# Deconstructing 'Universal Access' to Digital Information Infrastructure:
# The Case of Philadelphia Wireless Initiative

## Abstract

'Universal access' (UA) to information infrastructure has become one of the most important national goals. Yet, a comprehensive and systematic understanding of UA concept in the context of large-scale digital information infrastructures is still lacking. In this paper, we attempt to explore the complex nature of universal access to digital information infrastructures using Philadelphia Wireless initiative as an example. The analysis reveals that UA is multi dimensional and multilayered construct that is influenced by numerous stakeholders with varied interests. The antecedents and implications of this complexity are subsequently discussed.

**Key words**: Municipal Broadband Wireless Network, Universal Access, Digital Information Infrastructure

## 1. Introduction

Rapid diffusion of the Internet fueled by the advances in digital information and communication technologies (ICT) have ushered us into knowledge-based society. The availability and proliferation of digital technologies not only accelerated a global transformation, but also opens up numerous possibilities in everyday life. Consequently, being digitally connected has become a critical factor for the development of businesses, cultures, education, and eventually communities as a whole. The recognition of this societal imperative has given rise to multi-billion dollar efforts by both public and private sectors to provide every citizen with a basic level of access to digital information infrastructures. Yet, a range of obstacles remain for the widespread adoption and use of such technologies. Evidence suggests that, even in this 'digital world', there is still a large disparity in the level of access and usage of information technology. Social and economic inequalities have spilled over into (or even amplified by) the digital world and people who lack access are being relegated into an even more disadvantageous position. Therefore, raising the level of digital inclusion by improving citizens' access to the digital information infrastructure is now an important national and political goal. Consequently, 'universal access' (UA) has become one of the most endearing terms for policy makers and practitioners in this realm. However, a comprehensive and systematic understanding of the notion of UA concept in the context of digital information infrastructure is still lacking. As digital information infrastructure has the potential to weave through virtually every aspect of social experience, the concept of UA cuts across technological, social and economical realms. The challenge is then to identify strategies that engage the heterogeneous social actors with a complex set of technologies in order to provide economical access and encourage meaningful use. Most previous efforts have focused on the technical development of digital information infrastructures, and providing access devices and training.

The purpose of the current study is to explore a broad meaning of universal access in the context of a digital information infrastructure through an actor-network perspective. In what follows, we will provide a brief history of the notion of universal access, followed by a discussion on digital information infrastructures. We then present a case study of the Philadelphia Wireless Initiative, from which we develop a multi-dimensional framework of universal access. Drawing on this framework, we discuss the problematic nature of universal access in the context of a digital information infrastructure and provide insights for public policy and technology providers.

## 2. Literature Review

### 2.1. History of Universal Access

Universal access (originally termed as 'universal service') had been a key goal for traditional utility services such as electricity, natural gas or water, as well as typical information services such as telegraphy, postal services, telecommunications, and broadcasting (Crandall & Waverman, 2000). These services have spawned decades of debate on equitable and ubiquitous access which in turn has influenced policy making in numerous ways. The concept of UA was first incorporated into the 1934 communications Act, which formed the basis for many subsequent constructions of universal access objectives (Preston & Flynn, 2000). According to the 1934 act, UA refers to "making available, as far as possible, to all people of the United States, a rapid, efficient, nation-wide and world-wide, wire and radio communications services with adequate facilities at a reasonable charge" (Mueller, 1993, p.354). An analysis of the history of these utility and information services reveals that two core principles – accessibility (geographical uniformity and physical access) and affordability – have guided public discourse around the notion of UA. Unlike these utility and information services, a digital information infrastructure represents a complex web of socio-technical systems, which results in malleable, non-linear, and highly contested meaning of technologies. As such, principles that govern the UA to digital information infrastructure are likely to reflect the socio-technical complexity of the environments. Next, we will explore the complex nature of digital information infrastructures in order to better understand how it might influence the conventional beliefs of UA.

### 2.2. Complexity of Digital Information Infrastructures

A digital information infrastructure can be defined as a "shared, evolving, and heterogeneous installed base of IT capabilities among a set of user communities based on open and/or standardized interfaces" (Hanseth & Lyttinen, 2004; p.213). Two sets of characteristics make digital information infrastructures fundamentally different from other conventional utility services that have been subject to the public discourse about UA. First, a digital information infrastructure is different from other conventional utility services in its flexibility, range, and reach. A digital information infrastructure is the heterogeneous collection of different technologies, components and protocols to support varied applications covering large geographical distances. This plurality of technology is further complicated by the various content, the information resources, services and applications that individuals access via an infrastructure, which makes it inherently complex and highly malleable.

Second, a digital information infrastructure is different from convention utility services as it is designed to be shared by heterogeneous social actors who may not share the same goals when it comes to the use of the technology (Hanseth & Monteiro, 1998). At the same time, a digital information infrastructure needs to support a wide range of activities, not just tailored to one. Therefore, as noted by Star and Ruhdler (1996), a digital information infrastructure needs to be embedded in heterogeneous social contexts. Taken together, the installed technology base of a digital information infrastructure needs to reflect the diverse and evolving set of user needs, making it highly complex and inherently ambiguous. Echoing these aspects, Leiner et al (1997) note, "any information infrastructure, especially the Internet, is as much a collection of communities of users as a collection of technologies, and its success is attributable to satisfying the basic community needs". This suggests that in order to understand the UA of a digital information infrastructure, we need to take a socio-technical network perspective that brings together equipment, networks, people, and policies. As the complexity of such systems grows, the social and technical elements influence and shape each other, giving rise to new forms and structure the infrastructure itself. A digital information infrastructure then is no longer remains a coherent physical object that needs to be designed and managed, but a complex socio-technical system that is constantly evolving and emerging (Rolland, 2002).

## 3. Research Objective

The above analysis suggests that applying the original concept of UA that was originally developed for a uni-dimensional utility and information services to a digital information infrastructure designed to serve heterogeneous actors' divers needs through complex set of technology artifacts is potentially problematic. Further, the complexity, heterogeneity, and involvement of numerous user groups suggest that the concept of UA becomes highly malleable through series of negotiations among the involved actors. Different stakeholders have different needs, goals and viewpoints in relation to the infrastructure. Thus, universal access no longer remains a single coherent concept, but rather a multilayered, contextual and socio-technical phenomenon.

In this study, we analyze multiple perspectives of UA expressed by heterogeneous actors as they engaged in the development process of the Philadelphia wireless initiative, drawing on social construction of technology (Pinch & Bijker, 1987) and actor network theory (Callon & Law, 1986; 1988). We argue that neither technology artifacts nor actors are value neutral. They shape and are shaped by each other, constrained simultaneously by the material characteristics of the artifacts on one hand, and the values and needs of social actors on the other. To study this intersection between the technology artifacts and actors from diverse communities, it is essential to understand the systemic background of culture, economy, political and social elements. To ignore any one aspect separates technology from the social (Latour, 1996).

## 4. Methodology & Data Collection

Recently the idea of broadband municipal wireless networks (MWNs) has become more practical and cost-effective than ever before, and emerged a viable alternative to conventional means to access the Internet (Mandviwalla et al. forthcoming). The primary objective of Philadelphia initiative, according to the mayor's office, was to achieve "digital inclusion" by making a digital information infrastructure universally available and affordable to every citizen and business in the city.

We gathered data about the Philadelphia Wireless Initiative for this study from three primary sources. First, we collected articles and commentaries about Philadelphia Wireless Initiative by national and local news media including online forums. This includes 85 articles, spanning July 2004 through October 2006. Second, working with the city authorities, we organized a series of focus group discussions to elicit and understand the aspirations and requirements of various actors from different community groups who would eventually use the wireless service. The focus group sessions were conducted following guidelines by Fern (2001). A total of thirteen focus groups were organized with 120 individuals representing multiple stakeholder groups (e.g. Chambers of Commerce, Greater Philadelphia Tourism Marketing Corporation, small businesses owners, etc.). The discussions were tape-recorded and transcribed, and used for the analysis. Third, we analyzed seven reports and whitepapers published by the city as a part of their informational and promotional campaign. These three sources combined, provided rich qualitative data that was used for further analysis.

The primary objective of the analysis was to understand how the notion of universal access was negotiated and socially constructed by various stakeholders involved in the wireless Philadelphia initiative. Through this, we seek to understand the multiple meanings of UA to a digital information infrastructure. To contextualize the discourses of the social agents surrounding Philadelphia Wireless, we used a naturalistic mode of inquiry wherein insights were induced through interpretive means (Lincoln & Guba, 1985). We analyzed the data following the qualitative data analysis methodology suggested by Miles and Huberman (1994) and Strauss and Corbin (1990). The analysis was conducted in two stages. First, we used an open coding method (Strauss and Corbin, 1990), using a qualitative data analysis software, Atlas ti, to examine the texts from the three data sources. By comparing and categorizing data, we generated a preliminary coding scheme. These codes were then used to further categorize the data, and identify potential dimensions and sub-dimensions of each category. In the second phase, we employed an axial coding method by applying the theoretical sensitivity to suggest relationships among a category and sub-categories. Once a set of categories and their sub-dimensions were identified, the selective coding process involved linking the different categories to the core category (consisting of conditions, context, and consequences). This process helped us identify the key actors (institutions, individuals, technologies, etc) and issues that influenced the notion of universal access. The results of the study are presented next as a set of final dimensions and sub-dimensions.

## 5. Results

### 5.1. The History of Philadelphia Wireless Initiative

The wireless initiative was announced by the mayor of Philadelphia in the month of July, 2004. The initial vision in the words of the mayor was: "*Just like roads and transportation were keys to our past, a digital infrastructure based on wireless technology is the key to our future*" (Grant, 2004). To explore feasibility, the mayor's office established a Philadelphia wireless exploratory committee to formulate recommendations in several policy areas including business models, funding mechanisms, roles and responsibilities of several stakeholders, extent of service, privacy and security.

An impetus to this initiative also came from a consortium led by Intel Corporation including other large companies such as Cisco and IBM. The consortium led considerable research and development of wireless technologies and supporting equipment. As quoted in their annual report on wireless technologies, "*To help address basic community needs, bridge the digital divide, and promote economic growth, Intel has announced a new Intel® Digital Communities initiative to help communities use wireless technology and innovative applications to expand and* *improve services for municipal governments, businesses and citizens, and to enhance government efficiency, promote economic growth, foster greater community satisfaction and bridge the digital divide"* (Intel, 2005; p.3). To ensure a successful adoption of their technologies and related applications, Intel has been aggressively courting various cities around the country to adopt the wireless 802.11b technology.

In Philadelphia, the announcement of the initiative set in motion a wide range of social and political forces that got involved and attempted to reshape the objectives of the initiative. Primary among them were the existing telecommunications companies, Verizon and Comcast, who saw this initiative as a potential threat to the increasingly attractive broadband business. They argued that the city had no right to channel public funds into projects that might not necessarily pay off. These competitors also suggested that universal access to broadband is not a simple concept, but rather requires a unique marriage between ease and speed of the wireless and ubiquitous coverage of the cellular. One telecom official commented that "*I think the market does a better job of addressing the issue rather than municipal backed systems*" (Philadelphia Inquirer, 2006). This claim, however, was countered by a city official: "*if you ask the local telecom companies, they would say 90% of the city is covered. But if it is at a fee that most people in the city cannot afford, and if they don't have the computers to access the network, then having the network will not help overcome the digital divide*" (TechnewsWorld, 2005).

In order to counter the wireless initiative, incumbent telecom companies mobilized the support of Pennsylvania politicians who introduced a telecommunications regulation bill designed to prohibit all the municipalities from competing with existing private enterprises. However, the bill was modified to include a grandfather clause that allowed those cities that already had proposed such initiatives to finish the deployment before a certain deadline. The bill eliminated the possibility of several governance models. For example, the initial plan in Philadelphia was to invest city funds to develop the network, and provides free access to the citizens. However, this plan was not considered feasible as the city realized that if it invested major portions of available funds into developing the network, it will not be able to channel enough funds into the digital inclusion program (Fesenmaier *et al*, 2004).

Eventually, the city decided on a hybrid model and established a non-profit organization called 'Wireless Philadelphia' to manage the initiative. The plan was that Wireless Philadelphia, in turn, will outsource the design, development and maintenance of the network to a private firm. Access to the network would be made available through internet service providers (ISPs), telecom companies and other institutions that will provide access to customers at low rates. EarthLink, a member of the consortium led by Intel, was chosen as the primary contract for the development of the network. It agreed to invest the $10 million required to build the network. The contract included two other companies, Tropos and Motorola, who would provide the necessary equipments. EarthLink will charge about $20 to regular users and $10 for economically disadvantaged citizens. As a part of the digital inclusion program, EarthLink would: 1) provide 3000 free or discounted accounts to the city government, and 2) channel 5% of the revenue to provide equipment in low-income households. This agreement would define and guide the implementation of the wireless initiative, and define the notion of access to digital information infrastructure for the citizens of Philadelphia.

### 5.2. Key Actors in Philadelphia Wireless Imitative

We identify several key actors involved in Philadelphia Wireless Initiative. These actors brought different ideas about the notion of providing universal access. We categorize the myriad of actors into three broad domains - technical, socio-political, and economic/ business (see figure 1). Actors in each domain bring their unique perspectives and resources. To enable universal access to information infrastructure, there has to be a significant alignment between the interests and actions of these various actors.

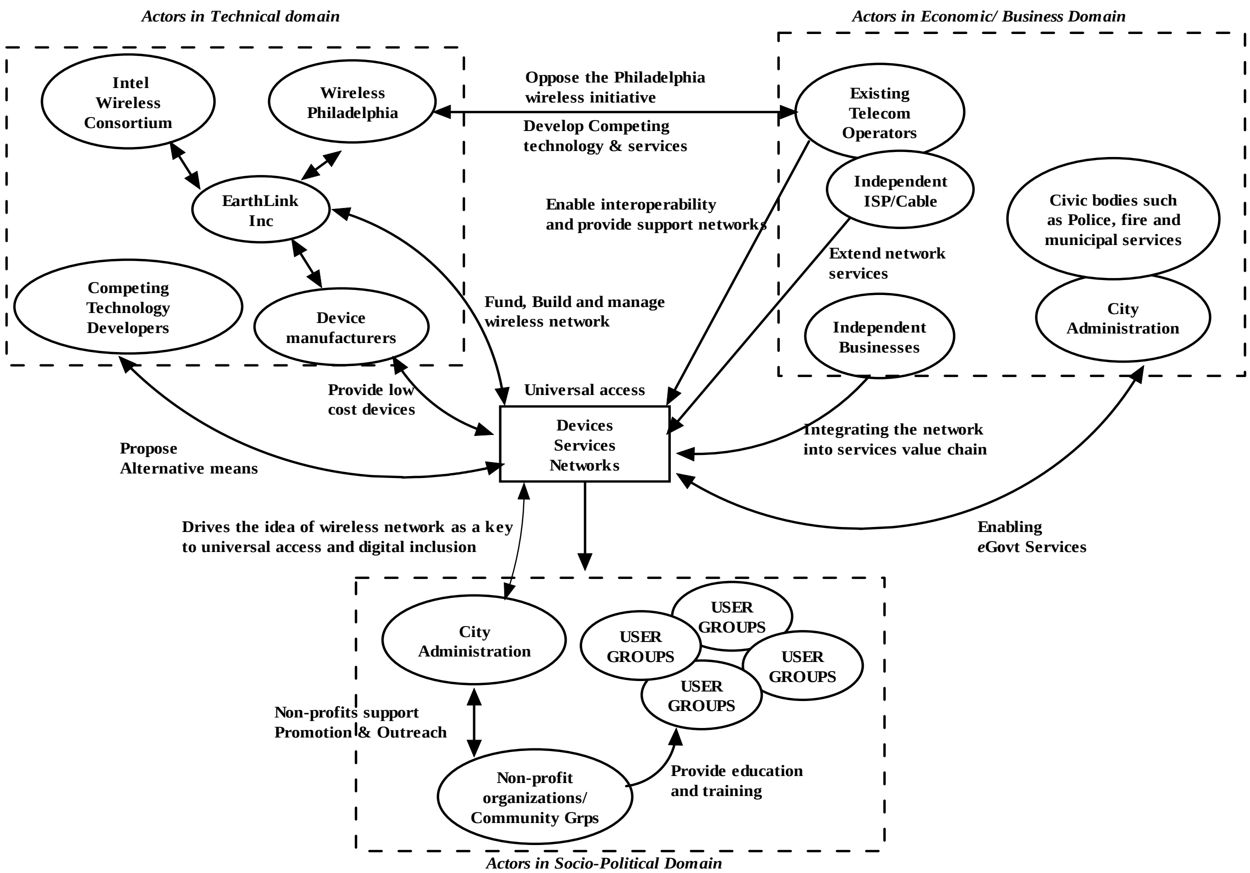


**Figure 1:** Various actors involved in Philadelphia Wireless Initiative

**Technology Domain**. This domain includes actors who provide the various technology artifacts in building the wireless network as well as devices that people operate to access the network. It also includes a broader set of technology companies who develop enabling technologies as well as those who develop competing technology platforms. They influence the evolution of US through the changes in the material characteristics of technology artifacts that are used in the infrastructure.

**Socio-Political Domain**. This domain encompasses the actors who are concerned with the social dimensions of Philadelphia Wireless who provide direct support to the users of the network including subsidized equipments and trainings. These actors include various types of non-profit community organizations that are specialized to different segments of the Philadelphia residents. These organizations also provide cultural context in which the users are embedded. Another important group of actors involved in this domain is the political and regulatory bodies. Further, the political actors at various levels were the ones who provided the impetus for the entire debate on UA (also in the case of the Philadelphia wireless initiative)

**Economic-Business Domain.** This domain includes actors create and sustain the economic context in which various forms of services provided through Philadelphia Wireless will be consumed in everyday life. On a day-to-day basis, the economics of using various forms of technology artifacts are crucial. Furthermore, it is crucial to have necessary financial resources to access network services and acquire necessary hardware devices. Hence, the actors in this domain influence the question of affordability, funding mechanisms, and the material resources required in building and sustaining Philadelphia Wireless through the market mechanism. This domain also includes all actors that produce telecommunications services by exploiting the opportunities provided by Philadelphia Wireless (Yoo *et al.*, 2005).

5.3. Dimensions of UA in Philadelphia Wireless

Having identified various actors, we explore how these actors perceived and reconstructed the notion of universal access, and whether this notion influence the evolution of the initial goals and ideas prescribed to by the city officials. Our qualitative analysis revealed three major dimensions of UA in the context of Philadelphia Wireless Initiative: technical, socio-political and economic. These dimensions seem to be aligned with three different domains of key actors who are involved in the implementation of Philadelphia Wireless Initiative. Furthermore, each of these dimensions reveals further sub-categories that reflect the complex socio-technical nature of the UA to a digital information infrastructure.

**Technical dimension.** Our coding reveals three technical aspects, performance, accessibility and interoperability, were prominently reflected with respect to accessing the wireless infrastructure (see Table 1).

**Table 1**: Categories and Sub-categories of technical dimension

| Category | Sub-Categories |
|---|---|
| Performance | • Speed & Reliability<br>• Standards<br>• Quality of equipment |
| Accessibility | • Availability of access devices<br>• Indoor vs outdoor connections<br>• Work vs home connectivity<br>• Ubiquity vs security |
| Inter-operability | • Connectivity through existing mobile platforms<br>• Connectivity to existing services |

Performance refers to the speed and reliability of connections, the quality of equipment to be used, and the quality of the service provided (the network by itself as well as in comparison to the existing wired and mobile communication infrastructures). However, achieving these performance attributes cannot be done without extending the costs associated with the development of the network. As one technology expert commented: "*building the network is easy, maintaining it is tough. That's the piece most people overlook in such initiatives. If an access point goes out, who will go out at 2 am to climb a pole and fix it? How much extensive support can you provide to the users? and at the same time maintain the costs?"*. Similarly, the issue of the standards adopted was also contested. One of the primary reasons for adopting the *IEEE* 802.11b wireless standard was its relative cost advantage which fit very well with the initial objectives of the city. According to the CIO of Philadelphia, Diana Neff, "*the city decided on the 802.11b wireless standard since it was cheap and relatively easy to install, especially if you are working with a city, and have access to public infrastructure such as street lamps, power etc*". However, one business owner argued the opposite: "*this standard is just a workable solution for today, and will seem less and less attractive with other wireless technologies currently being offered. For example, the EV-DO standard being rolled out by Verizon is much more powerful, faster, and works over larger distances. What is the guarantee that people won't shift to it?"*

Another aspect of the technology dimension was accessibility. This pertains to the issues such as where the network could be accessed and how it would be accessed. At this point in time, the city officials were still not sure of the technical capabilities, as well as the right cost structures to provide the service both indoors as well as outdoors. In comparison to the already existing wired ISPs, the value of just an outdoor wireless network was seen as very limited. Even if the network were to be provided only outdoors, there were proponents of the initiative who still envisioned fantastic opportunities. As one member of the Wireless executive committee said: "*Think of all the business transactions that can take place on something as simple as a park bench. Being outdoors is not as bad as you think*". Interestingly, a city resident indicated a problem with this rollout: "*security is a problem if the equipment is outside. Homeless or vagrants could vandalize or steal the equipment? Rittenhouse Square is a safer spot than the Parkway.*" Such a concern highlights the tension between the notion of UA and security. Another aspect of accessibility was the question of access devices. Particularly, the high cost and rapid obsolescence rate of the access devices were identified as a concern. For example, one participant observed that the cost of ownership of a personal computer is much higher than other major electronic media such as a television or mobile phone. Cost, coupled with the rate of technological change makes it difficult for the users to readily adopt one form of technology to access a digital information infrastructure. This reveals the temporal dimension of UA, as underlying technology changes, once accessible technology may become inaccessible over time.

Finally, the technical dimension includes the interoperability both from the standpoint of existing devices and existing services. Also, interoperability is critical in order to expand the access to those temporary users such as tourists and commuters from suburbs who may carry their devices and want to continue to access the services through the wireless network.

**Socio-cultural Dimension.** The social dimension includes the specific characteristics and needs of various social groups that eventually use the technology have to be taken into account. The requirements of the user groups with reference to the technology at hand could be summarized into interpretive flexibility, meaningful use and interconnectedness (see Table 2).

**Table 2**: Categories and sub-categories for socio-cultural dimension

| Category | Sub-Categories |
|---|---|
| Interpretive flexibility | • Selection of alternatives<br>• Agenda formation<br>• Appropriability |
| Meaningful use | • Uniqueness<br>• Justification for use and investment<br>• Information/communication/ entertainment needs |
| Interconnectedness | • Interoperability<br>• Access to social networks<br>• Cultural sensitivity |

Interpretive flexibility (Orlikowski, 1992; 2000) can be defined as the extent to which people perceive a technology is changeable. It depends on 1) the physical properties of technology, 2) the context in which users interact with technology, and 3) the skills, knowledge and perceptions of the users regarding the technology. For instance, a member of African-American chamber of commerce commented, "*what are people accessing the network for? We need to understand what people need and then promote the network based on use*". Interpretive flexibility also refers to the technology artifact being appropriable. Papert (1980) suggests that the positive or negative outcomes from the use of an artifact arise if it enables appropriable activities. To be appropriable, means the usage has to connect to some well-established personal knowledge of those involved in the activity. It has to make sense in the larger social setting surrounding it, and has to be personally meaningful. As one resident noted, "*Technology should be intuitive, similar to familiar systems. People have to feel comfortable with their own surroundings to use technology*. *Enable people to enable themselves. Don't force usage on everyone*".

Related to this discussion is the meaningful use notion. For meaningful use to be possible, technology artifacts need to be embedded in existing social and cultural contexts of the users. For example, some city residents actually needed to find a justification for the whole initiative itself. As one of them noted, "*Immediate barrier is trying to justify the expense. Why wasn't the 10 million (the budget for the initiative) spent on schools, or flu shots? Wireless is still a luxury and there are many unmet basic needs. In this state of affairs, I am not sure how many will embrace this initiative*". Meaningful use also refers to the relevance of the artifact in the day-to-day work practices of the users. A doctor from one local hospital commented: "*most of our work is definitely not time sensitive. For our profession, the benefits of instant communication are not important*". Another medical professional contended "*why would I transmit confidential medical information over a public network when I have secure digital lines for those purposes*"..

Finally, the concept of interconnectedness (Jung, Qiu, & Kim, 2001) suggests that when looking at technology as a resource, access becomes more than a question of ownership of the artifacts. Rather, it has to be defined in terms of the ability of technology to maximize the utility for pursuit of various goals. For example, meaningful use requires one to have access to various forms of social, economic and cultural capital and networks through a digital information infrastructure (Jung, Qiu, & Kim, 2001). This requirement was conspicuously reflected by one small business owner who noted "*to afford and acquire access, one needs money, but to use to it* *appropriately and meaningfully, one must have access to social and business networks*". Another city resident echoed similar sentiments by saying "what *will I do accessing the wireless if I do not have people to contact on the internet*?"

**Economic dimension.** The technical and social dimensions of access are inherently interlinked with the economic aspects. Material resources and economic capacities play a central role in determining whether people use IT artifacts (especially the Internet), and the nature, and subsequent patterns of that use (Murdoch *et al*, 1996).

**Table 3**: Categories and subcategories of Economic/Institutional dimension

| Category | Sub-Categories |
|---|---|
| Resource Mobilization | • Funding mechanism (business models)<br>• Cost reduction & Investment<br>• Social control |
| Affordability | • Subsidization<br>• Equitable distribution<br>• Complementary services |
| Sustainability | • Promotion & Outreach<br>• Education & training<br>• Value chain integration |

Considering these issues, resource mobilization becomes the primary aspect of achieving this goal. Resource mobilization refers to the process by which the relevant stakeholders generate the necessary resources that enable the development of such initiatives. Resource mobilization is especially important in city-driven initiatives since such projects are not a core competency of municipalities creates significant risk and challenges for the management and funding of network. Another interesting aspect that surfaced in this context was the issue of social control. Residents seemed to demand ownership over the network since it is considered a social initiative rather than economic. As one resident commented: "*the City has to initiate the program, not businesses; they will take too much advantage of grants and empowerment zones- Comcast reaped heavy benefits at the city's expense. Citizens should have 51% at all times. Make sure that Citizens have a significant amount of input*". This indicates that perhaps large public works projects automatically take on some civic ownership.

Complicating factors include dealing with the notion of affordability to *everyone* to the extent that "the project must be completed at zero cost to the taxpayers" (Mandviwalla *et al*, forthcoming). For example, the initial plan to provide the service free of cost to the citizens was blocked by the House of Representatives bill. However, even the final business model was contested. In an effort to reduce costs and drive scale, the city inserted a condition into the final contract that mandates EarthLink to grant other ISPs access to this infrastructure. A director at EarthLink said, "*any ISP that is willing to sell this service will be, for a fee, access our network. This will generate scales and foster competition, eventually driving down rates*". However, the wholesale business model is not without its own problems as one consultant pointed out: "*the network needs to be solid enough for other service providers to rely on it. Since this wireless is relatively inexpensive to install, as some point, it will become more attractive for the ISPs to* *build their own wi-fi networks and charge on their own basis. This again becomes a typical economic model*". This demand persists despite of repeated warnings from economic experts who suggest that public participation in such initiatives is detrimental in the long run.

Finally, reflecting the temporal nature of UA to the digital information infrastructure, sustainability emerged as another important dimension. This dimension suggests that the economic business model of Philadelphia Wireless needs to support not only the initial implementation of various layers of technology base that are necessary for the network, but to continue to make them affordable to those who need to use the network even as the technology changes. This also means economic resources to support continuing training and support for the users. Sustainability needs to include economic business models that support not only the end users who need to purchase the services and network, but also those who are on the supply side.

## 6. Discussion

It is evident from our analysis that the design, development, and diffusion of Philadelphia Wireless Initiative as a digital information infrastructure straddle technical, socio-political and economic-business domains. Therefore, conceptualizing UA in the context of a digital information infrastructure primarily through a technological frame is highly problematic. Instead, universal access to a digital information infrastructure such as Philadelphia Wireless Initiative needs to be approached as a socio-technical system, subject to multiple interpretations, and influenced by various key actors exhibiting who do not always have aligned interests.

The analysis also presents a dynamic landscape of converging issues. One major issue that emerged is the potential friction between the traditional 'top-down' perspective versus the 'bottom-up' perspective of UA. As digital information infrastructure intends to serve diverse set of social actors whose technical, socio-cultural and economic contexts vary significantly, merely focusing on geographic coverage and technical availability from a top-down perspective is not enough. Extant research on this issue has taken many forms such as technology diffusion (Rogers, 1983) and user acceptance (Davis, 1989) often focus on the physical access and use of technical artifacts themselves. However, it is evident that problems of universal access are related to not only adopting a new technology, but also having removing any barriers to the users ability to communicate, share information and participate constructively. Therefore, it is critical to expand the underlying theoretical basis when we attempt to study various aspects of universal access in the context of a digital information infrastructure. This also suggest econometric approaches in measuring the success and failure of digital information infrastructure need to be complemented with other forms of richer measures that cover these various dimensions of universal access.

Our study also suggests that when searching for strategies to diffuse complex technologies such as a digital information infrastructure in large populations, it is critical for the designers and policy makers to ensure that the infrastructure is synergistic with the socio-cultural and economic needs. This suggests that successful design and implementation of a digital information infrastructure requires active involvements of many different types of actors, such as government bodies at several levels, civic organizations, advocacy groups, and various forms of non-profit community organizations.

Finally, our study suggests that UA is a temporary concept and can become easily destabilized over time as underlying technologies evolve. The technology fields at all layers (network, access device, contents and services) experience unprecedented rate of changes. New technologies with more affordable economic models and better usability and functions constantly emerge. Such rapid of innovations in the technology domain can introduce new elements in any parts of the installed technology base. At the same time, such new configurations in the installed technology base can fundamentally alter the dynamics among the actors in other domains, resulting in diminished level of access to the network. Therefore, in order to guarantee more sustainable UA, one needs to consider the evolutionary paths in all three dimensions of UA.

## 7. Conclusions

In this paper, we attempted to deconstruct the meaning of universal access in the context of a digital information infrastructure from heterogeneous actors' perspectives. There is a rapid growth in deployment of digital information infrastructures to support widening social, economic, educational and even political activities. Both governments and private enterprises are aiming at enhancing digital inclusion by enabling universal access to these information infrastructures. However, to realize the promise of these technologies in an equitable and productive fashion, it is important to redefine the traditional notions of universal access. The discussion and analysis in this paper indicates that universal access is not a singular concept, but rather a multi-dimensional and highly contextual construct. Each dimension is influenced by multiple actors. The key to success in such initiatives is to understand this complexity from the user perspective, and provide sufficient resources to the user to activate, and reconfigure these networks according to his/her needs.

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