relative advantage and coercive pressure while the Fisher's exact test also revealed an association between normative pressures and IPv6 readiness. The individual survey items that make up the scales of relative advantage, coercive pressure and normative pressure, may be measuring the perceptions of IPv6 decision makers on the business case for IPv6 and how that can translate into return on investment. These survey items seem to measure the perception of potential gains offered by IPv6 in the areas of entering new markets, cost saving products and services, reaching new customers, and increased business efficiencies with customers, suppliers, and trading partners. These findings support the view that the lack of a justifiable business case for IPv6 is deterring many organizations from adopting.

# CHAPTER 8

## DISCUSSION, RECOMMENDATIONS AND FUTURE WORK

The extant literature on IPv6 adoption points to a need for more empirical research to understand both the IPv6 readiness of enterprise organizations and the technology adoption factors associated with IPv6 adoption readiness. This study fulfills this need as the first known empirical assessment of the IPv6 readiness of enterprise organizations in the United States and the first to investigate the technology adoption factors associated with IPv6 adoption readiness. Additionally this study makes a significant contribution to the technology adoption literature as the first to investigate IPv6 adoption readiness through the integration of diffusion of innovation and institutional theories within the technological-organizational-environmental framework.

The results of this study revealed that enterprise organizations in eastern North Carolina have not made significant preparations for IPv6 adoption in any of the following five facets of IPv6 preparedness, which are: (1) training, (2) high-level planning, (3) assessment of the current environment, (4) updated policy frameworks, and (5) IPv6 deployment. These findings support the industry IPv6 statistics available from the National Institute of Standards and Technology website which showed very few (2.4%) organizations in eastern North Carolina have been assigned IPv6 addresses. The study also revealed that the IT decision makers of many of the organizations surveyed were unaware of IPv6. This is a very concerning finding because if the IT decision makers in these organizations are unaware of IPv6, they are also very likely to be unaware of the exhaustion of the IPv4 address space and the potential impact to their business model going forward.

Of the respondents who were aware of IPv6, the large majority did not believe IPv6 adoption to be an urgent issue at this time for their organizations. The respondents cited a lack of industry pressure, having plenty of private IPv4 addresses, lack of vendor support, and availability of NAT solutions as the primary reasons for the lack of urgency. The majority of the respondents also indicated that they have no plans to deploy IPv6 within the next three years. This suggests that these decision makers do not perceive IPv4 exhaustion as a threat to their company's business model nor do they perceive any business case that justifies the investment of resources into an IPv6 migration. However, the literature shows that these views are misguided. IPv6 adoption is not just about adding more IP addresses to the network, but rather it is about upgrading the network to take advantage of a "Next Generation" of applications, services, and technologies that can allow an organization to leverage competitive advantage. It is about not being left behind while organizations that are early adopters of IPv6 take market share. Those that have not yet developed an IPv6 strategy are already late to the game and are at risk of having to deploy IPv6 in a rushed "put-out-the-fire" manner that exposes the organization to unnecessary costs and security vulnerabilities.

A model of IPv6 adoption was presented with factors influencing the IPv6 readiness of organizations. The model was developed based on the TOE framework and the innovation adoption factors included in the contexts were factors found to be significant in other prior studies on IT innovation adoption. The results of this study provided insight to which factors are associated with the level of IPv6 readiness of organizations. Statistical analysis using Fisher's exact test showed that of the nine technology adoption factors in the model, only three (i.e.

relative advantage, coercive pressure, and normative pressure) were significantly associated with differences in organizational levels of IPv6 readiness. This finding addresses the research question: "What technology adoption factors are associated with the IPv6 adoption readiness of organizations in eastern North Carolina?" and supports the anecdotal evidence linking the lack of a justifiable business case to the lack of enthusiasm of organizations to adopt IPv6. Typically the business case for adoption of a new technology is made in terms of a return on investment (ROI), which compares the magnitude and timing of the expected costs of a project, with the expected and gains. Organizations which do not perceive a competitive advantage or external pressure from trading partners are unlikely to translate IPv6 adoption into a measureable ROI.

Organizational leaders and decision makers unable to see the potential future benefit of IPv6 and the need to begin planning for its eventual adoption should carefully consider some of the very real implications that IPv4 exhaustion has on their business model and the possible consequences of inaction. Business revenues can be negatively impacted if the organization's brand and image are damaged due to customer perceptions which suggest the organization is a laggard in adopting new technologies and unable to provide next generation products or services. As IPv6 adoption increases, new applications and services requiring IPv6 will become more common and these will be unavailable to organizations still running an IPv4 only networks. New services or solutions, such as senor networks or new innovations made possible by the Internet of things, will likely require far more addresses than an organization has available in its private address pools. Additionally, IPv4 is already depleted in some geographic regions, and in these regions Internet growth is occurring with IPv6. This growing IPv6 internet is composed of potential customers and trading partners that may not be able to communicate with organizations that have not enabled IPv6 on external public facing services. Finally, the risks and costs associated with operating and maintaining a legacy IPv4 network infrastructure will only increase over time.

The longer an organization delays IPv6 adoption, the more direct and indirect costs it will incur to operate in the IPv4 internet. So the sooner an organization begins in IPv6 adoption planning, the more time it will have to perform the migration inside of normal upgrade cycles. By carefully planning the IPv6 migration, an organization minimizes costly mistakes, security breaches, network downtime, and expensive hardware and application upgrades. Hagen (2011) warns that a proper IPv6 deployment is a "systematic and time consuming process that can take from three to five years, or longer and involves more than just hardware and software upgrades, which are significant in themselves, but also auditing, testing, and reconfiguring every device and application on the network. To this point, some recommendations are given for organization decision makers to develop an IPv6 strategy.

## Recommendations

The first recommendation made by this study concerns future research into the adoption of information technologies by organizations. There are many theories available for use by researchers in technology adoption studies. The most commonly used theories are the technology acceptance model (TAM), the theory of planned behavior (TPB), the unified theory of acceptance and use of technology (UTAUT), diffusion of innovations (DOI), intuitional theory, and the technological-organizational-environmental framework (TOE). While TAM, TPB, and UTAUT have been shown to be useful in studies at the individual level of technology adoption, DOI, institutional theory, and the TOE framework each have a solid theoretical basis and are recommended to future researchers as a starting point for developing a technology adoption model. The TOE framework combined with DOI and institutional theory has proved, through previous empirical studies, to be useful in understanding and identifying the significant factors influencing the adoption of various information technologies such as VoIP, RFID, and Cloud. This study extended the use of the TOE framework to the investigation of factors associated with IPv6 adoption readiness with the results identifying technological and environmental constructs significantly associated with IPv6 readiness within organizations.

The TOE framework identifies three contexts that influence the technology adoption process: technological context, organizational context, and environmental contexts. Since the TOE framework is a high-level theoretical model and does not proved specific factors for establishing causal relationship, it is recommended that researchers should combine the framework with other theories and previous technology adoption studies to identify specific technological, organizational, and environmental constructs. Because the specific constructs identified with the three contexts may vary across different studies, it is further recommended that researchers perform an extensive literature review to determine the specific technological, organizational, and environmental constructs best suited for hypothesis development for the specific technology under investigation.

This study found that some hypothesized constructs derived from the TOE framework were insignificant in association with IPv6 readiness. This was not seen as a limitation of the TOE framework as a basis for the IPv6 readiness model. In order for the TOE framework to be generalized to other contexts, such as IPv6 readiness, more empirical studies must be conducted to validate and revise the model. It is recommended that future research into technology adoption incorporate other variables into predictive models for better understanding of the causality and interrelationships between variables.

The second recommendation is given to organizations that have not yet developed an IPv6 adoption strategy or begun IPv6 deployment. Leaders and IT decision makers within these organizations must understand the various IPv6 deployment options available so that a strategy that matches the organization's strategic goals can be implemented in an aggressive and well thought–out approach. Although each deployment will be different, and based on the business and technical drivers of the organizations, some generic guidelines are recommended to start the planning process:

1. Start IPv6 planning, as soon as possible. The scope of the IPv6 adoption process will likely be measured in years and not months or weeks. It is therefore imperative that organizations begin laying down the foundations of an IPv6 strategy as soon as possible.
2. Assess IPv6 skills. One of the first tasks to complete prior putting the IPv6 adoption plan into action is to ensure all organizational teams involved in the IPv6 migration (not just IT) are educated on IPv6. Areas of training should include, but not limited to: IPv6 technology, IPv6 security, IPv6 deployment, IPv6 configuration on operating systems, software development for IPv6 features, and user training on any new applications and services that will use IPv6. "The scope of the IPv6 project cannot be defined, IPv6 assessment cannot be performed, security policies to accommodate IPv6 cannot be written, and deployment of the protocol cannot be successful unless each team member involved in the process is adequately trained and familiar with IPv6" (Grossettete, 2008, p. 383).
3. Assess the environment. A full and accurate assessment for the IPv6 compatibility of all existing equipment, hardware, and software is required. IPv6 is an infrastructure

technology and it will touch everything on the network, not just PCs and servers. Assets identified as not IPv6 compatible should be replaced with IPv6 compliant devices within planned product lifecycles. By performing upgrades within planned cycles, additional expenditures above budgeted amounts are minimized. Hardware and software vendor support for IPv6 must also be assessed. Hagen (2011) warns, "just because it says so on the box does not mean it does. Organizations should be aware that IPv6 support on existing equipment may require purchasing additional licensing fees". IPv6 support also must be evaluated on the organization's Network Management Systems (NMS), which is typically used to manage and monitor devices on the network, as well as, the organization's application portfolio. Any applications that use hard-coded IPv4 address or IP address stored in 32-bit numeric fields may need to be re-coded or replaced.

4. Assess the IT policy framework. Updating IT policies are a key component of the IPv6 adoption process. Purchasing policies should be updated to include IPv6 requirements so that products with IPv6 capabilities are acquired through regular refresh cycles. Application development policies should mandate IP agnostic applications. Security policies must be modified for specific IPv6 vulnerabilities. Beyond updating these policies, constant monitoring of compliance with the policies is required.

5. Deploy IPv6. Many architectural decisions must be made when deployment actually begins. These include the development of a comprehensive IPv6 addressing plan, choosing which routing protocol(s) will be used, and what host IPv6 address provisioning method(s) will be used on the network. A decision must also be made

on where deployment of IPv6 will begin on the network, at the core or edge. In some cases an organization may have isolated IPv6 islands to connect specific applications or users which will require choosing appropriate IPv6 tunneling mechanisms. Regardless of the specific choices made by the organization, the network must still be fully operational during the migration process. All deployment tasks must be accomplished in a way that does not impact the quality, performance, or security of the existing IPv4 network.

This recommendation list includes very general planning steps that are certainly not exhaustive. Each organization will have its own unique requirements and IPv6 deployment strategies. No matter what unique strategy an organization uses, the key to a successful IPv6 deployment is early and careful planning that involves all stakeholders in the organization.

## Limitations of This Study

There are several limitations identified in this study. First, this study was limited to enterprise organizations within the geographic boundaries of eastern North Carolina and organizations that also had a history of collaboration with Eastern Carolina University. Most of the responding organizations in the study had fewer than 500 employees. Therefore the ability to generalize the findings of this study to other regions or larger organizations is limited.

A second limitation to this study is the fact that data was collected from a single respondent within the targeted organizations. There exists the possibility that the responses from these individuals may not be representative of the entire organization or senior organization leadership. However, most of the respondents were senior IT managers, operations managers, or C-suite officers (CIOs and CTOs) who would be familiar with strategic IT planning within the organization and would play an active role in shaping the technology adoption decisions.

Therefore, for the purpose of this study, it is presumed that the responses from these individuals are actually representative of their organizations.

Third, this study may not include all factors that influence an organization's intent to adopt IPv6. The factors used in this study were limited to those found to be signification in similar studies of similar IT technology adoption. The meta-analysis by Hameed et al. (2012) presents many innovation, organizational, and environmental factors that could be included in a future study.

## Future Research

There are several recommendations for future research to add to the body of knowledge of IPv6 readiness. The first recommendation is to extend this research beyond the geographic boundary of eastern North Carolina. Future studies could be national, regional, or global in scope. These studies would provide very interesting insights as to the overall level of IPv6 readiness and could make comparisons between the regions defined by the various internet registries. Such studies could be used to assess the effectiveness and impact of government IPv6 mandates and incentives put in place by various nations and economic and political partnerships, such as the European Union.

Because this study targeted only private enterprise organizations, and excluded government institutions, military units, and internet service providers, another interesting avenue for future research is to extend the study to these specific types and demographics of organizations. Examples could include state level agencies, academic institutions, hospitals, financial institutions, and military contractors. Each type of organization will fall under different regulator bodies, governing policies, and security and privacy mandates, all of which could have measurable levels of impact on levels of IPv6 readiness.

Another study that is of interest is one which assesses the IPv6 enablement of service providers at the regional and local level. Large service providers in the U.S., such as Verizon, Comcast, and AT&T, have made significant progress on IPv6 enablement and are connecting customers on IPv6. Evidence suggests, however, that smaller providers are behind in their IPv6 implementations. If these smaller service providers are not IPv6 ready, this will present a serious challenge to enterprise customers that wish to deploy IPv6.

Lastly, future research could further assess the predictive capability of the IPv6 readiness model through logistic regression analysis. The relative weight or importance of each factor on IPv6 readiness could be explored to better understand which factor is the best predictor of IPv6 readiness. This will require obtaining a sample size large enough to meet the assumptions of regression analysis.

The results of the study show that there is much work to be done to persuade organizational leaders of the importance of preparing for eventual IPv6 adoption within their organizations, even when adoption cannot be supported by business driven return on investment. This study, by drawing awareness to the issue, is an important first step. However, it is only a first step. After awareness is raised, specific and substantial actions must be taken by organizations in all five facets of IPv6 preparedness, starting with diverse forms of targeted training. It is hoped that the findings of this study as well as future studies will encourage and incentivize organization decision makers to begin planning for IPv6 now.

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# APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL

Indiana State University
More. From day one.

Institutional Review Board

Terre Haute, Indiana 47809
812-237-3092
Fax 812-237-3092

| | |
|---|---|
| DATE: | February 25, 2014 |
| TO: | John Pickard, PhD |
| FROM: | Indiana State University Institutional Review Board |
| STUDY TITLE: | [565752-2] ANALYSIS OF IPV6 READINESS OF END-USER ENTERPRISES IN THE NORTH CAROLINA EASTERN REGION |
| SUBMISSION TYPE: | Revision |
| ACTION: | DETERMINATION OF EXEMPT STATUS |
| DECISION DATE: | February 25, 2014 |
| REVIEW CATEGORY: | Exemption category |

Thank you for your submission of Revision materials for this research study. The Indiana State University Institutional Review Board has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations (45 CFR 46). You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exempt categories, you will have to reapply to the IRB for review of your modified study.

**Internet Research:** If you are using an internet platform to collect data on human subjects, although your study is exempt from IRB review, ISU has specific policies about internet research that you should follow to the best of your ability and capability. Please review Section L. on Internet Research in the IRB Policy Manual.

**Informed Consent:** All ISU faculty, staff, and students conducting human subjects research within the "exempt" category are still ethically bound to follow the basic ethical principles of the Belmont Report: a) respect for persons; b) beneficence; and c) justice. These three principles are best reflected in the practice of obtaining informed consent.

If you have any questions, please contact Dr. Anne Foster within IRBNet by clicking on the study title on the "My Projects" screen and the "Send Project Mail" button on the left side of the "New Project Message" screen. I wish you well in completing your study.

Call
Send SMS
Add to Skype
You'll need Skype CreditFree via Skype

**EAST CAROLINA UNIVERSITY**
**University & Medical Center Institutional Review Board Office**
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office 252-744-2914 · Fax **252-744-2284** ·
**www.ecu.edu/irb**

## Notification of Amendment Approval

From: Social/Behavioral IRB
To: John Pickard
CC:

Date: 4/2/2014
Re: Ame1_UMCIRB 14-000257
UMCIRB 14-000257
ANALYSIS OF IPV6 READINESS OF END-USER ENTERPRISES IN THE NORTH CAROLINA EASTERN REGION

Your Amendment has been reviewed and approved using expedited review for the period of 4/1/2014 to no expiration exempt 2. It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. A continuing or final review must be submitted to the UMCIRB prior to the date of study expiration.The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

| Document | Description |
|---|---|
| Copy of Survey_Pickardj.docx(0.02) | Surveys and Questionnaires |
| Recruitment Script and consent document(0.01) | Recruitment Documents/Scripts |
| Script and Consent (0.02) | Consent Forms |
| Other study staff added: Lancaster, Raines & Riddick | |

# APPENDIX B: SURVEY INSTRUMENT

Good morning,

You are receiving this email as a request for help in gathering information on the level of IPv6 readiness of organizations in the North Carolina Eastern Region. The purpose of the study is to investigate IPv6 readiness, identify the significant factors that influence IPv6 readiness, and make recommendations to help organizations plan for the transition to IPv6. More than 200 other organizations throughout the North Carolina Eastern Region are included in this study.

The survey questionnaire will take approximately 15 minutes to complete and your answers are confidential. You will not be asked to identify yourself nor your organization. The information collected will be useful in understanding the current state of IPv6 adoption in the North Carolina Eastern Region.

Thank you for taking the time to complete this survey, your feedback is vital to a better understanding of the level of readiness of organizations to deploy IPv6. The survey consists of 17 questions concerning IPv6 deployment and planning in your organization. You are free to decline to answer any particular question you do not wish to answer for any reason.

There are no known risks if you decide to participate in this research study, nor are there any costs for participating in the study. Your participation in this study is voluntary and anonymous. If you choose to participate, no one will be able to identify you, nor the company you work for.

If you have any questions about your rights as a research subject, you may contact the Indiana State University Institutional Review Board (IRB) by mail at Indiana State University, Office of Sponsored Programs, Terre Haute, IN 47809, by phone at (812) 237-8217, or by e-mail at irb@indstate.edu.

If you would like to request a summary report of the results of this study, or if you have any questions or concerns about the survey, please contact myself or my advisor, Dr. Chou.

Thank you in advance for your participation

**Follow this link to the Survey:**

Or copy and paste the URL below into your internet browser:

**Follow the link to opt out of future emails:**

Mr. John Pickard
Department of Technology Systems
East Carolina University
pickardj@ecu.edu
252.328.9646

Dr. Te-Shun Chou
Department of Technology Systems
East Carolina University
252.737.1037

By clicking the "NEXT" button, you are agreeing to participate in this study. You may skip any questions you want or exit the survey at any time. The survey will take approximately 15 minutes to complete.

ANALYSIS OF IPV6 READINESS OF END-USER ENTERPRISES

Intro Thank you for taking the time to complete this survey, your feedback is vital to a better understanding of the level of readiness of organizations to adopt the next generation Internet protocol, IPv6. The survey consists of a series of questions concerning IPv6 adoption, planning, and deployment in your organization. The survey will take approximately 15 minutes to complete. There are no known risks if you decide to participate in this research study, nor are there any costs for participating in the study. Your participation in this study is voluntary and responses will remain confidential. If you choose to participate, no one will be able to identify you or your company. If you would like to request a summary report of the results of this study or if you have any questions/concerns about the survey, please contact me:

Mr. John Pickard
Department of Technology Systems
East Carolina University
pickardj@ecu.edu
252.328.9646

By clicking the “NEXT” button, you are agreeing to participate in this study. You may skip any questions you want or exit the survey at any time.

Are you currently a senior IT manager, an IT professional, or familiar with IT-related topics/issues within your organization?

- ❍ Yes (1)
- ❍ No (0)

If No Is Selected, Then Skip To End of Survey

Q1 Have you heard of IPv6 prior to receiving this survey?

- ❍ Yes (1)
- ❍ No (0)

If No Is Selected, Then Skip To Please rate how important investing i...

Q2 Do you believe IPv6 adoption is an urgent issue for your industry sector?

- Yes
- No

Q3 Please briefly explain why you do or do not believe IPv6 adoption is an urgent issue.

Q4 Do you believe IPv6 is a necessary upgrade for your industry sector?

- Yes
- No

Q5 Please briefly explain why you do or do not believe IPv6 is a necessary upgrade.

Q6 Is your service provider ready to provide IPv6 connectivity?

- Yes
- No
- Don't Know

Q24 Has your organization obtained global IPv6 addressing space?

- Yes
- No
- Don't Know

Q7 Please indicate if your organization has completed the following steps regarding IPv6 readiness.

| | Yes (1) | No (0) | Don't Know (2) |
|---|---|---|---|
| Planned to investigate IPv6 for possible production use within the next 12 months | ❍ | ❍ | ❍ |
| Conducted a trial or evaluation of IPv6 in a test environment or non-production environment | ❍ | ❍ | ❍ |
| Developed a formal IPv6 deployment plan | ❍ | ❍ | ❍ |
| Performed a limited deployment of IPv6 in at least one area of the production environment | ❍ | ❍ | ❍ |
| Deployed IPv6 in a significant portion of the production environment | ❍ | ❍ | ❍ |

Q8 If your organization has plans to deploy IPv6 into the production environment, please indicate how soon such plans will be completed.

❍ Already deployed

❍ Less than 6 months

❍ 6 to 12 months

❍ 13 to 24 months

❍ 25 to 36 months

❍ Beyond 36 months

❍ No plans to deploy IPv6

Q9 Please indicate the extent to which your organization has conducted IPv6 training in any of the following areas.

| | Not at All (1) | To a Small Extent (2) | To a Moderate Extent (3) | To a Large Extent (4) | To a Great Extent (5) |
|---|---|---|---|---|---|
| IPv6 technology | ❍ | ❍ | ❍ | ❍ | ❍ |
| IPv6 deployment | ❍ | ❍ | ❍ | ❍ | ❍ |
| IPv6 security | ❍ | ❍ | ❍ | ❍ | ❍ |
| Configuring IPv6 on network equipment | ❍ | ❍ | ❍ | ❍ | ❍ |
| Configuring IPv6 on host operating systems | ❍ | ❍ | ❍ | ❍ | ❍ |
| Developing IPv6 applications | ❍ | ❍ | ❍ | ❍ | ❍ |

Q10 Please indicate the extent to which your organization has performed the following steps toward IPv6 adoption.

| | Not at All (1) | To a Small Extent (2) | To a Moderate Extent (3) | To a Large Extent (4) | To a Great Extent (5) |
|---|---|---|---|---|---|
| Commenced planning for IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Developed an IPv6 strategy | ❍ | ❍ | ❍ | ❍ | ❍ |
| Created an IPv6 project | ❍ | ❍ | ❍ | ❍ | ❍ |
| Assessed training requirements for IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Assessed IT assets for IPv6 readiness | ❍ | ❍ | ❍ | ❍ | ❍ |
| Assessed applications portfolio for IPv6 readiness | ❍ | ❍ | ❍ | ❍ | ❍ |
| Updated IT purchasing policies to include IPv6 requirements | ❍ | ❍ | ❍ | ❍ | ❍ |
| Updated application development policies to include IPv6 support | ❍ | ❍ | ❍ | ❍ | ❍ |
| Updated security policies to take into account IPv6 issues | ❍ | ❍ | ❍ | ❍ | ❍ |

| | | | | | |
|---|---|---|---|---|---|
| Conducted an IPv6 address plan | ❍ | ❍ | ❍ | ❍ | ❍ |
| Deployed IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |

Q11 Please indicate how much you agree or disagree with the following statements concerning IPv6 adoption as they pertain to your organization.

| | Strongly Disagree (1) | Disagree (2) | Neither Agree nor Disagree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|
| Adopting IPv6 will allow our organization to be more competitive | ❍ | ❍ | ❍ | ❍ | ❍ |
| Adopting IPv6 will allow our organization to enter new businesses or markets | ❍ | ❍ | ❍ | ❍ | ❍ |
| Adopting IPv6 will help our organization to reach new customers | ❍ | ❍ | ❍ | ❍ | ❍ |
| Adopting IPv6 will allow our organization to support new products or services | ❍ | ❍ | ❍ | ❍ | ❍ |
| Top management in our organization is interested in adopting IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Top management in our organization considers adoption of IPv6 strategically important | ❍ | ❍ | ❍ | ❍ | ❍ |
| Top management in our organization has shown support for IPv6 adoption | ❍ | ❍ | ❍ | ❍ | ❍ |

Q12 CONTINUED FROM PREVIOUS SECTION Please indicate how much you disagree or agree with the following statements concerning IPv6 adoption as they pertain to your organization.

| | Strongly Disagree (1) | Disagree (2) | Neither Agree or Disagree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|
| IPv6 is more difficult to understand from a technological perspective than IPv4 | ❍ | ❍ | ❍ | ❍ | ❍ |
| IPv6 adoption is a more complex process compared to IPv4 | ❍ | ❍ | ❍ | ❍ | ❍ |
| IPv6 is compatible with our organization's existing IT infrastructure | ❍ | ❍ | ❍ | ❍ | ❍ |
| IPv6 is compatible with our organization's current software applications | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization's hardware vendors support IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization's software vendors support IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization's network management systems (NMS) support IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization has an operational budget committed to IPv6 adoption | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization has the technical expertise in-house to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |

Q13 CONTINUED FROM PREVIOUS SECTION Please indicate how much you disagree or agree with the following statements concerning IPv6 adoption as they pertain to your organization.

| | Strongly Disagree (1) | Disagree (2) | Neither Agree or Disagree (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|
| Key customers are encouraging our organization to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization risks losing important customers if we do not adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Key suppliers are encouraging our organization to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization risks losing important suppliers if we do not adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Key trading partners are encouraging our organization to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization risks losing important trading partners if we do not adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our parent company is pressuring us to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Government mandates or regulations are pressuring us to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our key competitors are currently adopting IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |
| Our organization will use IPv6 to remain competitive | ❍ | ❍ | ❍ | ❍ | ❍ |
| Industry sources (such as trade associations) are pressuring us to adopt IPv6 | ❍ | ❍ | ❍ | ❍ | ❍ |

| | | | | | |
|---|---|---|---|---|---|
| Our organization participates actively in industry, trade, or professional associations that promote IPv6 adoption | ❍ | ❍ | ❍ | ❍ | ❍ |

Q14 Please rate how important investing in information technology is to top management in your organization. This includes all IT, not just specific issues, such IPv6.

❍ Not at all Important

❍ Very Unimportant

❍ Neither Important nor Unimportant

❍ Very Important

❍ Extremely Important

Q15 Please rate how important information technology is to the fulfillment of the following objectives in your organization. This includes all IT, not just specific issues, such as IPv6.

| | Not at all Important (1) | Very Unimportant (2) | Neither Important nor Unimportant (3) | Very Important (4) | Extremely Important (5) |
|---|---|---|---|---|---|
| Personnel cost reduction | ❍ | ❍ | ❍ | ❍ | ❍ |
| Operational cost reduction | ❍ | ❍ | ❍ | ❍ | ❍ |
| Productivity improvements | ❍ | ❍ | ❍ | ❍ | ❍ |
| Improved access to information | ❍ | ❍ | ❍ | ❍ | ❍ |
| Improved quality of decision making | ❍ | ❍ | ❍ | ❍ | ❍ |
| Improved competitiveness | ❍ | ❍ | ❍ | ❍ | ❍ |
| Improved service to customers | ❍ | ❍ | ❍ | ❍ | ❍ |

Q16 Please indicate the IT projects your organization has planned for the next 3-5 years. (Please select all that apply)

- ❑ Relocate/consolidate data center
- ❑ Redesign of the DMZ
- ❑ Upgrade network infrastructure
- ❑ Replacing mainframes
- ❑ Introduction of VoIP
- ❑ Public cloud services
- ❑ Private cloud
- ❑ Software Defined Networking (SDN)
- ❑ Other, please specify: ____________________

Q17 Approximately how many employees are there in your organization globally?

- ❍ Less than 50
- ❍ 50 to 249
- ❍ 250 to 499
- ❍ 500 to 999
- ❍ 1000 to 4999
- ❍ 5000 to 9999
- ❍ 10,000 to 25,000
- ❍ more than 25,000

Q18 Approximately how many IT staff does your organization employ?

- ❍ Less than 10
- ❍ 10-50
- ❍ 51 to 100
- ❍ More than 100

Q19 Please indicate which best describes your position in your organization.

- ❍ CEO/President
- ❍ Chief Information Officer (CIO)
- ❍ Chief Technology Officer (CTO)
- ❍ IT Operations Manager
- ❍ Service Manager
- ❍ Other, please specify ____________________

Q20 Please select the industry sector in which your organization is active.

- ❍ Aerospace, aviation and defense
- ❍ Agriculture, Forestry, Fishing
- ❍ Biomedical and pharmaceutical
- ❍ Business and financial services
- ❍ Construction
- ❍ Education
- ❍ Energy
- ❍ Finance and insurance
- ❍ Government and public administration
- ❍ Health services
- ❍ Information and communications technology
- ❍ Manufacturing
- ❍ Natural resource and mining
- ❍ Retail sales
- ❍ Service providing domain
- ❍ Trade, transportation, and utilities
- ❍ Leisure and hospitality

Q21 In which county of North Carolina is your local company branch located?

Q22 In what country is your company headquartered?

Q23 Please indicate the geographic regions in which your company operates. (Please select all that apply)

- ❑ North America
- ❑ Europe/Western Asia
- ❑ East Asia/Pacific
- ❑ Latin/South America
- ❑ Africa

End. This concludes the survey. Thank you for your time and participation. If you would like a summary report of the results, please send a request to: Mr. John Pickard Department of Technology Systems East Carolina Universitypickardj@ecu.edu252.328.9646

# APPENDIX C: CODE BOOK

| Variable | SPSS Name | Coding |
|---|---|---|
| | | |
| Aware | Q1 | 0 = No<br>1 = Yes |
| Urgent Issue | Q2 | 0 = No<br>1 = Yes |
| Explain Why Urgent | Q3 | Specify |
| Necessary Upgrade | Q4 | 0 = No<br>1 = Yes |
| Explain Why Necessary | Q5 | Specify |
| ISP Ready | Q6 | 0 = No<br>1 = Yes<br>2 = Don’t Know |
| Steps toward Readiness<br>Items 1 – 5 | Q7 | 0 = No<br>1 = Yes<br>2 = Don’t Know |
| How Soon Scale | Q8 | 1 = Already Deployed<br>2 = Less than 6 Months<br>3 = 6 to 12 Months<br>4 = 13 to 24 Months<br>5 = 25 to 36 Months<br>6 = Beyond 36 Months<br>7 = No Plans to Deploy IPv6 |
| IPv6 Training Scale<br>Items 1 – 6 | Q9 | 1 (Not at all) to 5 (To a Great Extent) |
| Adoption Steps<br>Items 1 – 11 | Q10 | 1 (Not at all) to 5 (To a Great Extent) |
| Organization Factors Scale1<br>Items 1 - 7 | Q11 | 1 (Strongly Disagree) to 5 (Strongly Agree) |
| Organization Factors Scale2<br>Items 1 - 8 | Q12 | 1 (Strongly Disagree) to 5 (Strongly Agree) |
| Importance of IT to TM | Q13 | 1 (Not at all Important) to 5 (Extremely Important) |
| Importance of IT to Org<br>Items 1 - 7 | Q14 | 1 (Not at all Important) to 5 (Extremely Important) |

| | | |
|---|---|---|
| IT Projects | Q15 | 1 = Relocation/Consolidate DC<br>2 = Redesign of DMS<br>3 = Upgrade Network Infrastructure<br>4 = Replacing Mainframes<br>5 = Introduction of VoIP<br>6 = Public Cloud Services<br>7 = Private Cloud<br>8 = Software Defined Networking<br>9 = Other (Specify) |
| Employees | Q16 | 1 = Less than 50<br>2 = 50 to 249<br>3 = 250 to 499<br>4 = 500 to 999<br>5 = 1000 to 9999<br>6 = 10,000 to 25,000<br>7 = more than 25,000 |
| IT Staff | Q17 | 1 = Less than 10<br>2 = 10 to 50<br>3 = 51 to 100<br>4 = More than 100 |
| Position | Q18 | 1 = CEO/President<br>2 = CIO<br>3 = CTO<br>4 = IT Operations Manager<br>5 = Service Manager<br>6 = Other (Specify) |
| Industry Sector | Q19 | 1 – 17 choices of sectors |
| HQ | Q20 | Specify |
| Regions | Q21 | 1 = North America<br>2 = Europe/Western Asia<br>3 = East Asia/Pacific<br>4 = Latin/South America<br>5 = Africa |
| Address Space | Q24 | 0 = No<br>1 = Yes<br>2 = Don’t Know |
| Organization Factors Scale3<br>Items 1 - 9 | Q25 | 1 (Strongly Disagree) to 5 (Strongly Agree) |
| NC County | Q27 | Specify |

# APPENDIX D: MEASUREMENT ITEMS FOR VARIABLES

| | Construct | Survey Item | Source |
|---|---|---|---|
| | **Technological Context** | | |
| | Relative Advantage (RA) | | |
| 1 | RA1 | Adopting IPv6 will allow our organization to be more competitive | (Kuan & Chau, 2001) |
| 2 | RA2 | Adopting IPv6 will allow our organization to enter new businesses or markets | (Tweel, 2012; T. E. Yoon & George, 2013) |
| 3 | RA3 | Adopting IPv6 will allow or our organization to reach new customers | New |
| 4 | RA4 | Adopting IPv6 will allow our organization to support new applications and services | New |
| | | | |
| | Complexity (CPX) | | |
| 5 | CPX1 | IPv6 is more difficult to understand from a technological perspective than IPv4 | (Basaglia et al., 2009) |
| 6 | CPX2 | IPv6 adoption is a more complex process compared to IPv4 | (Henderson et al., 2012; Wang et al., 2010) |
| | | | |
| | Compatibility (CMP) | | |
| 7 | CMP1 | IPv6 is compatible with our organization's exiting IT infrastructure | (Henderson et al., 2012; Tweel, 2012; Wang et al., 2010; T. Yoon, 2009) |
| 8 | CMP2 | IPv6 is compatible with our organization's current software applications | (Henderson et al., 2012) |
| 9 | CMP3 | Our organization's hardware vendors support IPv6 | New |

| | | | |
|---|---|---|---|
| 10 | CMP4 | Our organization's software vendors support IPv6 | New |
| 11 | CMP5 | Our organization's network management systems support IPv6 | New |
| | | | |
| | **Organizational Context** | | |
| | Top Management Support (TM) | | |
| 12 | TM1 | Top management in our organization is interested in adopting IPv6 | (Tweel, 2012; Wang et al., 2010; T. E. Yoon & George, 2013) |
| 13 | TM2 | Top management in our organization considers adoption of IPv6 strategically important | (Tweel, 2012; Wang et al., 2010; T. E. Yoon & George, 2013) |
| 14 | TM3 | Top management in our organization has shown support for IPv6 adoption | (Tweel, 2012; Wang et al., 2010; T. E. Yoon & George, 2013) |
| | | | |
| | Organizational Size (SZ) | | |
| 15 | SZ1 | Approximately how many employees are there in your organization? | (Basaglia et al., 2009; MacLennan & Belle, 2013; Teo et al., 2003; T. E. Yoon & George, 2013) |
| 16 | SZ2 | Approximately how many IT Staff are in your organization? | (Teo et al., 2003) |
| | | | |
| | Organizational Readiness (ORD) | | |
| 17 | ORD1 | Our organization has an operational budget committed to IPv6 adoption | New |
| 18 | ORD2 | Our organization has the technical expertise in-house to adopt IPv6 | (Henderson et al., 2012) |
| | | | |
| | **Environmental Context** | | |
| | Coercive Pressure (CP) | | |
| | | | |
| 20 | CP1 | Key customers are encouraging our organization to adopt IPv6 | (Teo et al., 2003; Tweel, 2012; T. E. Yoon & George, 2013) |

| | | | |
|---|---|---|---|
| 21 | CP2 | Our organization risks losing important customers if we do not adopt IPv6 | (Tweel, 2012; T. E. Yoon & George, 2013) |
| 22 | CP3 | Key suppliers are encouraging our organization to adopt IPv6 | New |
| 23 | CP4 | Our organization risks losing important suppliers if we do not adopt IPv6 | (T. E. Yoon & George, 2013) |
| 24 | CP5 | Key trading partners are encouraging our organization to adopt IPv6 | (Henderson et al., 2012; Wang et al., 2010) |
| 25 | CP6 | Our organization risks losing important trading partners if we do not adopt IPv6 | (Henderson et al., 2012) |
| 26 | CP7 | Our parent company is pressuring us to adopt IPv6 | (Basaglia et al., 2009) |
| 27 | CP8 | Government mandates or regulations are pressuring us to adopt IPv6 | (Henderson et al., 2012) |
| | Mimetic Pressure (MP) | | |
| 28 | MP1 | Our key competitors are currently adopting IPv6 | (Teo et al., 2003; Tweel, 2012; T. E. Yoon & George, 2013) |
| 29 | MP2 | Our organization will use IPv6 to remain competitive | (Henderson et al., 2012) |
| | | | |
| | Normative Pressure (NP) | | |
| 30 | NP1 | Industry sources (such as trade associations) are pressuring us to adopt IPv6 | (Henderson et al., 2012; Tweel, 2012) |
| 31 | NP2 | Our organization participates actively in industry, trade, or professional associations that promote IPv6 adoption | (Basaglia et al., 2009; Henderson et al., 2012; Teo et al., 2003; Tweel, 2012) |

# APPENDIX E: SPEARMAN'S CORRELATION TABLE

| | RA1 | RA2 | RA3 | RA4 | CPX1 | CPX2 | CMP1 | CMP2 | CMP3 | CMP4 | CMP5 | TM1 | TM2 | TM3 | SZ1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RA1 | 1.00 | .83** | .83** | .79** | -.26 | -.31 | .13 | .17 | -.10 | -.03 | -.15 | .80** | .86** | .80** | -.17 |
| RA2 | .83** | 1.00 | .94** | .79** | -.05 | -.14 | .24 | .27 | -.05 | -.02 | -.09 | .77** | .75** | .73** | -.12 |
| RA3 | .83** | .94** | 1.00 | .77** | -.16 | -.24 | .31* | .31* | -.05 | -.06 | -.07 | .75** | .78** | .74** | -.19 |
| RA4 | .79** | .79** | .77** | 1.00 | -.17 | -.22 | .16 | .14 | .05 | .07 | -.05 | .78** | .80** | .72** | -.02 |
| CPX1 | -.26 | -.05 | -.16 | -.17 | 1.00 | .78** | .02 | -.12 | .20 | .16 | .14 | -.31 | -.33* | -.38* | .33* |
| CPX2 | -.31 | -.14 | -.24 | -.22 | .78** | 1.00 | -.23 | -.37* | .19 | .05 | .10 | -.37* | -.40* | -.45** | .38* |
| CMP1 | .13 | .24 | .31* | .16 | .02 | -.23 | 1.00 | .70** | .21 | .19 | .46** | .15 | .13 | .17 | -.05 |
| CMP2 | .17 | .27 | .31* | .14 | -.12 | -.37* | .70** | 1.00 | .24 | .25 | .33* | .04 | .20 | .05 | -.14 |
| CMP3 | -.10 | -.05 | -.05 | .05 | .20 | .19 | .21 | .24 | 1.00 | .69** | .51** | -.11 | -.08 | -.19 | .60** |
| CMP4 | -.03 | -.02 | -.06 | .07 | .16 | .05 | .19 | .25 | .69** | 1.00 | .48** | -.05 | .00 | -.17 | .49** |
| CMP5 | -.15 | -.09 | -.07 | -.05 | .14 | .10 | .46** | .33* | .51** | .48** | 1.00 | -.15 | -.17 | -.19 | .28 |
| TM1 | .80** | .77** | .75** | .78** | -.31 | -.37* | .15 | .04 | -.11 | -.05 | -.15 | 1.00 | .90** | .95** | -.10 |
| TM2 | .86** | .75** | .78** | .80** | -.33* | -.40* | .13 | .20 | -.08 | .00 | -.17 | .90** | 1.00 | .87** | -.15 |
| TM3 | .80** | .73** | .74** | .72** | -.38* | -.45** | .17 | .05 | -.19 | -.17 | -.19 | .95** | .87** | 1.00 | -.17 |
| SZ1 | -.17 | -.12 | -.19 | -.02 | .33* | .38* | -.05 | -.14 | .60** | .49** | .28 | -.10 | -.15 | -.17 | 1.00 |
| SZ2 | -.10 | -.02 | -.09 | .06 | .41** | .56** | -.03 | -.18 | .53** | .41** | .30 | .01 | -.03 | -.09 | .86** |
| ORD1 | .55** | .46** | .50** | .38* | -.23 | -.48** | .18 | .37* | -.13 | -.03 | -.04 | .44** | .54** | .47** | -.37* |
| ORD2 | .28 | .29 | .45** | .29 | -.22 | -.40** | .49** | .34* | .07 | .12 | .25 | .20 | .31* | .23 | -.07 |
| CP1 | .46** | .45** | .50** | .37* | .02 | -.16 | .27 | .28 | -.03 | -.03 | .08 | .34* | .41** | .39* | -.02 |
| CP2 | .57** | .56** | .62** | .48** | -.02 | -.20 | .40* | .39* | .06 | .10 | .24 | .47** | .54** | .52** | .09 |
| CP3 | .54** | .54** | .60** | .46** | -.01 | -.19 | .43** | .39* | .09 | .12 | .28 | .46** | .53** | .51** | .14 |
| CP4 | .59** | .57** | .63** | .51** | -.03 | -.21 | .38* | .39* | .03 | .09 | .21 | .49** | .58** | .56** | .04 |
| CP5 | .57** | .57** | .62** | .49** | -.01 | -.19 | .39* | .37* | .06 | .11 | .23 | .47** | .54** | .52** | .10 |
| CP6 | .57** | .56** | .62** | .48** | -.02 | -.20 | .40* | .39* | .06 | .10 | .24 | .47** | .54** | .52** | .09 |
| CP7 | .57** | .52** | .61** | .49** | -.10 | -.27 | .37* | .33* | .04 | .05 | .18 | .51** | .56** | .60** | .03 |
| CP8 | .57** | .59** | .63** | .51** | -.07 | -.16 | .25 | .29 | -.03 | .03 | .22 | .43** | .51** | .48** | .17 |
| MP1 | .46** | .46** | .44** | .46** | -.08 | -.31 | .21 | .21 | -.04 | .26 | .01 | .61** | .55** | .61** | -.17 |
| MP2 | .78** | .73** | .70** | .60** | -.20 | -.30 | .15 | .14 | -.29 | -.18 | -.10 | .71** | .67** | .76** | -.32* |
| NP1 | .53** | .69** | .65** | .50** | .07 | -.15 | .41** | .33* | -.05 | .05 | .11 | .63** | .57** | .62** | -.18 |
| NP2 | .70** | .73** | .77** | .57** | -.21 | -.35* | .31* | .33* | -.29 | -.19 | -.25 | .66** | .70** | .72** | -.35* |
| HS | .30 | .40** | .42** | .36* | -.16 | -.18 | .15 | .14 | .23 | .10 | -.07 | .22 | .20 | .25 | .19 |

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

SPEARMAN'S CORRELATION TABLE CONTINUED

| | SZ2 | ORD1 | ORD2 | CP1 | CP2 | CP3 | CP4 | CP5 | CP6 | CP7 | CP8 | MP1 | MP2 | NP1 | NP2 | HS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RA1 | -.10 | .55** | .28 | .46** | .57** | .54** | .59** | .57** | .57** | .57** | .57** | .46** | .78** | .53** | .70** | .30 |
| RA2 | -.02 | .46** | .29 | .45** | .56** | .54** | .57** | .57** | .56** | .52** | .59** | .46** | .73** | .69** | .73** | .40** |
| RA3 | -.09 | .50** | .45** | .50** | .62** | .60** | .63** | .62** | .62** | .61** | .63** | .44** | .70** | .65** | .77** | .42** |
| RA4 | .06 | .38* | .29 | .37* | .48** | .46** | .51** | .49** | .48** | .49** | .51** | .46** | .60** | .50** | .57** | .36* |
| CPX1 | .41** | -.23 | -.22 | .02 | -.02 | -.01 | -.03 | -.01 | -.02 | -.10 | -.07 | -.08 | -.20 | .07 | -.21 | -.16 |
| CPX2 | .56** | -.48** | -.40** | -.16 | -.20 | -.19 | -.21 | -.19 | -.20 | -.27 | -.16 | -.31 | -.30 | -.15 | -.35* | -.18 |
| CMP1 | -.03 | .18 | .49** | .27 | .40* | .43** | .38* | .39* | .40* | .37* | .25 | .21 | .15 | .41** | .31* | .15 |
| CMP2 | -.18 | .37* | .34* | .28 | .39* | .39* | .39* | .37* | .39* | .33* | .29 | .21 | .14 | .33* | .33* | .14 |
| CMP3 | .53** | -.13 | .07 | -.03 | .06 | .09 | .03 | .06 | .06 | .04 | -.03 | -.04 | -.29 | -.05 | -.29 | .23 |
| CMP4 | .41** | -.03 | .12 | -.03 | .10 | .12 | .09 | .11 | .10 | .05 | .03 | .26 | -.18 | .05 | -.19 | .10 |
| CMP5 | .30 | -.04 | .25 | .08 | .24 | .28 | .21 | .23 | .24 | .18 | .22 | .01 | -.10 | .11 | -.25 | -.07 |
| TM1 | .01 | .44** | .20 | .34* | .47** | .46** | .49** | .47** | .47** | .51** | .43** | .61** | .71** | .63** | .66** | .22 |
| TM2 | -.03 | .54** | .31* | .41** | .54** | .53** | .58** | .54** | .54** | .56** | .51** | .55** | .67** | .57** | .70** | .20 |
| TM3 | -.09 | .47** | .23 | .39* | .52** | .51** | .56** | .52** | .52** | .60** | .48** | .61** | .76** | .62** | .72** | .25 |
| SZ1 | .86** | -.37* | -.07 | -.02 | .09 | .14 | .04 | .10 | .09 | .03 | .17 | -.17 | -.32* | -.18 | -.35* | .19 |
| SZ2 | 1.00 | -.31 | -.12 | -.01 | .07 | .11 | .04 | .08 | .07 | .00 | .13 | -.09 | -.26 | -.09 | -.31 | .07 |
| ORD1 | -.31 | 1.00 | .40** | .36* | .46** | .43** | .48** | .44** | .46** | .46** | .35* | .35* | .50** | .45** | .44** | .05 |
| ORD2 | -.12 | .40** | 1.00 | .32* | .43** | .45** | .42** | .43** | .43** | .41** | .29 | .23 | .20 | .34* | .33* | .21 |
| CP1 | -.01 | .36* | .32* | 1.00 | .87** | .87** | .86** | .87** | .87** | .82** | .78** | .36* | .32* | .48** | .41** | .30 |
| CP2 | .07 | .46** | .43** | .87** | 1.00 | 1.00** | .98** | 1.00** | 1.00** | .95** | .88** | .50** | .46** | .62** | .54** | .33* |
| CP3 | .11 | .43** | .45** | .87** | 1.00** | 1.00 | .98** | 1.00** | 1.00** | .94** | .88** | .49** | .45** | .60** | .53** | .37* |
| CP4 | .04 | .48** | .42** | .86** | .98** | .98** | 1.00 | .98** | .98** | .96** | .86** | .51** | .50** | .60** | .57** | .30 |
| CP5 | .08 | .44** | .43** | .87** | 1.00** | 1.00** | .98** | 1.00 | 1.00** | .94** | .88** | .51** | .47** | .62** | .54** | .35* |
| CP6 | .07 | .46** | .43** | .87** | 1.00** | 1.00** | .98** | 1.00** | 1.00 | .95** | .88** | .50** | .46** | .62** | .54** | .33* |
| CP7 | .00 | .46** | .41** | .82** | .95** | .94** | .96** | .94** | .95** | 1.00 | .83** | .53** | .47** | .58** | .54** | .34* |
| CP8 | .13 | .35* | .29 | .78** | .88** | .88** | .86** | .88** | .88** | .83** | 1.00 | .33* | .49** | .50** | .50** | .42** |
| MP1 | -.09 | .35* | .23 | .36* | .50** | .49** | .51** | .51** | .50** | .53** | .33* | 1.00 | .61** | .73** | .58** | .08 |
| MP2 | -.26 | .50** | .20 | .32* | .46** | .45** | .50** | .47** | .46** | .47** | .49** | .61** | 1.00 | .70** | .79** | .17 |
| NP1 | -.09 | .45** | .34* | .48** | .62** | .60** | .60** | .62** | .62** | .58** | .50** | .73** | .70** | 1.00 | .70** | .20 |
| NP2 | -.31 | .44** | .33* | .41** | .54** | .53** | .57** | .54** | .54** | .54** | .50** | .58** | .79** | .70** | 1.00 | .30 |
| HS | .07 | .05 | .21 | .30 | .33* | .37* | .30 | .35* | .33* | .34* | .42** | .08 | .17 | .20 | .30 | 1.00 |

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

# APPENDIX F: ANTI-IMAGE CORRELATION

| | RA 1 | RA 2 | RA 3 | RA 4 | CPX 1 | CPX 2 | CMP 1 | CMP 2 | CMP 3 | CMP 4 | CMP 5 | TM 1 | TM 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RA1 | **.76** | -.38 | .04 | -.13 | .00 | -.04 | -.19 | .13 | .24 | -.37 | -.06 | .33 | -.56 |
| RA2 | -.38 | **.77** | -.70 | -.10 | -.19 | -.09 | .40 | -.41 | -.08 | .09 | .12 | -.41 | .55 |
| RA3 | .04 | -.70 | **.84** | -.18 | .16 | -.22 | -.09 | -.03 | -.04 | .01 | -.12 | .15 | -.18 |
| RA4 | -.13 | -.10 | -.18 | **.92** | .04 | .05 | -.19 | .16 | -.11 | .02 | .15 | -.14 | -.13 |
| CPX1 | .00 | -.19 | .16 | .04 | **.62** | -.48 | -.34 | .23 | -.09 | -.04 | .27 | -.09 | .02 |
| CPX2 | -.04 | -.09 | -.22 | .05 | -.48 | **.66** | -.17 | .45 | -.11 | .18 | -.11 | .11 | -.19 |
| CMP1 | -.19 | .40 | -.09 | -.19 | -.34 | -.17 | **.61** | -.80 | .05 | .12 | -.28 | -.24 | .51 |
| CMP2 | .13 | -.41 | -.03 | .16 | .23 | .45 | -.80 | **.53** | -.08 | -.10 | .13 | .37 | -.51 |
| CMP3 | .24 | -.08 | -.04 | -.11 | -.09 | -.11 | .05 | -.08 | **.40** | -.60 | -.15 | .29 | -.23 |
| CMP4 | -.37 | .09 | .01 | .02 | -.04 | .18 | .12 | -.10 | -.60 | **.31** | -.28 | -.38 | .27 |
| CMP5 | -.06 | .12 | -.12 | .15 | .27 | -.11 | -.28 | .13 | -.15 | -.28 | **.47** | -.21 | .11 |
| TM1 | .33 | -.41 | .15 | -.14 | -.09 | .11 | -.24 | .37 | .29 | -.38 | -.21 | **.75** | -.66 |
| TM2 | -.56 | .55 | -.18 | -.13 | .02 | -.19 | .51 | -.51 | -.23 | .27 | .11 | -.66 | **.72** |
| TM3 | -.14 | -.12 | -.05 | .21 | .29 | .30 | -.41 | .42 | -.29 | .34 | .28 | -.53 | -.04 |
| ORD1 | -.13 | .07 | -.19 | .24 | -.16 | .28 | .00 | .06 | .11 | -.17 | .30 | -.01 | -.12 |
| ORD2 | .25 | -.24 | -.12 | -.07 | .08 | .44 | -.51 | .54 | .04 | .02 | -.23 | .36 | -.44 |
| CP1 | -.24 | .02 | -.07 | .06 | -.02 | .23 | -.06 | .12 | -.20 | .33 | .21 | -.09 | .09 |
| CP2 | -.30 | .18 | -.10 | -.02 | .10 | .08 | .14 | -.20 | -.26 | .54 | -.15 | -.51 | .44 |
| CP3 | .19 | -.03 | .24 | -.05 | -.14 | -.20 | .10 | -.25 | -.01 | -.05 | -.17 | .02 | -.06 |
| CP4 | .48 | -.40 | .39 | -.15 | -.16 | -.22 | .01 | -.06 | .38 | -.42 | -.29 | .57 | -.55 |
| CP5 | -.20 | .09 | -.27 | .24 | .15 | .11 | -.25 | .42 | .01 | -.30 | .51 | .05 | -.04 |
| CP7 | -.35 | .53 | -.41 | .02 | -.06 | .11 | .17 | -.12 | -.30 | .32 | .10 | -.24 | .49 |
| CP8 | .47 | -.31 | .17 | -.24 | -.11 | .08 | -.01 | .02 | .34 | -.27 | -.28 | .35 | -.41 |
| MP1 | .35 | -.12 | .22 | -.26 | -.08 | .00 | .06 | -.05 | .33 | -.58 | .00 | .25 | -.23 |
| MP2 | -.62 | .22 | -.12 | -.05 | .02 | .13 | .18 | -.04 | -.15 | .47 | -.24 | -.13 | .42 |
| NP1 | .45 | -.36 | .36 | .02 | -.18 | -.25 | .04 | -.23 | .07 | -.01 | -.32 | .05 | -.18 |
| NP2 | -.10 | .22 | -.39 | .24 | .05 | .06 | -.14 | .00 | .01 | .03 | .47 | -.14 | -.01 |

ANTI-IMAGE CORRELATION CONTINUTED

| | TM 3 | ORD 1 | ORD 2 | CP 1 | CP 2 | CP 3 | CP 4 | CP 5 | CP 7 | CP 8 | MP 1 | MP 2 | NP 1 | NP 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RA1 | -.14 | -.13 | .25 | -.24 | -.30 | .19 | .48 | -.20 | -.35 | .47 | .35 | -.62 | .45 | -.10 |
| RA2 | -.12 | .07 | -.24 | .02 | .18 | -.03 | -.40 | .09 | .53 | -.31 | -.12 | .22 | -.36 | .22 |
| RA3 | -.05 | -.19 | -.12 | -.07 | -.10 | .24 | .39 | -.27 | -.41 | .17 | .22 | -.12 | .36 | -.39 |
| RA4 | .21 | .24 | -.07 | .06 | -.02 | -.05 | -.15 | .24 | .02 | -.24 | -.26 | -.05 | .02 | .24 |
| CPX1 | .29 | -.16 | .08 | -.02 | .10 | -.14 | -.16 | .15 | -.06 | -.11 | -.08 | .02 | -.18 | .05 |
| CPX2 | .30 | .28 | .44 | .23 | .08 | -.20 | -.22 | .11 | .11 | .08 | .00 | .13 | -.25 | .06 |
| CMP1 | -.41 | .00 | -.51 | -.06 | .14 | .10 | .01 | -.25 | .17 | -.01 | .06 | .18 | .04 | -.14 |
| CMP2 | .42 | .06 | .54 | .12 | -.20 | -.25 | -.06 | .42 | -.12 | .02 | -.05 | -.04 | -.23 | .00 |
| CMP3 | -.29 | .11 | .04 | -.20 | -.26 | -.01 | .38 | .01 | -.30 | .34 | .33 | -.15 | .07 | .01 |
| CMP4 | .34 | -.17 | .02 | .33 | .54 | -.05 | -.42 | -.30 | .32 | -.27 | -.58 | .47 | -.01 | .03 |
| CMP5 | .28 | .30 | -.23 | .21 | -.15 | -.17 | -.29 | .51 | .10 | -.28 | .00 | -.24 | -.32 | .47 |
| TM1 | -.53 | -.01 | .36 | -.09 | -.51 | .02 | .57 | .05 | -.24 | .35 | .25 | -.13 | .05 | -.14 |
| TM2 | -.04 | -.12 | -.44 | .09 | .44 | -.06 | -.55 | -.04 | .49 | -.41 | -.23 | .42 | -.18 | -.01 |
| TM3 | **.81** | .14 | .17 | .23 | .30 | -.25 | -.45 | .27 | -.11 | -.22 | -.29 | .00 | -.22 | .17 |
| ORD1 | .14 | **.78** | -.22 | .09 | -.27 | -.06 | -.14 | .49 | -.01 | .00 | .04 | -.22 | -.30 | .42 |
| ORD2 | .17 | -.22 | **.68** | .05 | .04 | -.19 | .07 | -.10 | -.09 | .27 | .07 | .08 | -.09 | -.12 |
| CP1 | .23 | .09 | .05 | **.86** | .10 | -.15 | -.31 | .07 | .17 | -.20 | -.21 | .27 | -.23 | .21 |
| CP2 | .30 | -.27 | .04 | .10 | **.80** | -.31 | -.61 | -.46 | .25 | -.21 | -.27 | .46 | -.13 | .08 |
| CP3 | -.25 | -.06 | -.19 | -.15 | -.31 | **.96** | .25 | -.30 | -.09 | .12 | .15 | -.22 | .35 | -.17 |
| CP4 | -.45 | -.14 | .07 | -.31 | -.61 | .25 | **.71** | -.23 | -.64 | .48 | .39 | -.44 | .50 | -.34 |
| CP5 | .27 | .49 | -.10 | .07 | -.46 | -.30 | -.23 | **.82** | .03 | -.38 | -.12 | -.07 | -.49 | .27 |
| CP7 | -.11 | -.01 | -.09 | .17 | .25 | -.09 | -.64 | .03 | **.80** | -.34 | -.34 | .38 | -.25 | .19 |
| CP8 | -.22 | .00 | .27 | -.20 | -.21 | .12 | .48 | -.38 | -.34 | **.76** | .51 | -.37 | .28 | -.15 |
| MP1 | -.29 | .04 | .07 | -.21 | -.27 | .15 | .39 | -.12 | -.34 | .51 | **.75** | -.39 | -.09 | -.20 |
| MP2 | .00 | -.22 | .08 | .27 | .46 | -.22 | -.44 | -.07 | .38 | -.37 | -.39 | **.76** | -.37 | -.19 |
| NP1 | -.22 | -.30 | -.09 | -.23 | -.13 | .35 | .50 | -.49 | -.25 | .28 | -.09 | -.37 | **.78** | -.35 |
| NP2 | .17 | .42 | -.12 | .21 | .08 | -.17 | -.34 | .27 | .19 | -.15 | -.20 | -.19 | -.35 | **.84** |