Assistive Navigation: a Study Incorporating the Use of Wi-Fi Networks to Provide Realtime, Interactive Wayfinding in Enclosed Structures for Individuals Who Have Visual Impairments

by

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Abstract

Those who suffer from visual impairments can find their ability to integrate into mainstream society challenged in significant ways. There are a variety of methods that aid an individual's ability to navigate his/her way through unfamiliar environments. However, many of these approaches are ineffective and impractical for use by those who are visually impaired.

This thesis considers the feasibility of providing a dynamic wayfinding solution based on existing mainstream technology. It also considers the design influence that conventional technologies may exert upon devices specific to the disabled community. The result is a solution that may empower individuals who are visually impaired and increase the level of their interaction in many environments while seeking to reduce negative stigma associated with disability. Ultimately, this solution may prove to be attractive not only to individuals with disabilities, but also to the general public.

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With all the sincerity of my heart, thank you all. I hope this work makes you proud.

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List of Abbreviations

A-GPS	Assisted Global Positioning System
AP	Access Point
AT	Assistive Technology
CDC	Centers for Disease Control
GPS	Global Positioning System
LBS	Located-Based System
OS	Operating System
RFID	Radio Frequency Identification
UW	University of Washington
WAI	Web Accessibility Initiative

Chapter 1 Introduction to the Problem

1.1 Problem Statement

The World Health Organization (2006) estimates that, worldwide, more than 161 million people are visually impaired. Among these individuals, 124 million have low vision and 37 million are blind. In the United States alone, 1.3 million are legally blind and 11.4 million individuals suffer from visual impairment. Despite society's continuing medical advancements, an increase of one to two million cases of blindness occurs each year (Thylefors, 1998).

Blindness is a condition describing a significant loss of vision, usually in the range of 20/200 or less. 20/200 eyesight would be the equivalent of a person observing at a distance of 20 feet what can be observed by the general population at a distance of 200 feet. Often, the term is used to describe a condition where an individual possesses very little or no functional use of vision. Outside this group are other individuals who are not legally blind, but possess only partial sight. The sight of these individuals is stated to be between the range of 20/70 and 20/200 (American Foundation for the Blind, 2011). It is fitting that both groups of people are considered collectively when everyday challenges they face are weighed.

Historically, lagging economic development has been the primary indicator of the prevalence of vision impairments among the world's population (Figure 1). However, vision impairment is also largely a function of age (Figure 2). Seventy percent of people who possess severe visual impairments are age 65 or older. Fifty percent of that group are legally blind (World Health Organization, 2006). As age demographics within the most advanced economies of the world change, blindness will become most prevalent among their populations.

Figure 1 Prevalence of blindness versus per capita income (Ho & Schwab, 2001)

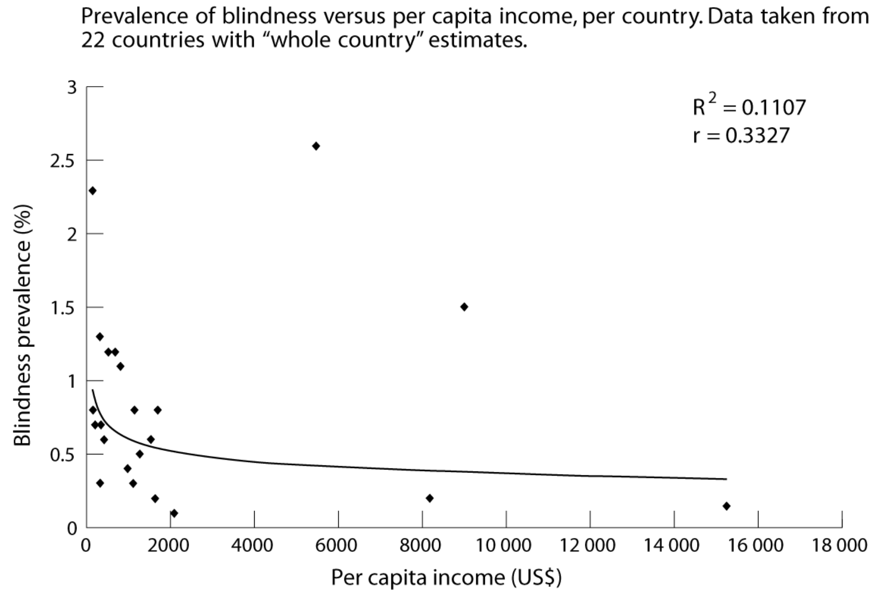
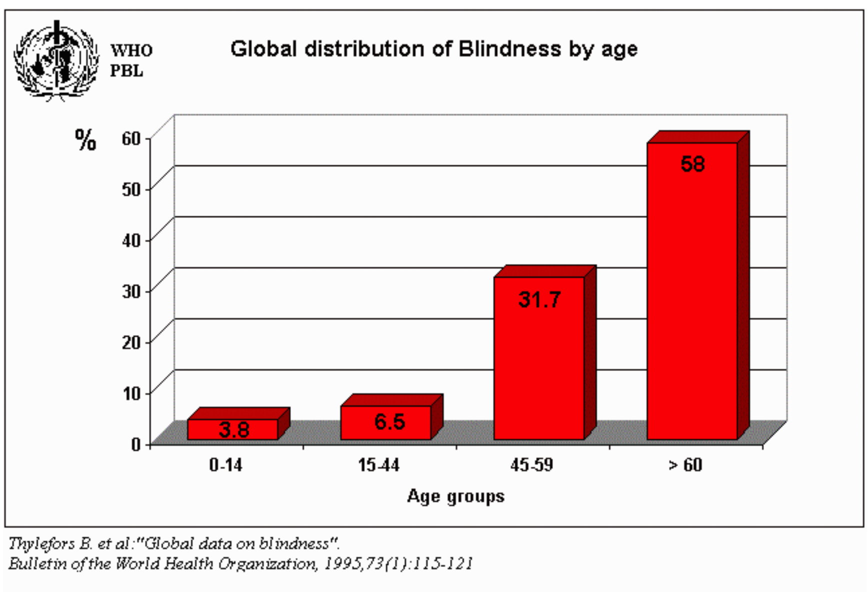
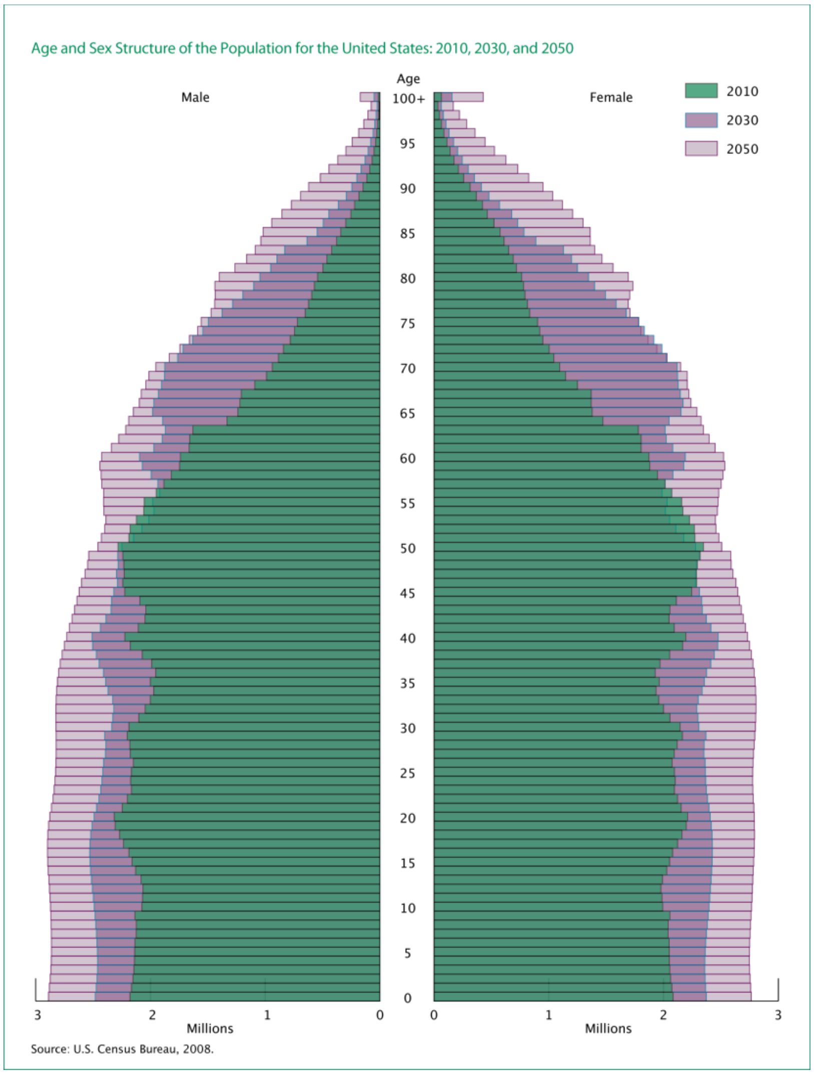


Figure 2 Global distribution of blindness by age (World Health Organization, 1995)



One reason for this change can be tied to life expectancy, which was 55 years in 1920 and has increased to over 80 years today (Commission of the European Communities, 2007). The early stages of an aging population have already begun: between 1990 and 2002, the world population increased 18.5%, but the population of those age 50 and older increased 30% (Resnikoff, et al., 2004). By 2050, it is projected that the general U.S. population will grow 41.6%, but the population aged 65 and older will grow 120.1% (Figure 3) – nearly three times as fast (Vincent & Velkoff, 2010). As a result, the U.S. and other aging populations will be affected more profoundly by vision loss than in the past. These changes could pose serious socioeconomic consequences (Frick & Foster, 2003).

Figure 3 Projected age populations for the United States: 2010, 2030, and 2050 (Vincent & Velkoff, 2010)



1.2 Effects of Visual Impairments

Visual impairment strikes a profound toll upon its victims because sight is an important indicator of health and quality of life (Swanson & McGwin, 2004). It is generally recognized that vision loss and its subsequent effects cause unique difficulties in the emergence of a positive self-image (Cook-Clampert, 1981). Results from a number of population-based studies and hospital-based studies indicate that visual impairment is associated with higher rates of depression (Bazargan & Hamm-Baugh, 1995; Black, 1999; Carabellese, et al., 1993; Rovner & Ganguli, 1998; Rovner & Shmuely-Dulitzki, 1997; Rovner, Zisselman, & Shmuely-Dulitzki, 1996; Valvanne, Juva, Erkinjuntti, & Tilvis, 1996; Wahl, Heyl, Oswald, & Winkler, 1998; Woo, et al., 1994) and a greater risk of physical injury (Roberts & Norton, 1995; Zwerling, Whitten, Davis, & Sprince, 1998). Those suffering from vision loss are affected in so many ways that it would be impossible to delineate every effect it takes upon its victims. It may be feasible, however, to establish general categories where the effects of vision loss are known and can even be measured. It has been suggested that impairments and disabilities may disadvantage an individual by limiting or preventing the fulfillment of six important "survival" roles: orientation, physical independence, mobility, occupation, social integration and economic self-sufficiency (Bickenbach, Chatterji, Badley, & Ustün, 1999).

For example, a 1997 study comparing students who were blind, low-vision, and sighted found that students who had visual impairments had limited opportunities for social integration with, and acceptance by, sighted age mates. Students who had vision loss and held friendships with sighted friends had to work harder to maintain those relationships than they did to maintain their friendships with peers who had visual impairments. These same students required more support than sighted students, but had fewer friends that could provide the needed support (Wolffe & Sacks, 1997).

While vision impairments bestow losses upon the affected individual, impacts also reverberate among the general population. As seen in Figure 4, The American Foundation for the Blind states that, in the U.S., approximately 74% of working age people who are blind are unemployed (American Foundation for the Blind, 2009), relying on their families for financial assistance (American Foundation for the Blind, 2008). A study performed by Wagner et al. found that youths who suffered from vision loss were likely to be unemployed and became more socially isolated the longer they were out of school, with nearly 50 percent of them still living with family members three to five years after they had left school (1992). On a more general note, it is estimated that excess, informal (unpaid) care for individuals who have visual impairments totals $5.48 billion annually (Prevent Blindness America, 2007). The estimated lifetime cost of support and unpaid taxes for an individual who suffers from blindness has been tallied at $916,000 (Willis & Helal, 2005). The reference to this data is by no means intended as a slight towards those who experience visual impairments; rather, it is intended to demonstrate that society has largely failed to implement approaches that could moderate the strain upon these individuals and encourage their interaction within the general population.

Figure 4 Employment of individuals who are visually impaired (American Foundation for the Blind, 2009)

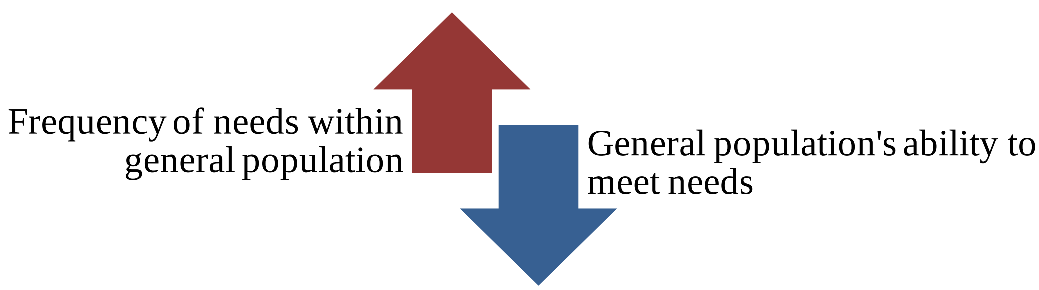
Employment Data Pertaining to People with Vision Loss (16 Years of Age and Over)

Month/Year	Not in Labor Force	Labor Participation Rate	Unemployment Rate	Employment to Population Rate
December 2009	3,163,000	21.7%	13.0%	18.9%
March 2010	3,132,000	23.0%	15.3%	19.5%
June 2010	2,903,000	25.4%	13.2%	22.0%
September 2010	2,955,000	25.4%	13.1%	22.1%

1.3 Need for Study

Shifting age demographics will force society to quickly come to terms with the needs of individuals who possess vision impairments. If the status quo approach continues, a burgeoning population with increasingly unmet needs (as a function of age) will stand in contrast to a proportionately contracting population that is expected to deliver more assistance than ever before (Figure 5). This does not paint a rosy picture. However, any practical response will likely demand a move away from labor-intensive approaches that the general population may not be capable of offering as abundantly on an individual basis. Practical solutions to this dilemma may likely require knowledge-based approaches or technologically advanced methods that provide more efficient results.

Figure 5 Dichotomy between population needs and ability to satisfy needs



1.4 Study Objectives

The objective of this work is to evaluate the effectiveness of traditional navigation systems (such as signage) and, where necessary, identify a directional navigation solution in indoor environments for individuals who are visually impaired. Daily interactions that occur within these facilities (worksites, shopping malls, medical and educational facilities, airports, etc.) are a foundational part of life in advanced societies, often providing individuals with the means to accomplish significant tasks. The research will consider the shortcomings of many traditional means of navigation direction, and will consider whether more advanced methods are capable of responding to the needs of individuals with vision loss. The social aspects of the solution will also be contemplated, in an effort to provide a response that is not only functional, but delivers a satisfying approach that individuals who suffer from visual impairments are willing to adopt.

1.5 Definition of Terms

Accelerometer: A device that measures acceleration (i.e., movement).

Access Point: A device that allows connection to a wired network via Wi-Fi.

Algorithm: A mathematical procedure that reduces the solution to a series that generates the best or closest-matching answer.

Application ("App"): A shortened or narrow software application designed to perform tasks on smartphones and smart devices.

Assistive Technology (AT): Any device or system that allows an individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed.

Braille: A system of writing and printing for individuals with vision impairments. Braille employs a pattern of raised dots, representing letters and numerals, which are read by touch.

Database: An organized collection of data used for signal comparison.

Disability: A condition affecting the physical movements, senses, or activities. This term will be used interchangeably with *impairment*, *impaired*, *disabled*, and *vision loss* in this work.

Feature Phone: A low-end mobile phone with minimum computing ability.

Fingerprint: A unique beacon signature representing a specific point or position.

Global Positioning System (GPS): A navigational system based on the reception of signals from an array of orbiting satellites.

Inertia Tracking: A process used to estimate current position, based on last known position (or fix) and advancing that position based upon known or estimated speeds over elapsed time, and course. Also called *Dead Reckoning*.

Information Staff: Individuals who are employed for the purpose of providing information and assistance, such as directions, locations, etc.

Infrared: An invisible, electromagnetic wavelength that can be used to transmit information.

Kriging: A geostatistical technique used to construct the value(s) at an unobserved location, using known observations gained from nearby points.

Localization: The process of determining the location of an individual or object.

Location-Based System: A tool used to establish the location of an individual or object.

Map: A diagrammed representation of an area, showing physical features and pathways.

Navigation: The process of ascertaining one's position and establishing a route.

Radio-Frequency Identification (RFID): A small, electronic device consisting of an antenna and a chip (typically referred to as a "tag") that is capable of storing information and relaying the same.

Smart device: A small, handheld device that offers advanced computing ability and may or may not offer the ability to make phone calls.

Smartphone: A mobile phone that offers more advanced computing ability and connectivity than a feature phone.

Signage: The use of signs as a means of providing direction and/or instruction.

Sonar: A technique using sound propagation to detect the presence of nearby objects.

Spatial Orientation: The process of establishing a relationship between the perception of the environment and the knowledge of the environment, stored in memory as a cognitive representation.

Spatial Updating: The ability to preserve orientation and relationship while in movement.

Spoofing: A situation in which one person or program masquerades as another by falsifying data.

Stress: Physical, mental, or emotional strain or tension.

Symbol: A shape used to represent something else or to convey information without the use of written language. Synonymous with the term *graphic* in this work.

Trilateration: The process of determining absolute or relative location by measurement of distances, using the geometry of spheres.

Ultrasonic (ultrasound): The use of sound waves with a frequency above the upper limit of human hearing to detect the presence of nearby objects.

Visual Impairment: The absence of vision to the extent that it causes significant functional challenges for the individual. Synonymous with the terms *visually-impaired*, *vision loss*, and *vision impairment* in this work. *Blindness* will also fall within the definition of these terms.

Wayfinding: The act or process of finding one's intended destination. Additional definitions of this term will be further developed and discussed in the work.

Wi-Fi: A technology allowing wireless connectivity to a local area network (LAN) via radio waves, based on IEEE 802.11 standards. It allows device-to-device communication and information transfer.

Wi-Finding: The process of establishing user location through the use of Wi-Fi access points.

1.6 Literature Review

A pivotal requirement of everyday life is the ability to successfully navigate through one's surrounding environment. This action is essentially known as *wayfinding*. There are many definitions of wayfinding, one holding it as "…knowing where you are in a building or an environment, knowing where your desired location is, and knowing how to get there from your present location" (University of Michigan, 2011, para. 1). This definition suggests that wayfinding is a mental state that exists only when an individual understands how to get from a present location to a desired locale, whether through the aid of external features or not. Operating under this definition, a successful interaction with the environment cannot take place until this mental state has been achieved. Successful wayfinding can be very challenging for individuals who suffer from visual impairments.

Another definition holds that wayfinding is "…the organization and communication of our dynamic relationship to space and environment" (Mayor's Office for People with Disabilities, 2001, 4.1c, para. 1). The term *dynamic* is an important one: it reinforces the idea that individuals possess an ever-changing relationship to their environment, with each individual's needs being unique to the whole. Wayfinding aids should allow every individual to develop a plan to take them from his/her location to the intended destination and negotiate any required changes while executing the plan (Mayor's Office for People with Disabilities, 2001). This is a dynamic process. However, many wayfinding approaches are not dynamic, but static, providing information in fixed contexts that may meet the needs of many, but not the needs of all. Despite this limitation, static wayfinding approaches continue to thrive, which can be a detriment to those whose needs remain unmet.

The Cost(s) of Insufficient Wayfinding. Even for the general population, wayfinding applications often fall short of basic needs. It is sad to report that "…wayfinding receives less than its due in planning, research, and building evaluation" (Hunter, 2009, para. 10). Wayfinding elements are an important feature of a successfully functioning locale, but these have historically been relegated to afterthoughts or low-priority budget items (Gerber, 2009). The uptake of this issue by architects and designers has stalled (Hunter, 2009), leading to undue burdens upon society.

There are a number of theories that explain why wayfinding often takes a back seat in design and architecture. One thought suggests that wayfinding suffers because the author of a work might not fully understand the context of how the design will be used (Muller, 2007). Another holds that architects and designers may possess an intimate knowledge of the environment they have created, but they are then unable to divorce themselves from that knowledge, instead extending special demands upon others who do not have the luxury of a known locale (MacMinner, 2002). It is not uncommon to hear of new building or design projects in which the general public invests considerable hope, only to have those aspirations largely shattered due to nightmarish wayfinding results. These inadequacies can prove to be distractions for otherwise commendable architectural achievements (Carlson, 2010).

In many cases, wayfinding systems are not considered adequately until a serious problem occurs (Hunter, 2009). This is a risky approach because a loss of some sort must transpire before there is any rectification. These losses are not always immediately apparent, but they can be significant, and include the following:

- lost staff time
- reduced staff concentration caused by the need to provide directions or other interventions
- lost business and dissatisfaction due to frustration and ill-will of users
- costly missed appointments or delayed meetings
- additional security staff and traffic management costs
- compensatory environmental communications systems
- potential lawsuits surrounding lack of safety and accessibility
- anger to users wandering into limited access areas of buildings
- injury and death during emergency situations

(Arthur & Passini, 1992; Carpman & Grant, 2002; Zimring, 1990)

Several studies have shown these risks are more than simple theory. Both Carpman and Grant (2001) as well as Huelat (2004) noted effects caused by problematic wayfinding in complex environments that included raised blood pressure, headaches, increased physical exertion, and fatigue. Another study conducted at a regional 604-bed hospital found the hospital's annual wayfinding system cost in excess of $220,000 per year ($448 per bed), largely because the actual wayfinding system fell short of patient/visitor needs. The measured effects of insufficient wayfinding included lost staff time when employees (other than information staff) were required to supply direction, among other setbacks. Losses added up to more than 4,500 staff hours annually – more than two full-time staff positions (Zimring, 1990).

Essential Elements of Wayfinding. Well-delivered wayfinding must provide users with essential starting points that serve as the foundation for further interaction. One crucial piece of wayfinding is an ordered environment – one that holds a clear possibility of choice and a starting point for acquisition of further information (Hunter, 2009). This need can account for the confusion some may experience when they are thrust into the heart of a wayfinding system that may not offer a clear starting point (such as disembarking a flight in the middle of an airport terminal). Visitors must also be provided with a clear visual sweep of the site or building upon entering to provide them an overview of their surroundings. The intent is to let individuals observe a large number of elements and their relationships (Figure 6), at the same time giving them a sense of their relation to the whole (Lynch, 1960).

Figure 6 Visual overview provided by map (Transport for London, 2011)

This connection is important to navigation because it allows an individual to develop and maintain spatial orientation. Spatial orientation can be defined as the process of establishing a relationship between the perception of the environment and the knowledge of the environment, stored in memory as a cognitive representation (Peruch & Savoyant, 1993). Spatial orientation requires the ability to localize one's position, identify the position of buildings or features, and keep track of movements in the environment through moment-to-moment interactions within the surroundings. The ability to preserve orientation and relationship while in movement is often referred to as spatial updating (Easton & Choll, 1995; Farrell & Robertson, 1998; Pick & Rieser, 1982; Presson & Montello, 1994; Rieser, 1998), which reemphasizes that wayfinding is a dynamic endeavor, constantly evolving and transforming as the individual is in motion.

The proper advancement of one's relationship in a changing environment is not always easy to maintain. One reason is that individuals have been shown to retrieve spatial information more effectively from experienced perspectives than from new perspectives (Iachini & Logie, 2003). When users are thrust into a position of a familiar environment from a different perspective, wayfinding can become problematic. A 2003 study by Iachini and Logie discovered that when users experience a large-scale, real environment by way of direct exploration, an orientation-dependent representation in memory is created. They found that perspective constitutes a primary interface between individuals and environment. Based on their findings, re-experiencing an environment from a known perspective is likely to lead to more successful wayfinding results.

This can present a tricky situation when users who possess previous experience from one perspective in a symmetrical environment are asked to find their way from another perspective from which they have no experience. Symmetrical buildings – while seemingly straightforward in plan view – often possess similar appearances from multiple perspectives (Figure 7), and may lack features that can assist in the development of spatial orientation (windows through which to observe the environment outside, artwork, etc.). This can prove confusing to visitors unless areas of the structure are clearly differentiated (Salmi, 2007). For these reasons, wayfinding aids must provide a constant flow of information (spatial updating) so that spatial orientation is preserved.

Figure 7 Example of symmetrical building – Natural History Museum, University College London (Tuuraan78, 2010)

Each wayfinding element – an ordered environment with a starting point, spatial orientation, and spatial updating – is vital to the success of wayfinding. The omission of any can create problematic issues for visitors to a building. For this reason, it is necessary to evaluate how effective wayfinding methods are in fulfilling the evolving needs of dynamic individuals. An effective wayfinding approach should resolve the wayfinding needs of not only the general population, but those who may have unique needs, such as individuals who are visually impaired or otherwise disabled. This would encourage increased interaction and equitable access for all.

Chapter 2 Analysis of Wayfinding Methods

2.1 Signage

There are a number of traditional methods in practice that respond to important wayfinding needs. By far the most popular is signage (Figure 8). In many circles, wayfinding and signage are held as transposable terms. While signage is an important part of wayfinding, the scope of wayfinding is much larger than signage alone. Perhaps the roots of this misconception can be attributed to the context in which the term wayfinding was first coined. Urban planner Kevin Lynch first used the term in his 1960 book, *Image of the City*, wherein he referred to maps, street numbers, and directional signs as way-finding devices. Indeed, a great deal of literature devoted to the topic of wayfinding focuses on traditional developments in this subject matter. Definitions aside, signage presents one of the simplest and most straightforward wayfinding tools. In large-scale man-made environments, signage is often the first alternative that visitors will turn to fulfill wayfinding needs. Signage provides an opportunity to place needed information in areas where the information is relevant and necessary, often necessitated by building design (Hunter, 2009).

Figure 8 Examples of signage (Visual Impact, 2011)

While in no way diminishing the benefits of signage, it is also important to note that it does possess its share of drawbacks. Where wayfinding needs exist, the knee-jerk reaction may often be to display additional signage in an effort to relay information where it is anticipated individuals will experience wayfinding needs. This can lead to displaying too many signs, creating clutter and visual overload (Figure 9). On the other hand, when not enough signage is present, the temptation may be to list as much information as possible on existing signage. This tradeoff can result in seemingly unimportant information being relegated further down in the information hierarchy, making it difficult for those who require this information. Details may end up buried and may not be perceived at all, or they may be screened out and not remembered.

It has been stated that "…information at the wrong place is as good as no information at all" (Arthur & Passini, 1992, p. 34). This is a substantial challenge for signage systems.

Figure 9 Cluttered signage (Canadian Public Transit Discussion Board, 2011)

Another hurdle is created when the user does not read, or reads in a language other than what has been used to convey building information. Where individuals speak numerous languages, such as in the context of an international airport, signage and directory information that is provided in all-text format is also a barrier which limits access to the "contents" of the building (Salmi, Ginthner, & Guerin, 2002; Salmi & Guerin, 2007). Even those who possess a strong command of language skills can be puzzled by signage, such as when directories require decoding ability (Figure 10) or when densely-packed text is difficult to decipher (Salmi, 2007).

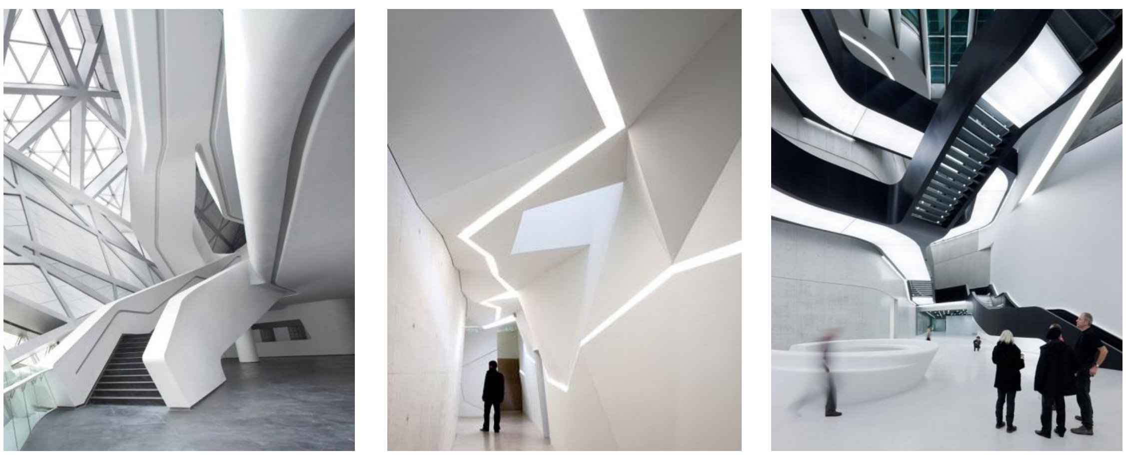
Figure 10 Extensive signage coding (Salmi, 2007)

Yet another challenging aspect of signage is the use of symbols and graphics. Currently, there are no international symbol standards (Gerber, 2009). Often, there is also no systematic format agreed upon for location and placement of signs (Schintlmeister, 2010). Building code requirements can even dictate certain signage characteristics or placements that, when compared to the overall wayfinding system, seem ill-fitted to the environment and/or the wayfinding detail. Another challenge posed by signage occurs during transitional periods, such as when a building is remodeled, or when signage systems are updated. Older or obsolete signage should be removed in these instances, but often times, previous signage is simply left in place, creating clutter and perhaps even contradiction. An analysis of London's pedestrian sign system in 2006 found the remnants of more than 34 different signage systems, some of which were ineffective and often confusing, creating situations where travelers often turned to maps located in subway stations underground to navigate their way above ground (Reising, 2010). This is a situation to avoid.

As a final note on signage, some buildings simply are not designed in a manner that invites signage as the central method of providing wayfinding direction. Werner and Schindler

(2004) found that environments with perpendicular intersecting hallways gave better wayfinding performance than those with angled intersections. In other words, hallways and features intersecting at non-perpendicular angles may prove difficult to navigate. Ruddle and Péruch (2004) came to the conclusion that well-designed signs can be ineffective in highly complicated buildings that do not enable natural movement. As seen in Figure 11, wayfinding needs in complex environments may not always be met by the traditional use of signs (Rooke, Tzortzopoulos, Koskela, & Rooke, 2009).

Figure 11 Examples of architecture posing a challenge to signage use (Bustler, 2010; The Furniture Industry Blog, 2011; Thecoolhunter, 2011)

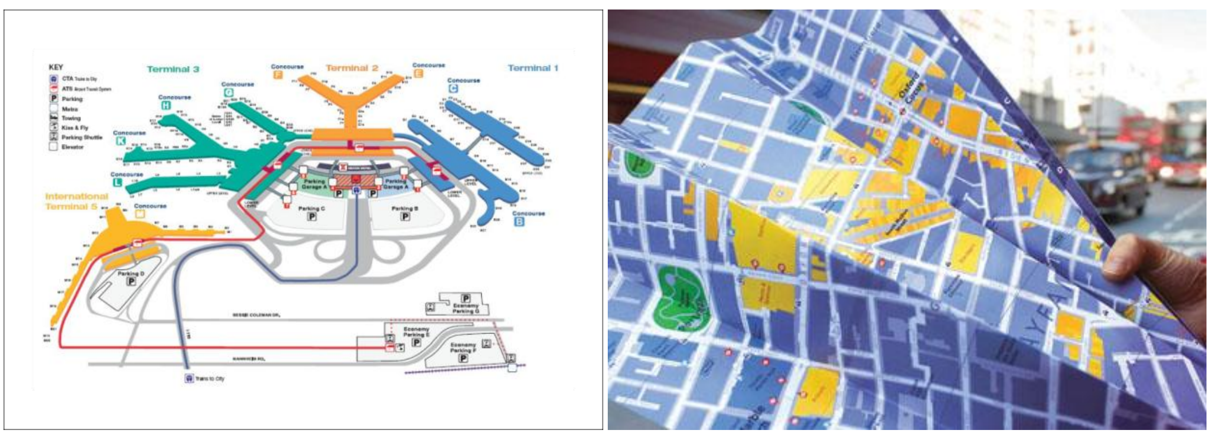


None of this is to say that signage is obsolete or that its presence is uninvited. The intent here is to demonstrate the pitfalls of an approach that considers signage to be the only method of assisting wayfinding, or assumes that signage is always the best method of providing direction and orientation to users. Signage is likely to remain a critical, popular form of navigational assistance, despite its shortcomings. This said, where signage is employed, the operators of a premises must be cognizant of its limitations in order to establish that unmet wayfinding needs may still exist.

2.2 Maps

Another traditional wayfinding tool is the map. One advantage of maps is that they allow individuals to develop spatial orientation with their surroundings, an important characteristic of wayfinding that posted signs alone may not provide (Figure 12). Portable maps offer users a reference along their route, in essence answering needs as they arise. However, in most cases maps must be aligned with the environment in order to facilitate navigation effectively. This is known as the alignment effect. It has been found that if the alignment effect is violated, such as if straight-up on the map does not correspond to directly forward in the environment, subjects tend to be less accurate in judging the correct direction to take (Levine, 1982; Levine, Jankovic, & Palij, 1982; Levine, Marchon, & Hanley, 1984; Palij, Levine, & Kahan, 1984).

Figure 12 Examples of Maps (Chicago Traveler, 2011; Reising, 2010)



It is also important to note that learning features from a map can produce reliance on an orientation-dependent representation. This differs from spatial information that is gathered directly from the real environment, allowing for environment appreciation from several viewpoints, which may result in orientation-independent representations. Thorndyke and Hayes-

Roth (1982) studied this phenomenon, coming to the conclusion that those who possessed real experience with an environment (i.e., interaction) were better able to point out locations within a building than those who had learned layout from a map. On another note, maps are not universally available and users may not possess knowledge of their presence when they are. Fewer than half of all hospitals currently provide basic user guides or maps to aid in wayfinding, although they have proven to be of valuable assistance to patients and visitors (Cooper & Berger, 2009). Even when available, care must be taken to assure that they are not overly complex nor obsolete, and that terminology and graphics in print materials are consistent within themselves and with posted signage.

2.3 Braille

In consideration of signage, maps, and other traditional print versions of wayfinding, it is important to note that none of these methods provides a practical wayfinding solution for individuals who have visual impairments; hence, additional methods must be evaluated. Policies such as the Americans with Disabilities Act (ADA) of 1990, Title III, have served to encourage building codes that assure physical access to and within public settings, but universal access to all users has not necessarily been reached (Salmi, 2007). Some may consider Braille a worthy and successful method of delivering information and guidance to the visually impaired, but data shows that most who suffer from vision loss have not learned to read Braille (Crandall, Bentzen, Myers, & Brabyn, 2001). For those who do read Braille, text must be sought after and discovered, which hardly seems to be an equitable solution for those who cannot visually observe that which they are forced to find. This can be very awkward in public settings, perhaps a reason why individuals who can read Braille often use it to confirm information and detail rather than to obtain instruction and direction. Braille, too, is a static form of information provision (Figure 13), one which can fall short of responding to the dynamic needs of users in an unfamiliar locale.

Figure 13 Braille signs (Office Sign Company, 2011)

2.4 Information Staff

A response to dynamic needs may be the use of informational staff, potentially the most dynamic approach available. However, information staffs represent a perpetual investment. In the day of increased competition and cost-cutting, information staff may be some of the first to go. They may also be present only during limited hours, creating circumstances where parts of the wayfinding system essentially “clock out” when information employees leave. Even when present, information staff can be limited by the capacity to assist only a certain number of individuals at any given time. Further, where navigation information is relayed, it is often given entirely at one time – the visitor is required to remember the information sequence, a memory that may be fleeting. This approach stands in contrast to the idea of providing the ideal amount of information when it is needed. Finally, it is no secret that many people do not like to ask for directions. When this occurs, the advantage posed by the presence of information staff is limited. Because of these issues, the use of information staffs could become less commonplace in the future.

2.5 Interactive Wayfinding Approaches

Advances in technology and design may yet provide answers that can adapt to user wayfinding needs in a dynamic fashion that provides information where it is needed. An effective use of the same could greatly improve the odds of successful wayfinding, both for individuals who have impairments as well as the general population. Technical advances are increasingly allowing for the experimentation of Location-Based Systems (LBSs) based on a wide array of wireless technologies that are readily available. A major advantage of these systems is that they can not only establish user location with reasonable accuracy, but in many instances they can sense direction and motion, allowing for dynamic updating and realtime direction. As the deployment of these technologies becomes more customary (for a variety of purposes), it is possible that the approaches could supplement or even replace traditional wayfinding approaches that have been employed in the past.

GPS Wayfinding. The consumer market for wayfinding technology exploded with options following a Presidential directive in 2000 to remove “selective availability” from positional signals sent via satellite based on the Global Positioning System (GPS) (Bell, Jung, & Krishnakumar, 2010). In essence, prior to this directive, satellite positioning signals available to the general public could not pinpoint location with enough detail to make the use of consumer GPS technologies practical. Since the 2000 directive, however, this type of technology has become mainstream (Figure 14).

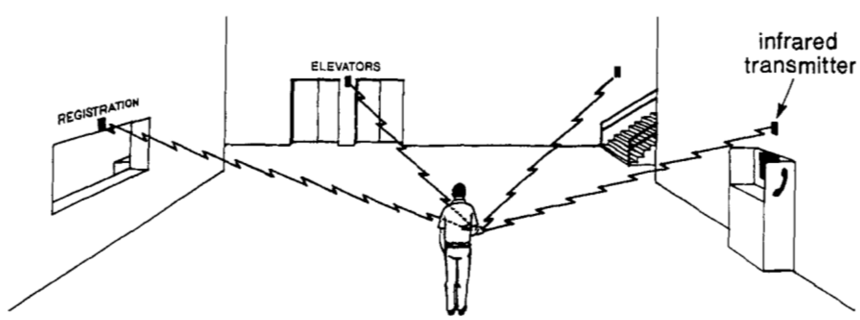
GPS uses multiple orbiting satellites to triangulate the position of a mobile receiver on the earth's surface. Location is calculated by triangulating the time of flight of satellite transmissions to the receiver. Localization – the process of determining physical location of a user (Kim, Fielding, & Kotz, 2006) – can typically be tracked to within a few meters. Its accuracy over a wide geographical area is one reason that GPS has become very popular (Furey, Curran, & McKevitt, 2008). However, GPS suffers from a couple key setbacks that make it impractical for certain uses. It can take considerable time to chart its first position (Li, Quader, & Dempster, 2008). GPS receivers also require a clear view of the sky (multiple satellites must be "seen" in unison by the GPS device), so GPS typically does not work well indoors, under cover, or in urban canyons (Hightower, LaMarca, & Smith, 2006). For these reasons, its use in indoor applications is impractical.

Figure 14 Garmin 550t handheld GPS unit (Garmin, 2011)

Development of the Assisted Global Positioning System (A-GPS) integrates GPS functionality with cell phone technology to measure signals from nearby cell phone towers, increasing the GPS response rate (Weyn & Schrooyen, 2008; Zandbergen, 2009). This would theoretically decrease the time needed for a GPS device to establish location once powered up. Many of the newer A-GPS systems also employ high-sensitivity GPS, allowing function in indoor or urban canyon environments. Nevertheless, even these receivers are not consistently able to obtain a position fix indoors, particularly inside buildings where large amounts of steel have been employed in the construction, or where signals must pass through several layers of concrete or brick (Zandbergen, 2009). Again, this renders GPS technology unviable for the purposes of indoor wayfinding at this time.

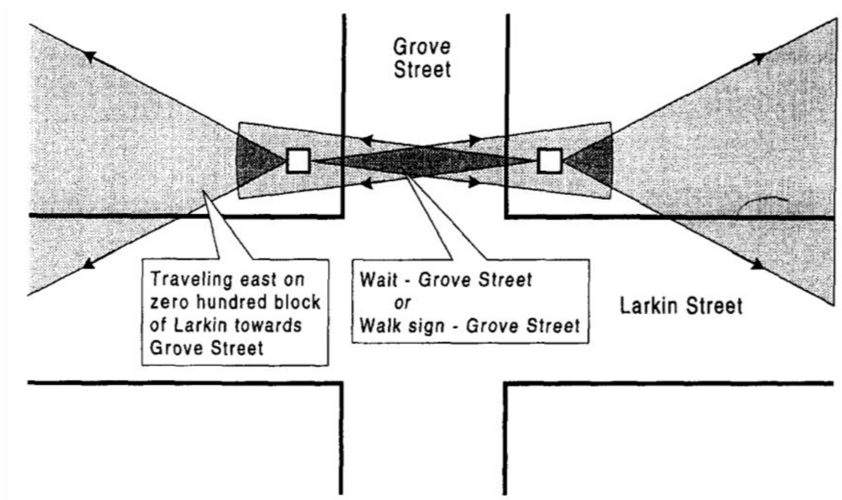
Infrared Wayfinding. The use of infrared signals to transmit wayfinding information is another approach that has been explored. The premise behind infrared wayfinding is that when users are within range of one or more infrared transmitters, directions can be relayed to the user (who carries a device that reads the signal), with the cycle repeating itself as the user passes into the range of additional transmitters until the destination has been reached (Figure 15).

Figure 15 Illustration of Infrared Signals (Crandall, Bentzen, Myers, & Brabyn, 2001)



A major hindrance preventing widespread adoption of this technology lies in concerns related to signal strength and power supply. As for the former concern, infrared signal range is limited (Figure 16), requiring the location of multiple transmitters in any large-scale environment employing this type of system. Further, infrared signals degrade in direct sunlight, which could prevent its use in buildings with windows or open areas (Bahl & Padmanabhan, 2000), and infrared signals are severely impaired by line-of-sight obstructions (Woo, et al., 2011). As for the latter concern, transmitters need a power supply, meaning they must either be hard-wired into building circuitry or transmitters must be located near an existing plug source, which might represent significant installation and/or maintenance costs (Bahl & Padmanabhan, 2000). A study of infrared wayfinding at the Powell Street transit station in San Francisco demonstrates these points. The entire station is located underground – most structures are located above ground, where sunlight may affect infrared's effectiveness. Ninety-three transmitters were required (throughout the three levels of the station) due to limited broadcast range. Each had to be connected to 110-volt plugs (Crandall, Bentzen, Myers, & Brabyn, 2001). Many premises operators may not be willing to invest this greatly into their building infrastructure.

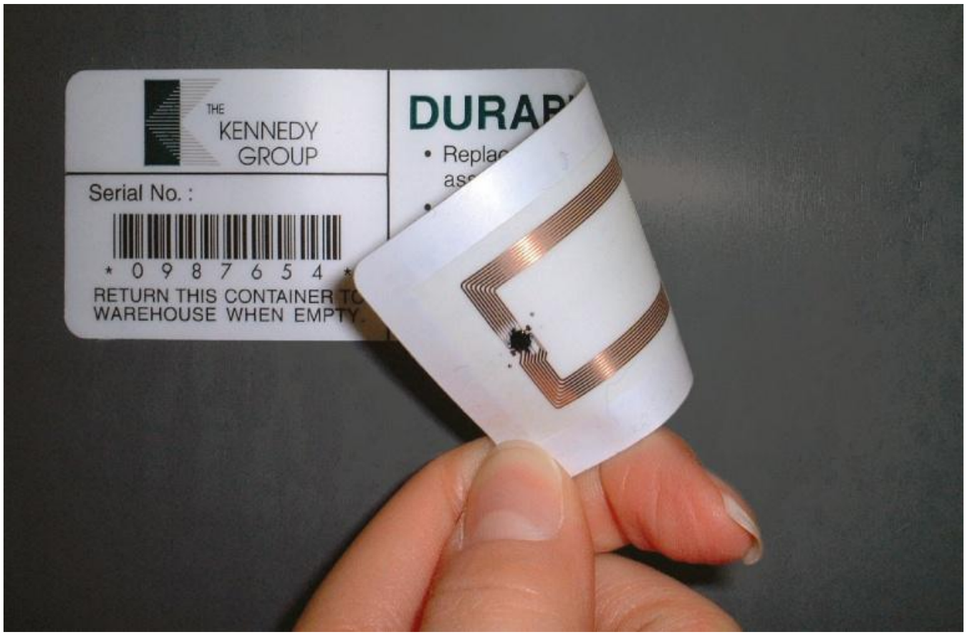
Figure 16 Infrared signals (Crandall, Bentzen, Myers, & Brabyn, 2001)



RFID Wayfinding. Radio Frequency Identification (RFID) is a technology that has been around for decades, but has only recently encountered interest for wayfinding purposes. RFID systems use tags to mark items, each tag emitting a message that can be decoded by RFID readers (RFID Journal, 2011). In practice, RFID would emit wayfinding instructions to users as they pass near RFID tags. The operation of the system would largely be dependent upon the type of RFID tag used, as there are two types: passive and active.

Passive RFID tags are very inexpensive, perhaps fueling their popularity (Figure 17). These tags do not have a built-in power source, but are instead powered from the radio frequency (RF) field produced by the RFID reader antenna. However, a key disadvantage to the use of passive RFID for localization is that in order to function at all (in order for RFID tag-embedded messages to be received), an RFID reader must be located within close proximity of the RFID tag. This is usually a matter of a few centimeters (Willis & Helal, 2005). It is not difficult to imagine that for the many users, visually impaired or not, this proximity requirement would be impractical. Similar to the disadvantage of seeking Braille, using passive RFID tags to deliver wayfinding directions might add another task to visitors' list, as the act of finding one's way could end up being preceded by the act of looking for RFID tags. Passive RFID technology may find success for uses in product tracking and building environments such as museums where tags can be utilized at displays (in areas where visitors are expected to look for information and where user location may be logically predicted), but it may not be practical for the purposes of large-scale wayfinding at present.

Figure 17 Passive RFID tag (International Coolhunting Magazine, 2011)



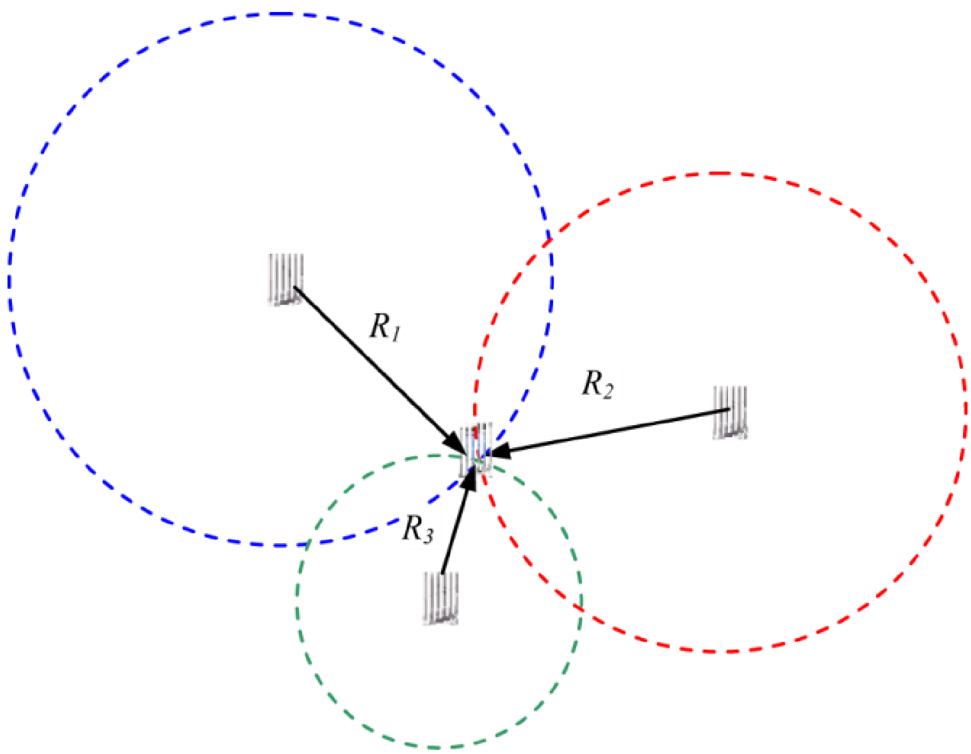
Active RFID tags differ from passive tags in that they have an on-board power source, making it possible to detect signals up to a range of about a hundred meters (Tesoriero, Gallud, Lozano, & Penichet, 2008). However, as seen in Figure 18, active RFID tags are larger, and also far more expensive than passive tags, limiting their appeal (Weinstein, 2005). Due to their cost, they are usually suited for tracking high-value items (Ni, Liu, Lau, & Patil, 2004). For the purposes of wayfinding, active RFID tags would likely need to be permanently installed in the building infrastructure, presenting another case of increased costs in addition to unit costs. Where non-line-of-sight RFID signaling is a factor, the need for even more tags may be necessary, raising costs again. However, despite cost factors, active RFID tags do hold considerable promise as an interactive wayfinding form, one that could find a foothold in the future. However, the author has chosen not to pursue this technology as the medium for a dynamic wayfinding system at this time.

Figure 18 Active RFID tag (MoreRFID, 2011)

Wi-Finding. IEEE 802.11 b/g/a/n represents standard Wi-Fi protocols defined by raw data transfer rate and signal frequency (Weyn & Klepal, 2009). Wi-Fi is a wireless technology allowing for enabled devices to share a single high-speed network connection (St. John's University, 2011). Wi-Fi networks have proliferated due to falling prices, increased ubiquity of Wi-Fi enabled devices (cell phones, laptops, tablets, PDAs, etc.) and simplified setup of Wi-Fi access points (APs). Over the past several years, tens of millions of APs have been deployed by individuals, homeowners, businesses, academic institutions, retail stores, and public buildings (Zandbergen, 2009).

Due to its prevalence, experimentation with Wi-Fi is growing and has resulted in a number of valuable innovations for which the technology was not initially intended, such as location positioning. The underlying idea behind Wi-Fi wayfinding (hereafter called *Wi-Finding*) is that a Wi-Fi-enabled device signal source can be located, and therefore a distance from the AP can be calculated. The density of APs in urban areas is so high that the signals often overlap, creating a natural reference system for determining location (Zandbergen, 2009). This idea is demonstrated in Figure 19. The method, known as *trilateration*, utilizes algorithms to perform calculations and operates in a way very similar to the function of GPS (Bell, Jung, & Krishnakumar, 2010). With position being established, a search algorithm within a database can locate all routes connecting point A (user current location) and point B (intended destination) and then calculate the path with the shortest distance. Wi-Fi is able to maintain constant contact with the user, allowing for a dynamic relay of information as needed. This makes it an attractive approach in for interactive wayfinding.

Figure 19 Example of trilateration via Wi-Fi access points (Li, Quader, & Dempster, On outdoor positioning with Wi-Fi, 2008)



2.6 The Evolution of Wayfinding

Each of the advanced wayfinding means described in the previous section (2.5) could be deployed in a setting that offers dynamic wayfinding. These systems would allow quicker, more efficient information flow, and could penetrate barriers to information access for those who have found that traditional wayfinding approaches have fallen short. Further, as it has become commonplace for consumers in advanced economies to carry various electronic devices with them at all times, it is possible that these dynamic wayfinding tools could capitalize and deliver wayfinding information seamlessly through their existing devices.

This is one reason why Wi-Finding is an attractive option. Wi-Fi's presence today is prolific, and its use as an LBS seems beneficial at relatively low cost – many businesses that would benefit from this approach already have instituted their own Wi-Fi networks. As a result, Wi-Finding could be deployed without significant investments or alterations in a building's infrastructure. Wi-Fi has also proven competitive, if not more accurate, than many other wireless LBS technologies (Bell, Jung, & Krishnakumar, 2010), the result being that Wi-Fi positioning has attracted much attention from both researchers and companies (Ladd, Bekris, Rudys, & Marceau, 2002). It is this dynamic wayfinding approach that the author intends to discuss more thoroughly.

Chapter 3 In-Depth Analysis of Wi-Finding

3.1 Third-Party Administered Wi-Fi Localization

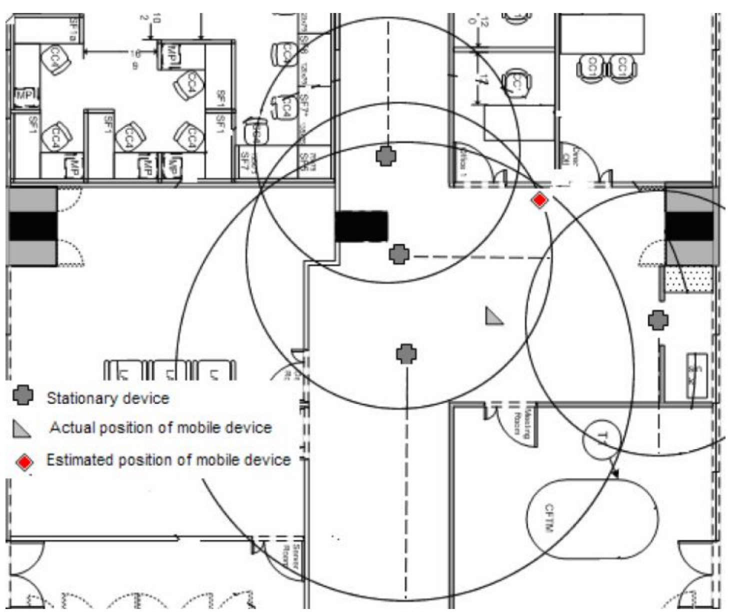
There are several Wi-Fi positioning systems currently in operation and available to the public (these establish location only). Skyhook Wireless, Navizon, WeFi, and PlaceEngine are a few examples. Each of these systems operates in a similar manner. Users install an application on a web-enabled device, and then the application records available Wi-Fi signals and sends the information to a remote location server (Figure 20). The location server compares the signals received to those in an established database, allowing for an estimated location to be sent back to the user (Zandbergen, 2009). Theoretically, the user then knows his/her precise location.

While the process is rather simple, this approach suffers from a series of setbacks. For one, positional accuracy is dependent upon accurate location of APs (Jones, Liu, & Alizadeh-Shabdiz, 2007). One analysis of positioning errors using Skyhook Wireless' database found errors consistently greater than 20 meters and sometimes in excess of 50 meters, and a couple examples of even larger error (one over 500 meters, and another over 10 kilometers from the correct location) (Bell, Jung, & Krishnakumar, 2010). These errors likely resulted from users who entered AP erroneous locations on Skyhook's website. Where user error becomes part of the equation, it is virtually impossible for the system to filter those errors out.

Figure 20 Description of Wi-Fi localization from Skyhook Wireless (Skyhook Wireless, 2011)

Even when users input information correctly, AP positions are still unlikely to be exact. This is because precise AP location is usually unknown and unlikely to be uploaded by the individual(s) who possesses this information, which is not easy to obtain. Many operators in fixed infrastructures will not disclose AP locations out of reasons for safety or privacy (Li, Quader, & Dempster, 2008). In lieu of this data, AP position is calibrated considering the signal strength emitted from the AP. Often these calibrations are gathered by way of a *war-drive* – the process of collecting Wi-Fi beacons by driving or walking (*war-walking*) through an area to discover and map AP locations (Kim, Fielding, & Kotz, 2006). War-drives began as an attempt to establish Wi-Fi "hotspots" so that those who desired could frequent the locale with the intent of uploading/downloading information at these sites through free Wi-Fi connections. For this purpose, precise AP location by way of a war-drive is not a vital issue. However, when attempting to establish AP position for the purpose of localization, AP position errors are a critical issue: any error in the AP position database will be reflected subsequently in establishing the user's position (Figure 21). Kim et al. conducted a study in 2006, finding that the median error in estimated AP locations via war-driving was 40.8 meters and 31.6 meters when war-walking was employed. They also found that war-driving/war-walking did not always reveal all the AP locations that were present. Using actual AP locations that were known to exist, their study found location estimates were improved as much as 70% indoors. This is one reason the author does not feel that it would be in the best interest of brick-and-mortar businesses to pursue Wi-Fi localization approaches that utilize data that has been uploaded by outside parties. Businesses who maintain control of their own Wi-Fi setup would inherently possess knowledge of the exact AP position and would be able to design wayfinding around the same without disclosing this information to the public.

Figure 21 Example of Wi-Fi localization error (Bose & Foh, 2007)



3.2 Wi-Fi Fingerprint Databases

While trilateration via Wi-Fi works in theory, in order to operate at maximum performance, APs must detect signal strength with consistent sensitivity. This can be troublesome in environments where obstacles (walls, objects, etc.) decrease or reflect signal strength (Bell, Jung, & Krishnakumar, 2010). Consequently, localization and wayfinding direction provided purely by Wi-Fi trilateration might be unreliable in some instances where obstacles and barriers are present. A technique that can alleviate this concern, however, employs training and tracking phases in establishment of user localization. During the training phase, the received AP signal strength is filtered, interpolated and eventually stored in a database as sample points. In the tracking phase, the user position is determined by comparing the received signal strength with the sample points stored in the database (Woo, et al., 2011). The observed Wi-Fi signals are compared to the database previously recorded in order to determine the closest match. This method of database correlation is known as *radio-mapping*, but more commonly called *fingerprinting* (Zandbergen, 2009), as each point represents a signal combination that is unique to that location. The achievable positioning accuracy of Wi-Fi location systems using this method is usually claimed to be within 1 to 3 meters (Mok & Retscher, 2007). The steps involved in fingerprint database construction are illustrated in Figure 22. Figure 23 demonstrates how signals are scanned during the tracking process, compared against the fingerprint database, and a corresponding (or near corresponding) position is returned back to the user.

Figure 22 Process of building fingerprint database (Woo, et al., 2011)

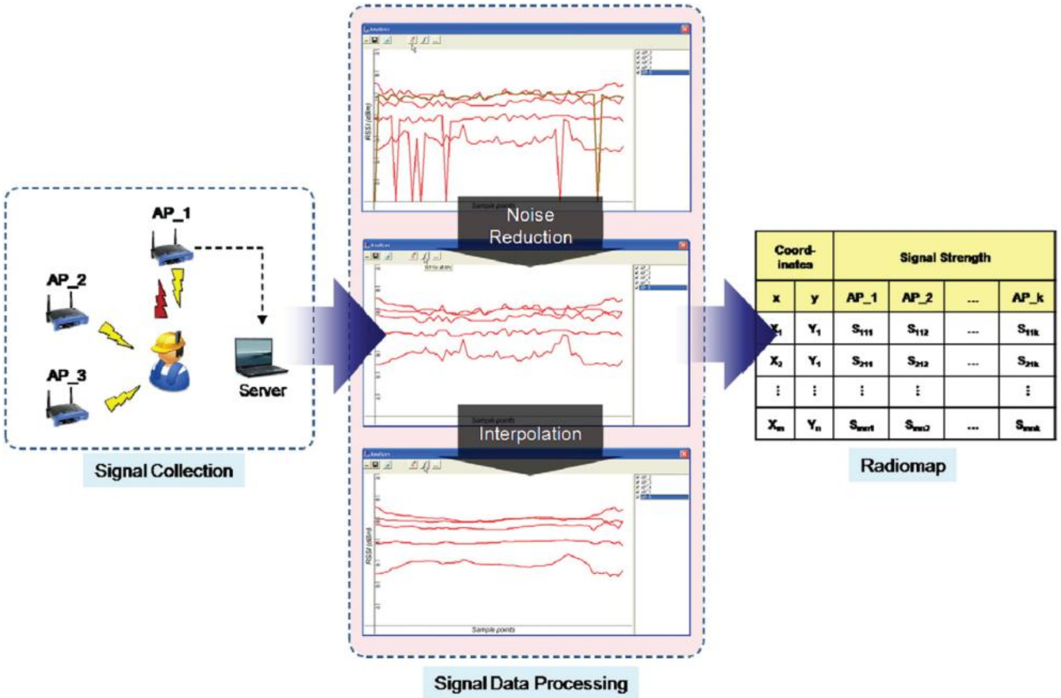
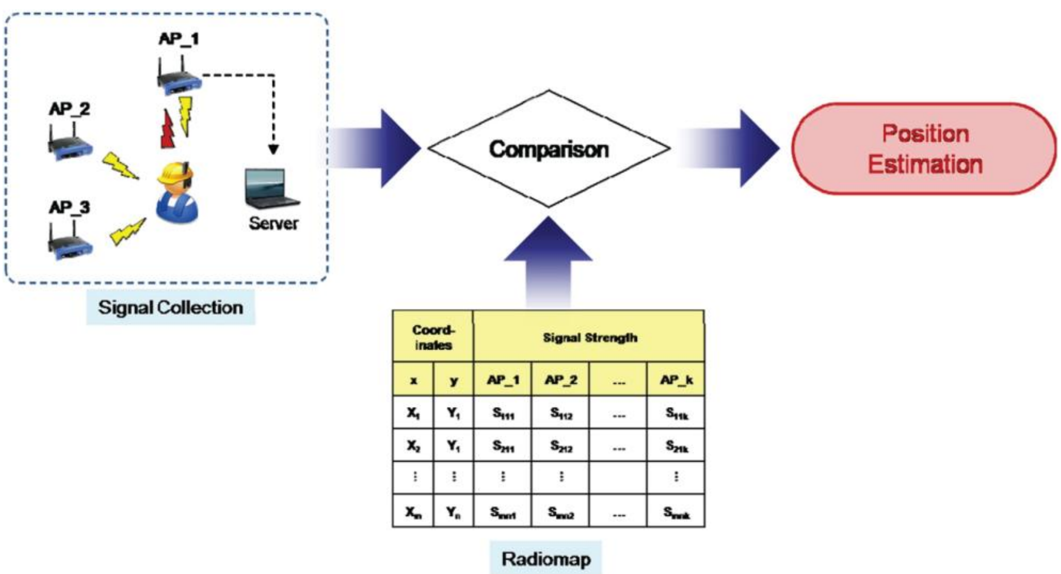


Figure 23 Position estimation via signal comparison with database fingerprints (Woo, et al., 2011)



To achieve a reasonably accurate estimation of user location, granularity within the fingerprint database must be reduced. The idea of granularity is similar to the concept of digital photo pixelation. When more pixels are present, digital photo details are finer and more precise. As more pixels are introduced, the detail provided by each additional pixel lessens, until additional pixels provide little measurable benefit. Wi-Fi fingerprint databases function in much the same way, where a certain level of detail is required to provide reasonable accuracy (Li, Wang, Lee, Dempster, & Rizos, 2005). However, due to user orientation to the AP (facing the AP, back to the AP, etc.), the mobile device signal may be affected by the user's body or other objects, impeding signal strength. As a result, in many cases four different orientations are performed on each calibration point during the training phase of fingerprint tracking (Retscher, 2006). Localization database fingerprints using Wi-Fi are normally created with distances ranging from 1 to 3 meters from the next point (Weyn & Schrooyen, 2008).

Understandably, constructing a fingerprint database can be a very time-consuming survey procedure, a potential deterrent to their deployment in large-scale indoor operations (Kaemarungsi & Krishnamurthy, 2004). Further, databases may need updating, or portions of the database may need to be rebuilt, when an environment changes significantly, such as after a major building renovation (Li, Wang, Lee, Dempster, & Rizos, 2005). Even accounting for each of the above, the positional accuracy can depend on the surrounding environment (such as busy times inside a building, or items brought onto a sales floor while stocking shelves). These circumstances can potentially create readings that might not correlate to the original database readings (Mok & Retscher, 2007).

The foregoing may lead one to believe that a Wi-Fi LBS is a poor choice. Indeed, these are some valid criticisms that are voiced in regard to the idea of employing a Wi-Fi based wayfinding system. However, the author believes there are a number of approaches that may alleviate the laborious duty of building a useable fingerprint database and allow for reasonably precise tracking where environmental circumstances pose challenges.

3.3 Reduction of Fingerprint Database Requirements

Cell Identification. It is entirely possible that, depending on the context and construction of the building in use, a fingerprint database with points measured every 1 to 3 meters from the next may prove to be overkill for the particular wayfinding task at hand. Areas of a building being mapped may be divided into cells (such as offices, hallways, etc.), representing areas of a building, rather than exact points where extensive mapping detail may prove unnecessary. Hence, for visitors to receive necessary wayfinding information, the database may only need to know that the subject is located in a designated cell, as opposed to the precise point in the cell where the subject is located. Using the cell method to establish a fingerprint database, researchers at Rice University successfully mapped a 135,178 square foot building divided into 510 cells (equivalent to the size of a 150' x 150', 6-story building) in a matter of 28 man-hours. Wi-Fi localization was able to indicate the correct cell 95% of the time. Following their work, they discovered that the building could have been mapped in less than half the time, and the database would not have suffered any appreciable loss in successful user localization (Haeberlen, Flannery, Ladd, Rudys, Wallach, & Kavraki, 2004).

Kriging. Another method that could dramatically reduce the time required to generate a fingerprint database utilizes a method known as kriging. When a point is mapped in a fingerprint database, it provides hints about the characteristics of nearby points, even if those points have not been mapped. Kriging is a geostatistical technique used to interpolate the value of a random field at an unobserved location using observations of known values at nearby locations

(Wikipedia, 2011). In simple terms, kriging is the process of mapping unknown points using the information from known points in the nearby vicinity. This would allow fingerprint database to be constructed using only a fraction of the points normally required.

This method was used by researchers at the University of New South Wales, Australia. In their study, they found Wi-Fi localization using the original database (typical fingerprint database) produced an average distance error of 1.35 meters. They also conducted Wi-Fi localization using kriging – where data from only 1/8 of the normal fingerprint database's points were utilized. The average distance error in this case was 1.49 meters – an increase of only 10% error from the normal, more labor-intensive fingerprint database (Li, Wang, Lee, Dempster, & Rizos, 2005). The author feels that for many applications, a database requiring far less input in exchange for minimal additional error would be an acceptable tradeoff. Of course, the success of such an approach would likely be dependent upon building architecture and the context of its use, but the overall benefit of this technique remains clear.

3.4 Supplemental Tracking Methods

Inertia Tracking. It is possible that during the process of Wi-Finding (when using a fingerprint database), a user's device signal may not correspond with the fingerprint database for a brief instant. Though this may seldom occur, it remains important for user location to be known when anomalies arise. Many portable Wi-Fi-enabled devices employ tools such as accelerometers or digital compasses that could perform their own calculations to determine visitor location in the event that a fingerprint database loses track of the individual. This method has been called *inertia tracking* (Furey, Curran, & McKevitt, 2008) or *dead reckoning* (Serra, Carboni, & Marotto, 2010). The process estimates a user's current position based upon a previously known point, and advances the user's location based upon measured speeds over an elapsed time and course (information that could be provided by the accelerometer and compass). A 2010 study found that inertia tracking accurately detected user orientation and displacement in indoor environments over short runs (fewer than 100 meters) (Serra, Carboni, & Marotto, 2010). Furthermore, this could serve as a powerful tool that might improve database signal calibration. It seems logical that where the Wi-Fi fingerprint database "sees" both recognized and unfamiliar user signals along a path, the unfamiliar signal information could be added to the database for further comparison, a way of "connecting the dots" and estimating location of unrecognized signals. An algorithm could be developed that would consider trends (time of day, day of week, etc.) corresponding to new signals (such as busy times in a building). The new signal information could then be used as the trends dictate, enhancing database relevance, and therefore, the accuracy of tracking.

History-based Tracking. Another method of increasing localization accuracy entails a history-based approach. This procedure would employ user-mobility profiles to specify the likelihood of user location based on historical user patterns (Bahl & Padmanabhan, 2000). This approach could assist in the event of signal irregularity from a user's device.

An example will help to illustrate this point. If a Wi-Fi database in a university building was aware, based on previous usage, that a student typically followed the same path to a certain destination (i.e., a classroom) at the same times on repeating days, a user pattern would be established. On a day corresponding to the pattern, the user enters and along the way to the destination, it is assumed that environmental circumstances cause an abnormal signal to be read, where no match exists in the database. Instead of losing track of the individual or estimating the wrong location, the user's history pattern could be consulted to provide direction as needed.

This type of approach has been tested in the past, with favorable results. A study at the University of Freiberg has shown that by using similar methods, estimations of the wrong room or wrong floor could be improved by 69.7% and 50%, respectively. Additionally, average spatial error distance decreased by 8.4% (Zhou, 2006). In another study, Intel Research Seattle found that when users revisited a place, an algorithm allowed for environment recognition more than 90% of the time, with errors being reduced upon each subsequent visit (Hightower, LaMarca, & Smith, 2006).

3.5 Potential Ramifications

There are a number of ramifications to a historical approach, the most obvious being privacy. It is important to highlight a couple key features of Wi-Finding for the sake of this discussion. First, where normal (non pattern-based) wayfinding occurs, Wi-Fi signals are not stored on the server. The information relayed by the user device can be analyzed without archiving visitor information, simply allowing the database to compare signals and return wayfinding information to the user (Zhou, 2006). Second, where a user history might be used, it is understandable that many individuals may not prefer to have their locations tracked, patterns developed, or whereabouts known in a way that could be potentially discovered by others. For these, a pattern-based approach may not be attractive. However, for a user who suffers from visual impairment, the gains in accuracy by way of historical patterns may outweigh any privacy concerns. It may even provide peace of mind, allowing user location to be proven at a later point (i.e., a student proving (s)he had attended class). Whatever the case, the author believes that the user should always control the decision to opt-in or opt-out of any tracking system that might store visitors' signal information.

There is yet another perceived risk of using Wi-Fi as a foundation for wayfinding, which involves a danger for network spoofing and location database manipulation attacks (Tippenhauer, Rasmussen, Pöpper, & Capkun, 2009). It is important to note, however, that these risks are not exclusive to Wi-Finding. This is a hazard of using Wi-Fi for virtually any purpose. Despite these known risks, Wi-Fi networks proliferate today. Just as when using Wi-Fi for networking purposes, the user must take reasonable care to avoid spoofing or hacking, while there are steps that the premises operator may also employ to discourage any such attempts.

Indeed, should Wi-Finding find a foothold in the consumer market, the issues of privacy, security, and device energy consumption, among others, will deserve greater attention and investigation. The breadth of these issues is greater than the author could hope to address in the course of this work. Notwithstanding these questions, the use of Wi-Fi networks to provide wayfinding services is a promising thought that does not appear to be very far off in the future. Wi-Fi could end up becoming the medium for a variety of uses – tracking staff, hospital patients, assets – a variety of uses in addition to its initial purpose (Stantchev, Schulz, Hoang, & Ratchinski, 2008). As for Wi-Finding, the ability for this technology to provide a dynamic, interactive connection with the user makes it an alluring subject that will undoubtedly find greater attention as time moves forward.

Chapter 4 Assistive Technology

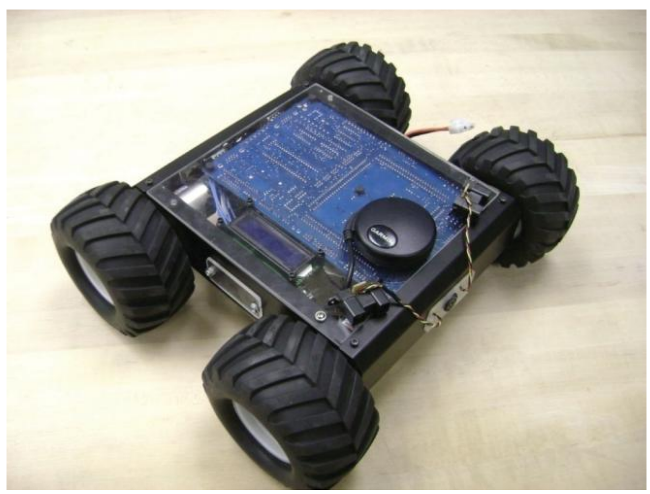
Wi-Finding is an approach that could be developed for those who deal with the rigors of disability, such as individuals who have visual impairments. Designed for this market, Wi-Finding would represent an Assistive Technology approach. Assistive technology is defined as "…any device or system that allows an individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed" (Cowan & Turner-Smith, 1999, p. 325). In the Technology-Related Assistance for Individuals with Disabilities Act of 1988, assistive technology is defined as: "Any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customized, that is used to increase, maintain or improve functional capabilities of individuals with disabilities" (Section 3, para. 1). The intent of assistive technology is clear – to alleviate strain upon a person who is impaired and encourage expanded interaction within mainstream society.

4.1 Examples of Proposed Assistive Technologies

Navbelt. For individuals who suffer from vision loss, a number of Assistive Technology (AT) projects have been undertaken in the past, some of which will be discussed here. One project, entitled the *Navbelt*, consists of a portable computer, ultrasonic sensors, and stereophonic headphones (Figure 24). The visually-impaired user wears the Navbelt around the waist, in a style similar to a "fanny pack," while the portable computer is carried as a backpack (Shoval, Borenstein, & Koren, 1998). The Navbelt provides auditory signals (or an acoustic "image") that is sent to the user through the headphones, in an attempt to lead him/her around obstacles that may be present (Shoval, Borenstein, & Koren, 1998). The function of the system is not much different from the idea of sonar guidance in submarines.

Smart-Robot. Another proposal, named the *Smart-Robot*, entails three obstacle detection sensors (ultrasonic and infrared), mounted to a chassis (similar in appearance to a remote-controlled car) that also holds other hardware, such as a battery, GPS antenna, and RFID antenna (Figure 24). During travel, the Smart-Robot provides audible information to the user through a speaker on the chassis and tactile directions through vibrating motors embedded in a glove worn by the visually-impaired user. The information from the speaker and directional information from the glove motors constitute a wayfinding system that guides the user to the intended destination (Yelamarthi, Haas, Nielsen, & Mothersell, 2010).

Figure 24 Navbelt (left) and Smart-Robot (right) (Shoval, Borenstein, & Koren, 1994; Yelamarthi, Haas, Nielsen, & Mothersell, 2010)



GuideCane. Yet another AT proposal, dubbed the *GuideCane*, comprises a long handle and sensor head unit that is attached at the distal end (opposite the user) of the handle. The head unit is attached to a steerable, two-wheeled axle. The user pushes the GuideCane ahead of him/herself, essentially like a stroller. Ultrasonic sensors on the head unit detect obstacles and steer the device around it. The user is able to sense the steering command as a force through the handle and is encouraged to follow GuideCane's path (Borenstein & Ulrich, 1997).

There are likely hundreds to thousands of AT ideas (ranging from mere concept to full-blown reality), all of which could not possibly be broached in the course of this paper. The objective in mentioning the concepts indicated above is to aid reader visualization of some approaches and to illustrate that while AT device proposals may alleviate the burden of a certain disability, they may be designed with user assumptions that sometimes can be inaccurate. Further, even where the device provides needed assistance, the context may not be one the user desires.

4.2 Flaws in Assistive Technology Design

Assumptions of User Abilities. One reason that AT devices are not always accepted by those for whom they are intended is that in an attempt to overcome a disability, AT developers may unintentionally interfere with other existing (non-impaired) user abilities. For example, assistive navigational devices that require the user to wear headphones can deprive the individual of sounds that are vital to his/her perception of the environment (Krishna, Colbry, Black, Balasubramanian, & Panchanathan, 2008). Though the target audience for AT design are individuals who suffer from impairments, these individuals still have other abilities that can help compensate for their disabilities – but they must not be obstructed.

In a similar line of thought, AT developers must also be cognizant that an impairment or disability, in most cases, is not synonymous with a complete absence of ability. Many developers may assume that without an assistive technology, an individual is helpless, a view that is not often representative of reality (Shinohara & Wobbrock, 2011). It is critical that AT designers grasp the meaning of this critique. When it is assumed that the intended user's affected ability has zero function, AT design may aim to fulfill a need in an unnecessary way. Visual impairments provide a good example of this. The fact that a person is classified as being legally blind is different from the idea that an individual possesses absolutely no sight. In fact, many individuals who have significant vision loss still possess remaining visual abilities and use those capabilities as far as they are able. Hence, some people with visual impairments may not feel the need for a complex (and potentially expensive) AT device that informs him/her of objects in the immediate vicinity, when they may be able to discern the same on their own through comparatively simple means. When AT devices cannot be customized to assist where needed, or scaled back when unwanted, AT solutions may prove unusable.

AT designers must also be aware of another improper assumption – the idea that assistive technologies functionally eliminate a person's disability (Shinohara & Wobbrock, 2011). This can lead to an unrealistic expectation being leveled upon an individual who has a disability. The person may gain from the use of AT assistance; however, his/her level of functionality may yet be far off from what a non-impaired individual experiences. A 2003 survey of individuals with disabilities found that 13 to 21% of respondents would still be unable to perform a task – despite the presence of an AT device – without additional outside aid. Further, the study showed that where the impairment is more severe, AT solutions are less likely to be used exclusively (Agree & Freedman, 2003). Even when an impairment has been essentially rectified by the AT device, one must recognize that other issues may arise, such as pain, fatigue, or loss of time associated with AT use. The presence of the same can make it difficult for the user to function as if his/her disability has been remedied completely, nor should developers expect that impairments will be entirely remedied by the AT approach .

Social Rejection of Assistive Technology Designs. There is another aspect of AT use that is more difficult to measure. This relates to the social consequences associated with the use of these devices. This matter is far too often dispensed with by AT providers or perhaps considered only after all other issues deemed more important have been resolved. Developers must appreciate that AT devices are not used in a vacuum, nor are they used in isolated laboratories. Design of such technologies must be assessed for impacts on social and professional interactions (Shinohara & Wobbrock, 2011). At its heart, the social impact of an AT device may well determine whether it finds widespread acceptance (spelling success for the developer) or overall failure (being viewed as a bust), no matter how effective the design.

When impaired individuals use AT devices, the apparatus itself may "announce" (by appearance, sound, etc.) the user's impairment. This can invite not only unwanted attention, but unwanted responses. In a 2010 study at the University of Washington (UW), individuals shared encounters where, when strangers or others became aware of an individual's impairment, study participants were offered unwanted help, or non-impaired individuals responded in ways that were uninvited. This included non-disabled individuals grabbing, pushing or pulling individuals with vision loss, over-articulating or speaking loudly to a person with hearing loss, or even composing emails in large fonts on behalf of individuals with vision impairments (consequently, this individual had to adjust her AT software that already allowed her to read smaller fonts) (Shinohara & Wobbrock, 2011). One respondent's quote in their study captures how individuals may prefer the ability to acknowledge a disability on their own:

> The kind of thing that I have a problem with, and I do not use, is a white cane. I mean, that is – that is a hurdle that, boy, that's gonna be awhile before I get over that one. …

Because, it just immediately, kind of marks you out as different, as having vision problems. Most people who meet me, until I tell them, have no idea. And, I guess I kind of prefer that. (Shinohara & Wobbrock, 2011, p. 709)

Where AT design effectively preserves the individual's ability to disclose the presence of a disability on his/her own accord, AT device use is likely to increase.

Assistive Technology Stigma. Considered from a social perspective, obvious assistive devices signal membership of a minority group – "the disabled." Along with this classification often comes a deluge of attendant images of passivity and helplessness, rather than individual identity or uniqueness (Hocking, 1999). Sometimes, this is the case because assistive devices may be aimed at the impairment (Figure 25) rather than the person (Barber, 1996). The device can then become a representation of impairment, leading to the assumption that the user is different from the rest of society. When a person's self-presentation does not meet expected social norms, the individual is found to deviate from others and social interaction is disrupted. It is then that people may be marked for their difference. Goffman (1959) defines this as *stigma*: when an attribute that is deeply discrediting is associated with an individual.

Figure 25 A functional device may not be a socially acceptable device (Attainment Company, 2011)

Stigma creates invisible but known barriers that limit the success of a class of individuals. The limitations individuals who have disabilities face in education, employment, housing and transportation are not always the products of their medical condition, but are often the result of social attitudes of neglect and stereotypical images about individual capacities and needs (Gartner & Joe, 1987). One participant in the study at UW shared her sentiments as to why she did not disclose to her employer that she was losing her sight, apparently due to fears of stigma and societal implications:

> I must admit, I kept it from them so they didn't know. …because I didn't want to lose my job. Because I know – this was back in the 80's, and I saw how the workplace was. The people with disabilities were often… let go for various reasons. So … I think if you look more mainstream, you look more able, then you're more likely … to be employed. (Shinohara & Wobbrock, 2011, p. 712)

Therefore, while the use of assistive technology may ease access for people who have visual impairments, the use of assistive technology can also disclose impairment and lead to stigma. This disclosure sometimes creates an atmosphere of deviance and disability, an identity from which most would choose to distance themselves. Individuals who possess impairments are often confronted with this dilemma of concealment or disclosure, as they may find themselves forced to trade social respect and empowerment for improved cooperation and efficiency (Reich, 2006).

This is an aspect of AT design that should never be overlooked. There is an association inferred between objects used and how individuals tend to define their identity

(Csikszentmihalyi, 1981). Within a consumer society, objects have meanings which people attempt to transfer to themselves by purchasing or using those objects (Barber, 1996). AT devices and their owners are no different. In fact, one could make the argument that for these devices, the effect is magnified. Through the use technologies today, individuals not only expand what they can do, but express their personal and social characteristics, leading others to make assumptions about their identity (Figure 26). Unfortunately, if the connotations of an AT device are negative, these are abandoned at high rates, not as a matter of function, but often due to the personal meaning associated with the same (Pape, Kim, & Weiner, 2002). Adoption or rejection of an assistive technology is best understood in context of its impact on an individual's identity (Hocking, 2000; Wielandt, McKenna, Tooth, & Strong, 2006). Although the intent of an assistive device is to help individuals overcome impairment, an assistive device that marks a user in a negative manner may create social barriers to access, rather than helping the individual to overcome the same (Shinohara & Wobbrock, 2011).

Figure 26 The use of atypical devices can lead to assumptions being made about the user (Dreamstime, 2011; Engage as you age, 2011)

One study which examined this relationship found that adolescents with disabilities may be at risk of rejection by non-disabled peers when they are unable to conform to social norms (Mulcahey, 1992). For these individuals, being "normal" is a strong desire, yet the use of assistive devices which are viewed as unnatural may draw others' attention and increase the risk of social isolation. Another study found that when using AT was an option and not an enforced choice, definitions of what constituted normality seemed to be the principal factor that determined whether or not young individuals were willing to use the technology (Kent & Smith, 2006). This can cause individuals to refuse useful technologies, preferring to conceal their disabilities or at least avoid being conspicuous (Hocking, 1999). When one visualizes the AT device proposals indicated at the beginning of this chapter, it is not difficult to imagine why some users might feel this way. Even when the user's impairment prevents him/her from personally observing the appearance of the AT device in the same way that non-impaired individuals might, the social effect is nevertheless understood. One participant in the study at UW shared the following:

> I like things attractive. Whatever adaptive equipment, I want it to look nice. You know, you got everybody with their iPods and their iPads and their Blackberries, you know, and they're whipped out, they're small… and they're nice looking. 'Cause – Apple would not be selling their "I" stuff if it wasn't good looking. And, as a blind person, yeah, maybe I don't see it, but other people see it, and I want to be, you know, just as glamorous as the next guy. (Shinohara & Wobbrock, 2011, p. 709)

Another participant in the same study shared similar sentiments:

> The original BrailleNote used to ship- I don't remember what color they were- but they were the ugliest earbuds you could possibly- like, bright orange or something. It came with these hideous earbuds. And, I had one of my friends – sighted friends – is like, "man, you – those things are awful, dude. You should <u>never</u> use those." And I had no idea. But, of course, they just thought, since it was a bunch of blind people they're shipping this stuff to, it didn't matter. (2011, pp. 708-709)

AT devices, therefore, must represent more than a remedy to impairment. Without considering the context and social interaction, a device which responds effectively to needs but fails to be socially accepted is likely to be rejected.

Self-Acceptance and Device Acceptance. It has been established that individuals may face a difficult time being accepted by others when their disability is publicized in unwanted ways. What has not been discussed is the idea that in many cases, these individuals often struggle to accept themselves – that is, to psychologically accept the reality that impairment will accompany their life. A 2002 study by Pape et al. observed that people with disabilities were more likely to abandon an assistive device if they did not accept their disability, if the device socially excluded them (made them feel different from peers), or if the device significantly clashed with cultural values. When considering individuals who have vision loss, this association is noteworthy, because, as stated earlier, an increase in visual impairment prevalence correlates to an increase in average age. In other words, many who suffer from visual impairments are not born with the condition, but experience the onset of the impairment at some point (usually later) in life. These individuals may struggle to accept their new lifestyle. For these individuals, a socially-accepted AT device design may reduce its likelihood of being rejected.

4.3 Positive Social Impacts of Assistive Technology

Thus far, the discussion has centered on the negative and detracting aspects of AT design. It is useful to understand that, just as these devices have the ability to carry a negative stigma, an AT design that makes a person feel less disabled and more like significant others possesses the chances that its adoption will increase (Ravneberg, 2009; Wielandt, McKenna, Tooth, & Strong, 2006). Perhaps "cool" devices would indicate that a disabled person is as capable as everyone else (Shinohara & Wobbrock, 2011). Pullin (2009) emphasized that addressing creative conflicts between function and fashion in assistive technology may support "positive images of disability" (p. 38). Shinohara and Wobbrock (2011) found that if a device looked similar to mainstream devices, participants did not report feeling self-conscious.

To obtain a high level of usability and widespread adoption, assistive technologies must reduce physical, cognitive, and linguistic effort and promote convenience, efficiency and productivity. In other words, they must be functional. But even more importantly, a positive impression of the user in the eyes of significant others must be established (Söderström & Ytterhus, 2010). The availability of these technologies in a socially transparent way will contribute to full inclusion within mainstream society of individuals who have disabilities (Cook, 2010).

Chapter 5 Trends in Inclusive Design

5.1 Historical Design Approaches for Individuals with Disabilities

The functional, aesthetic and social demands placed upon the AT designer can be overwhelming and difficult to meet. This task can even seem unattainable, as the goal is often a moving target. This may be due to economic constraints that obligate AT developers to await the introduction of new technology(s) upon which the AT device can be based. Thus, being reactive, once AT artifacts have been designed around a mainstream technology, the mainstream technology itself has moved forward, leaving the AT device (and its users) in the past (Dobransky & Hargittai, 2006; Emiliani, 2006). This thought is captured in one participant's statement in the study conducted by Shinohara & Wobbrock (2011):

> A term that gets thrown around sometimes is blind ghetto products. … cell phones have, like, all these neat features and stuff, but, …the BrailleNote's just catching up. When you know, it doesn't even have like, 802.11n, which is the new networking standard. You know, but it costs six grand. I mean, come on. (p. 708)

Much of this blame can be placed on bare-minimum efforts to satisfy the needs of the individuals with disabilities by the entities running at the front of the technology curve. Although the U.S. was the first nation to fully embrace and codify design as a civil right for people with disabilities (Fletcher, et al., 2010), in the past these codes were often adopted by coercion, leading to satisfactory outcomes (by definition of the code) that were hardly breakthrough.

5.2 Inclusive Design Motivation

New requirements and demographic trends, however, have triggered more progressive approaches, resulting in positive changes for those who suffer from impairments. One force behind this change is the Workforce Investment Act of 1998. Section 508 of the Rehabilitation Act Amendments, as amended by the Workforce Investment Act of 1998, requires the following:

> …when Federal agencies develop, procure, maintain, or use electronic and information technology, they shall ensure that the electronic and information technology allows Federal employees with disabilities to have access to and use of information and data that is comparable to the access to and use of information and data by Federal employees who are not individuals with disabilities, unless an undue burden would be imposed on the agency. Section 508 also requires that individuals with disabilities, who are members of the public seeking information or services from a Federal agency, have access to and use of information and data that is comparable to that provided to the public who are not individuals with disabilities… (Architectural and Transportation Barriers Compliance Board, 2000, p. 80500)

An important element of this legislation is also found in Paragraph (d) of the same document, which "requires that software programs, through the use of program code, make information about the program's controls readable by assistive technology" (p. 80508). Section 255 of the Communications Act of 1996 was another catalyst for AT development, which introduced performance-based requirements based upon the functional capacity of the communication technologies. It assumes that technology is dynamic and continuously changing and that performance measures can be responsive to an evolving knowledge base (Fletcher, et al., 2010).

In essence, these measures require (at least at the Federal level or within the genre of communication technologies) that electronic and information technologies must be equally accessible by all individuals, including those who have disabilities. This has instigated the development of all sorts of software programs that enabled those who previously may have had great difficulty using the same. It also contracted the disparity in time between the introduction of new, mainstream technologies and the subsequent AT devices based on the same. In many cases, the introductions of both now take place concurrently.

5.3 Consumer Market Response

Although these measures largely did not establish new, compulsory standards in the private sector, they did serve as a wake-up call for the consumer market, stimulating the growth of new design movements, such as inclusive design and universal design (also known as *trans-generational design* or *design for all*). Inclusive design stipulates that the design of products and environments must be usable by everyone, to the greatest extent possible, without the need for adaptation or specialized design (Burgstahler, 2011). Universal design inspires developers to make more intuitive products that work better with less effort and lower risk of injury. It makes products usable for people with a greater diversity of abilities in a wider range of environments for a longer period of their lives and as their abilities change (Bauer & Lane, 2006). The interests of these causes have allowed for renewed consideration and vigor that contemplates the needs of all users within the design field.

Alas, corporate goodwill may not be the only motivation for inclusive design approaches. It is certain that a large number of these entities recognize the changing demographics in the largest consumer markets, resulting in a flourishing of market demand for devices adhering to the principles of inclusive design. The growing senior's market is a major driver for innovation, attracting the attention of major manufacturers of telecommunication, computer, health care, and consumer products (Bauer & Lane, 2006). Whereas the focus may have been upon meeting a code (if one existed) in the past, the focus is now upon design and usability. Though attitudinal barriers may keep firms from "tooting their own horn" about the extent of their endorsement and adoption of inclusive designs, there is no doubt that the design field is evolving to incorporate it (Fletcher, et al., 2010).

An example of this is the World Wide Web Consortium, which began the Web Accessibility Initiative (WAI). The WAI rejects the narrower goal of making the web usable through the use of assistive technology by individuals who suffer from vision loss (although a promising goal), instead favoring a quest for building knowledge that makes the web more usable by everyone, including older users (Fletcher, et al., 2010). Aims such as this have created increased buy-in from all corners of the consumer market. This is creating substantial change within the technology-based approaches that are used in the fields of disability and rehabilitation (Robitaille, 2010). Increasingly, technological innovations developed for specific market genres (such as individuals with disabilities) have considerable cross-market relevance (Bauer & Lane, 2006). What may be one person's mainstream technology might be another person's AT device (Petrie & Edwards, 2006). One instance of this approach is the BT Big Button 100 telephone (Figure 27), originally designed for elderly people and sold through BT's special needs catalogue. Within one month of its release, the Big Button 100 telephone was BT's fourth-best selling phone and the ninth-best selling in the market (Disability Rights Commission, 2004).

Figure 27 BT Big Button 100 (BT, 2011)

5.4 Inclusive Design versus Assistive Technology

Traditionally, inclusive design and AT approaches have been seen as two distinct topics, each side claiming possession of their respective territory (Petrie & Edwards, 2006). This sometimes led to skirmishes between inclusive design devotees and traditional AT device experts. These squabbles have given way to a common commitment to promote inclusive design as a baseline for standard products, with AT spanning the gap for individual users whose functional limitations lie beyond the reach of the inclusive baseline (Fletcher, et al., 2010). Today, mainstream product and AT device manufacturers are entering into collaborative relationships that leverage the AT manufacturer's unique knowledge of disability markets. In turn, AT manufacturers have benefitted from the enlarged technical, financial, marketing, and distribution capabilities these mainstream manufacturers possess. This has resulted in vastly improved, high-quality products that are introduced into a broader marketplace within shorter timeframes (Bauer & Lane, 2006). Insofar as its approach can reach, inclusive design is allowing a greater diversity of users to participate in new product releases that previously may have been available only to the non-impaired public, or only to individuals with impairments after they had taken exhaustive, customized measures to enable their access to the desired technology.

Inclusive Design and AT Inputs. One inclusive design technique places “hooks” within mainstream technologies, allowing for assistive technologies to latch on and establish an interaction between the mainstream technology and a user who may have a disability (Lewis, Eckert, & Clarkson, 2004). Microsoft’s operating system, Windows, is an example, as it allows ATs such as screen readers to access information that the AT software transforms into synthetic speech or Braille that is transmitted to the user as desired (Petrie, 2001). Mainstream products also increasingly employ “hidden” means for adaptation for different users that are embedded within the product purchased by all individuals, disabled or not. Examples include browsers which allow users to change font and graphic sizes and operating systems which allow keyboard and mouse customizations. This can also be a different approach that cancels out the need for a separate AT purchase, such as Apple’s VoiceOver (Figure 28), a screen-reading technology made available on every version of Mac OS X, and Apple Spotlight, which allows users to launch applications and conduct all functions using only a keyboard (Fletcher, et al., 2010). Similar features, such as text-to-speech functionalities, are built into products such as the Amazon Kindle and many Android-based devices (Stroud, 2010).

Figure 28 Apple iPhone with VoiceOver Software (Apple, 2011)

In many ways, the competition to develop the most inclusive design-friendly device is just beginning to heat up, largely to the benefit of all consumers. Microsoft and Apple are perhaps the most obvious examples of this rivalry, but other well-known entities such as Google and Android are entering the mix more and more. Smaller, application-specific competitors will also play a role, such as SmartArt, which since 2007 has allowed users to access graphics tools and create complex graphics without having to use a mouse (Fletcher, et al., 2010). Mainstream technologies available off-the-shelf with embedded/hidden inclusive design tools will also spur the development of other technologies that make use of these inclusive design aids. One example is Apple, whose decision to make iPhone application software freely available to anyone has generated a spectacular windfall of applications, some with the potential to replace assistive technology (Fletcher, et al., 2010). This creates an opportunity for AT development at reduced cost. Andre Lukatsky, director of computer services at the Hadley School for the Blind, agrees: "Because these are mainstream devices, (schools) don't have to invest a huge amount of money in the technology" (Stroud, 2010, para. 5).

Consequently, these mainstream technology devices are becoming tools that function in a variety of manners depending on user needs. This also allows users with disabilities to take advantage of a wide range of technological features and enables the use of many programs that previously were limited to AT-specific devices. Tracy Gray, director of the National Center for Technology Innovation, confirms the same: "What we're seeing is a growing convergence in technology for general consumers and technology for different needs," (Stroud, 2010, para. 3).

Inclusive Design Limitations. While inclusive design has certainly grayed the line between mainstream technology and assistive technology, it must be acknowledged that it can only go so far in meeting the needs of users with disabilities. At some point, extra technologies (i.e., AT-specific devices) are needed to allow universal access where inclusive design-based approaches fall short (Petrie & Edwards, 2006). It is also worth noting that although inclusive design advances have been great, barriers to its widespread adoption still exist, one of the most significant being the cost to offer inclusive design implementations on a wide range or variety of technology platforms. In practice, manufacturers may have to limit the extent of platforms offered (Fletcher, et al., 2010). Nonetheless, there is no doubt that inclusive design is allowing for an ever-expanding set of users. Their access to off-the-shelf tools once reserved for only those without disabilities will mean more empowerment and social acceptance for all (Robitaille, 2010).

Chapter 6 Existing Technology and Consumer Use

In order to develop an appropriate concept for Wi-Finding applications, it is necessary to examine the benchmark standards that the device must meet. Further, an assessment of current technologies would reveal whether current approaches exist that could implement Wi-Finding in a seamless manner.

6.1 Wi-Finding Device Criteria

Obviously, a fundamental requirement of the device would be the ability to connect to Wi-Fi networks. The device must relay information to the user, whether visually, through tactile senses, audibly, etc., and must allow for user customization to account for the presence or lack of user abilities. The presence of hooks that allow for AT software usage and/or embedded features that allow for its use by most disabled users' would be essential, as well. Finally, any existing technology employing each of these characteristics would need to be reasonably affordable.

6.2 Smartphones

Many smartphones and smart devices (Figure 29) on the market today employ inclusive design characteristics in addition to a wide feature set that would make this platform an attractive medium through which Wi-Finding could be offered to individuals with disabilities. Before assuming that this is the ideal approach, it would also be worth discussing whether these devices are even a rational choice for individuals who are sight impaired, especially in light of the correlation between vision loss and older age.

6.2 Smartphone Market Penetration and Demographic Use

It may be tempting to assume that a wayfinding approach that employs the use of smartphones or smartphone-like devices is better suited towards younger individuals, as the assumption may be that older individuals may not use mobile phones extensively and would be even less likely to own smartphones. In light of historic mobile carrier phone usage, this criticism may be expected. This critique, however, ignores the fact that smartphone devices have not been around very long. Even the prevalence of normal mobile phones is a rather recent development, becoming widespread only during the last decade.

Figure 29 Examples of smart devices (Newsarama, 2011; Pective, 2011; Tech2, 2011; Verizon Wireless, 2011)

Older populations are adopting mobile communication forms at an increasing pace (Figure 30). The drift towards mobile communication devices among all population ages is a known fact that has been studied by the Center for Disease Control (CDC). The CDC found that in 2010, more than one in every four homes in the U.S. had only mobile carrier telephones (Figure 31). Three years earlier, this figure was one in every eight households, demonstrating how quickly households are moving towards portable cellular communications and away from landlines (Blumberg & Luke, 2010). The CDC's data does show that older individuals are less likely to live in a cellular-only household ("only wireless," as phrased by the report). However, growth of cellular-only households is very rapid among the elderly, particularly over the last few years.

Figure 30 Data on individuals with only mobile telephone service by age (Blumberg & Luke, 2010)

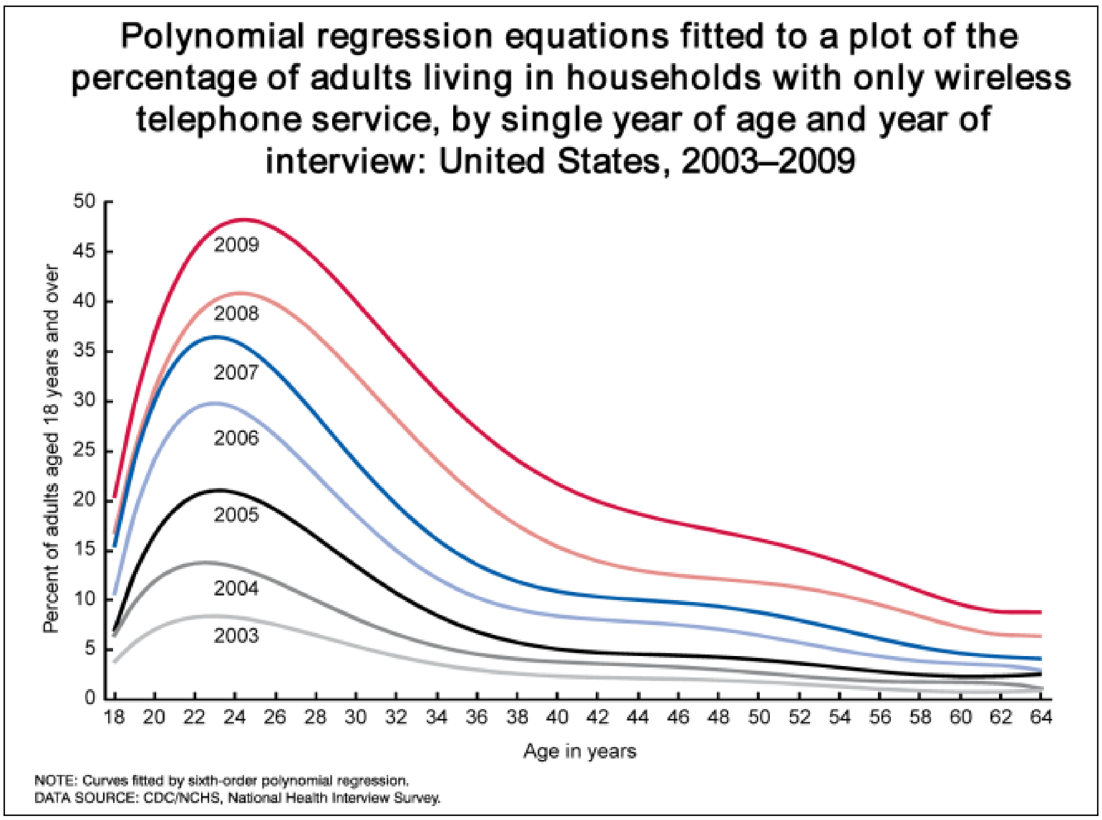
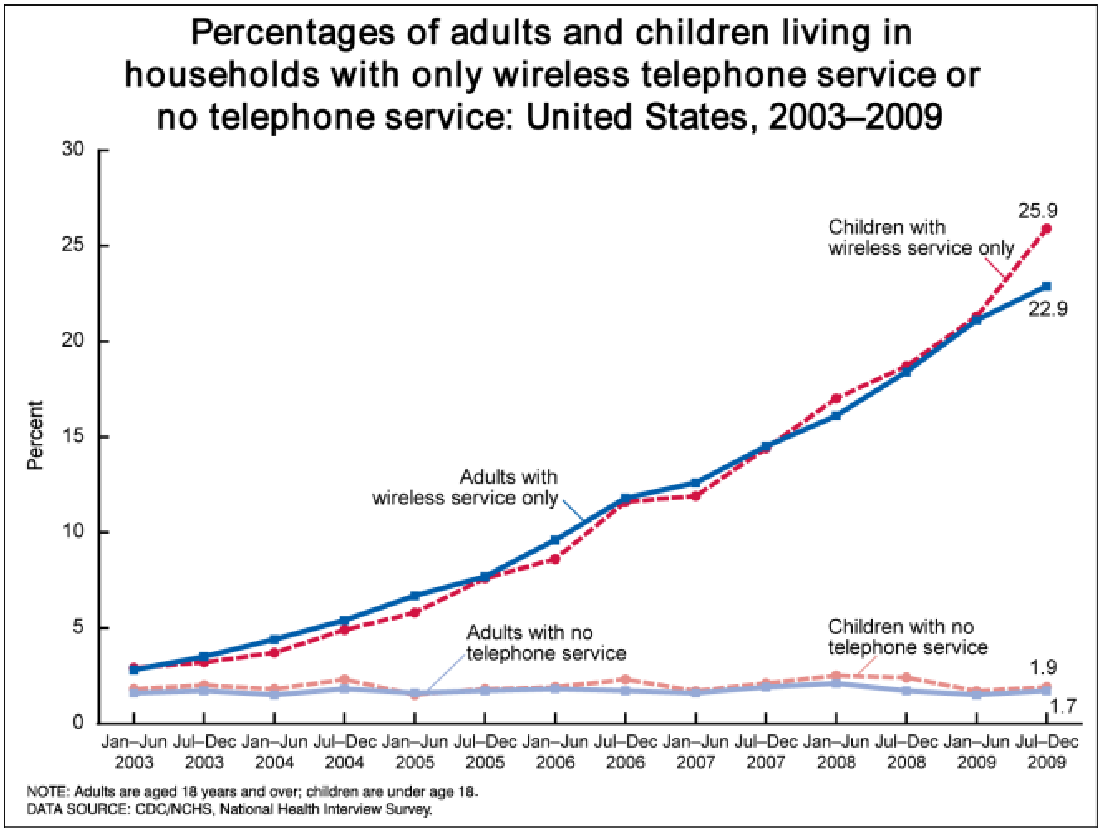
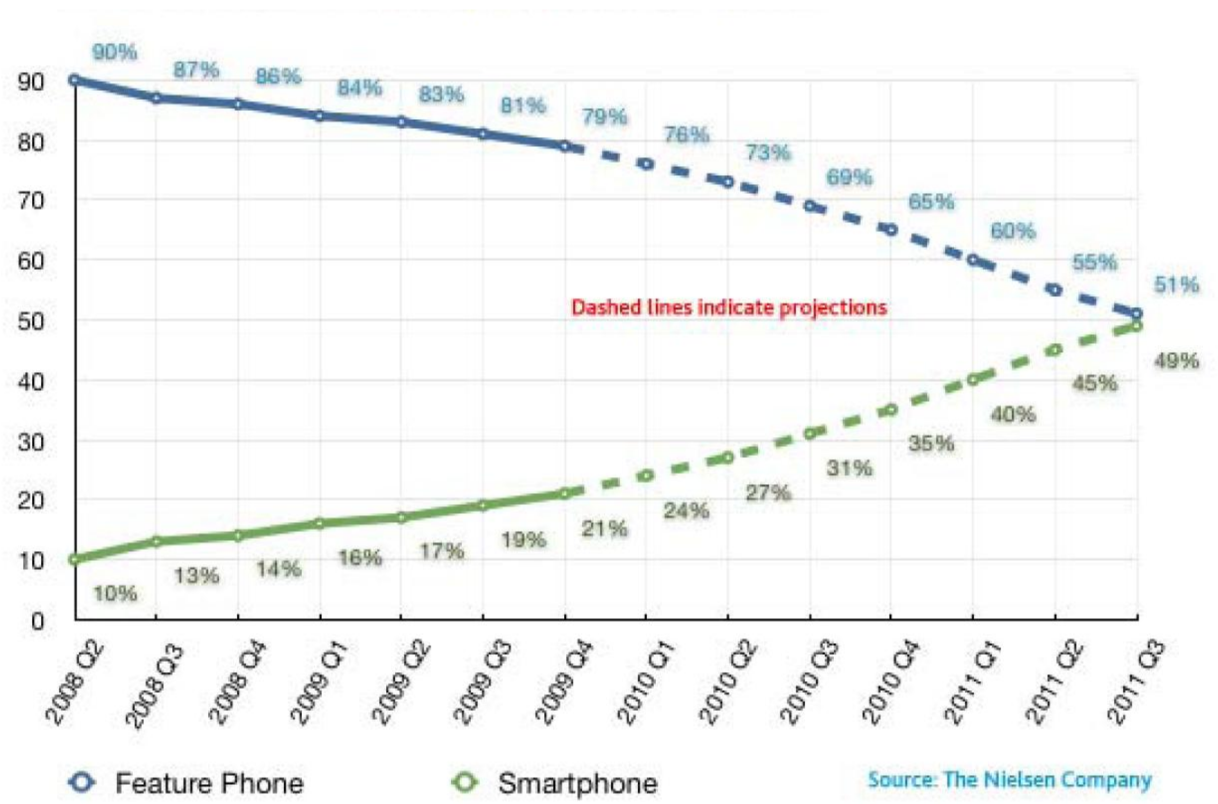


Figure 31 Percentages of households with only mobile phone service (Blumberg & Luke, 2010)



As for smartphones, within a matter of a few years these devices have already established considerable market presence and their popularity is gaining consumer attention quickly. A 2010 Nielsen study found that 28 percent of U.S. wireless users own smartphones (Nielsen Wire, 2010a). Nielsen's data is represented in Figure 32. Forty-five percent of respondents indicated that their next cellular device will be a smartphone. By the end of 2011, Nielsen expects there will be more smartphones in use in the U.S. market than typical mobile carrier feature phones (Nielsen Wire, 2010b). Where it was very uncommon to see these devices only a few years ago, they are now becoming technology staples within mainstream society. Thus, when the CDC's report is considered jointly with Nielsen's predictions, it is apparent that individuals and households are turning to mobile phones as their primary form of telephone-based communication (if not the only form of telephone communication), and that smartphones will soon outnumber feature phones. Given the trends, it appears foreseeable that these trends will influence all ages of society within the next decade.

Figure 32 U.S. Smartphone Penetration & Projections (Nielsen Wire, 2010a)



It is also worth noting that the nature of consumer use is evolving rapidly, as users move from normal feature phones to smart devices. Nielsen Wire found that 5% of feature-phone users access Wi-Fi with their phone, as opposed to 50% of smartphone users (2010b). The ability for smartphone owners to connect to Wi-Fi networks is a distinct advantage over feature phones, but not the only one. Internet connectivity aside, the computing means of smart devices has become so advanced that they are being used in a variety of ways with which feature phones could never compete. For a matter of a few hundred dollars (often less, when purchased with a mobile carrier contract), users can access a multitude of applications and information. Many of these devices have more accessibility software built into them than most computers had just a few years ago (Akkad, 2010). Applications, or "Apps" designed for smart devices, are also exploding in popularity. In 2009, 300 million smart phone Apps were downloaded, but just one year later, 5 billion were downloaded – a 16-fold increase (Mobile Future, 2011). The smartphone revolution has turned once-simple phones into multipurpose devices able to indicate information about one's location, social calendar, favorite restaurants and much, much more. These devices are changing the manner in which individuals interact with their surroundings and with each other, affecting culture, identity, and relationships (Traxler, 2008). Their use for wayfinding purposes would not seem unusual or unfitting in most social environments, as individuals use smartphones for all sorts of purposes within mainstream society. Considering that many smartphones are available off-the-shelf with embedded features that allow access by the disabled community, or are present with hooks that allow access through the use of AT software, the result is that individuals who suffer from disabilities are largely able to access the same applications everyone else can. This leads the author to believe that individuals who are visually impaired, whether of advanced age or not, will be just as likely to adopt a Wi-Fi navigation system deployed through the use of smartphones and other smart devices.

6.3 Assistive Technology-Specific Device Relevance

While Wi-Finding could essentially be delivered to consumers via an existing smartphone that implements inclusive designs, it does not necessarily indicate that an AT device approach is inappropriate. For one, it is necessary to identify whether Wi-Finding is attractive to the general population, or only to smaller crowds, such as those who suffer from disabilities. If the concept proved unpopular to the general public, an AT-specific device designed around the needs of individuals with disabilities may be a more fitting method of Wi-Finding delivery. Nevertheless, the foregoing AT design discussions (Chapter 4) would be implemented, in hopes of providing a socially-acceptable, functional product that would please potential users. Further, it is conceivable that this design approach, while intended for users with disabilities, could prove popular for non-impaired individuals who may be considering the purchase of a smartphone or smart device, as has occurred in the past (Akkad, 2010). At this point, however, it is unclear whether an AT design approach or an inclusive design implementation is better, or if both options present attractive paths towards this goal. This is an answer the author sought to expose by way of further study.

Chapter 7 Wayfinding Study

7.1 Building Description

An important step in determining the general public's desire for Wi-Finding is the assessment of how well traditional, static wayfinding methods are meeting general user needs. The author operates under the assumption that if the general population's demands are already being met at a reasonable level by traditional approaches, an overarching need for Wi-Finding probably does not exist. Under this outcome, an assistive technology design approach would be adopted in an effort to meet the needs of those who have disabilities. On the other hand, if the general public expresses a desire for the same, an inclusive design approach would be fitting.

To gauge general user wayfinding demand, the author identified several criteria to select a building where navigation was expected to be very challenging for visitors. A large building with a considerable amount of foot traffic (potential survey candidates) was necessary, while building symmetry, with limited features allowing spatial orientation, would likely challenge the effectiveness of visitor wayfinding. A general lack of wayfinding aids (i.e., signage) was also desired for the purposes of this study. These characteristics would essentially blend to form a worst-case scenario, where a high level of wayfinding demands would be anticipated in light of a rather challenging environment.

Auburn University's Haley Center was selected for this purpose (Figure 33). Built in 1969, the building is the university's largest (covering more than 400,000 square feet on 10 floors), capable of serving 8,000 students during academic hours, and likely the busiest building on campus as well (Auburn University Libraries, 2011; Auburn University, College of

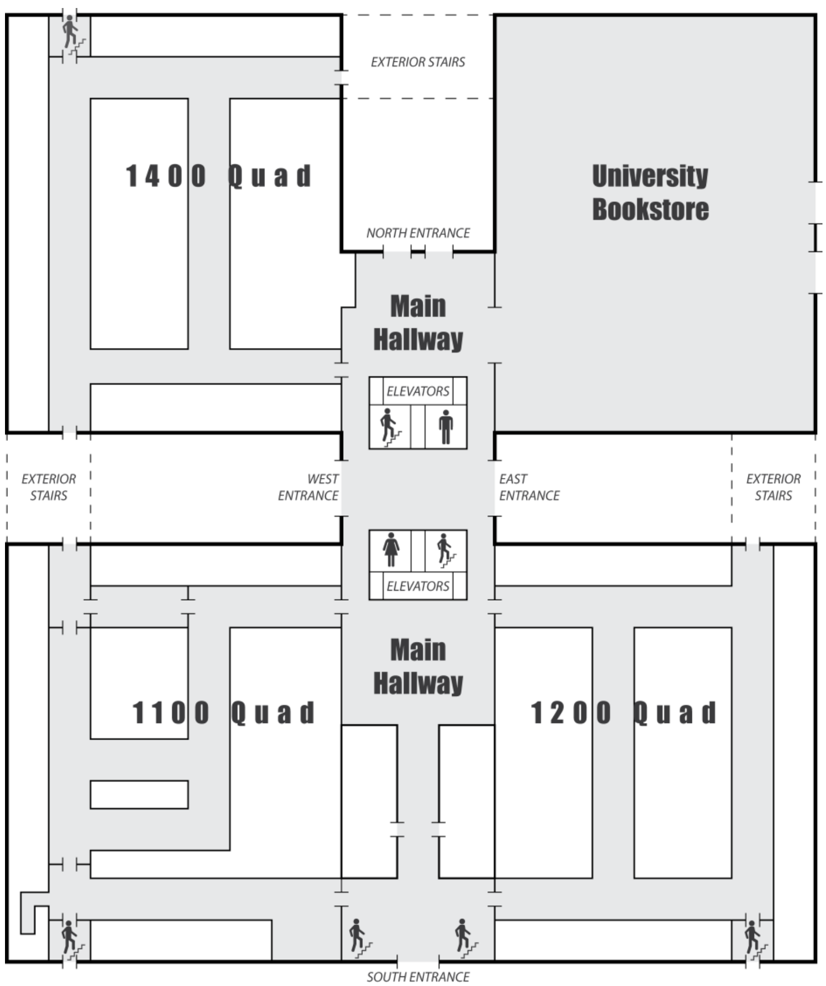
Education, 2011). To this day, very limited wayfinding aids are present within the structure. There are a few locations where signage is posted, though the signs are usually small and sometimes posted in inconspicuous areas. Some departments or individuals have even resorted to posting their own department-specific signage to assist visitor guidance (Figure 34). Room numbering within the building is also a challenging issue, as numbers do follow a pattern, though the numbering sequence is not immediately apparent. Yet another potential for disorientation exists because the building is largely symmetrical within the interior (on all levels), and there are few features that allow for orientation to be established.

Figure 33 Haley Center Exterior

Figure 34 Department-posted signage at Haley Center

A physical description of this building would be beneficial. On the main floor, Haley Center is composed of a central hallway and four “quads” (Figure 35). The hallway (the most popular entrance into the building, with multiple entry points) provides a connection to various destinations within the building via elevator access, stairway access, and quad entrances. The quads (each situated at corners of the main hallway) house classrooms and offices, the typical destinations for building visitors. The second and third floors are similar in layout to the main floor, while the upper floors have no quad areas and house department or individual professor offices. Foot traffic is considerably lighter on these floors.

Figure 35 Haley Center: Main floor layout



7.2 Introduction of Wayfinding System

The author mapped out the main floor of Haley Center and designed a series of 22 wayfinding signs of varying size and appearance. Four of these were large, double-sided signs, approximately 21 inches tall by 33 inches wide. Another one-sided sign, of identical measurement and similar layout, also joined this group. These signs were suspended (double-sided signs) or affixed (one-side sign) in the main hallway, just outside quad entrances within the building interior. Each sign provided directions to various quad locations, occasional directions to various departments, as well indications of bathroom and stairway locations, among other details. Two more first-floor overview "maps" (these were affixed to columns and not transportable), oriented to visitor position when viewed, were also displayed in the main hallway area. Each of these measured 15 inches wide by 22 inches tall. As for the quad areas, a total of eight signs were posted among two quads, while in another quad (one with a more complex layout), seven signs were posted. These were affixed to walls about 60 inches from the floor. While there was a little variation in the size of the quad signs (depending on the extent of information being relayed), none was smaller than 9.6 inches tall by 20 inches wide. (The remaining first-floor quad, occupied by the university's bookstore, was left untouched due to its own set of wayfinding features.) The signs are depicted in Figure 36. Figure 37 provides examples of the areas where the signs were posted within the building (both figures are presented on the following page).

Figure 36 Examples of test signage installed at Haley Center

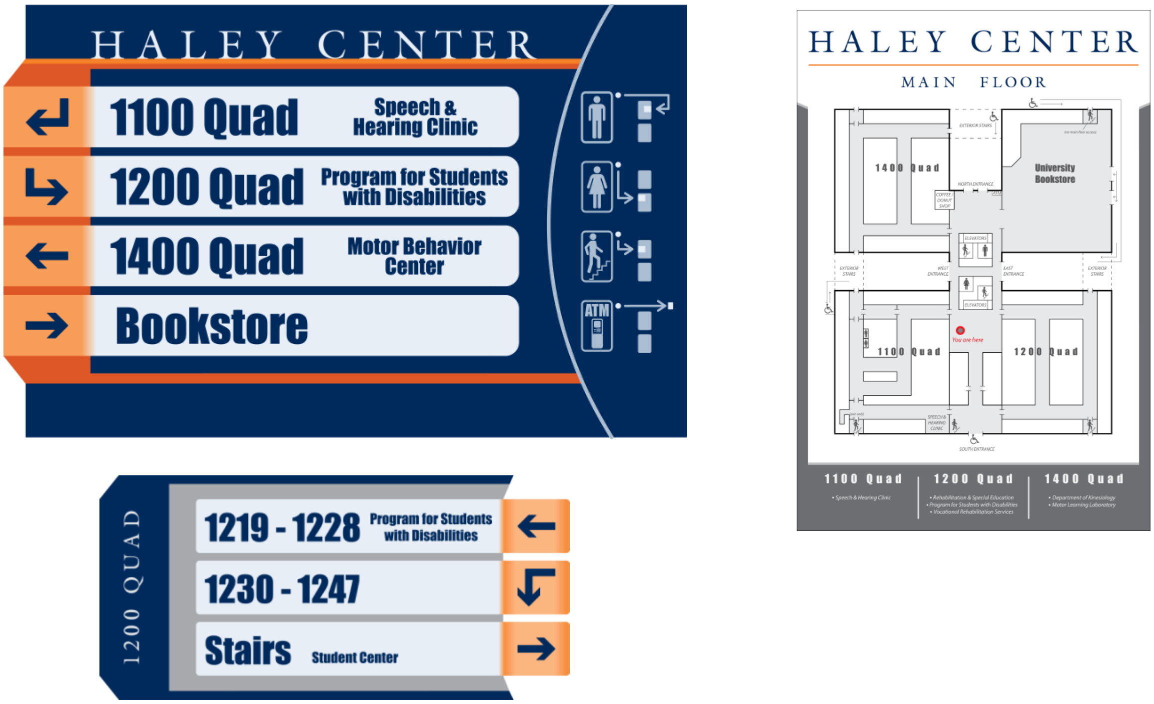
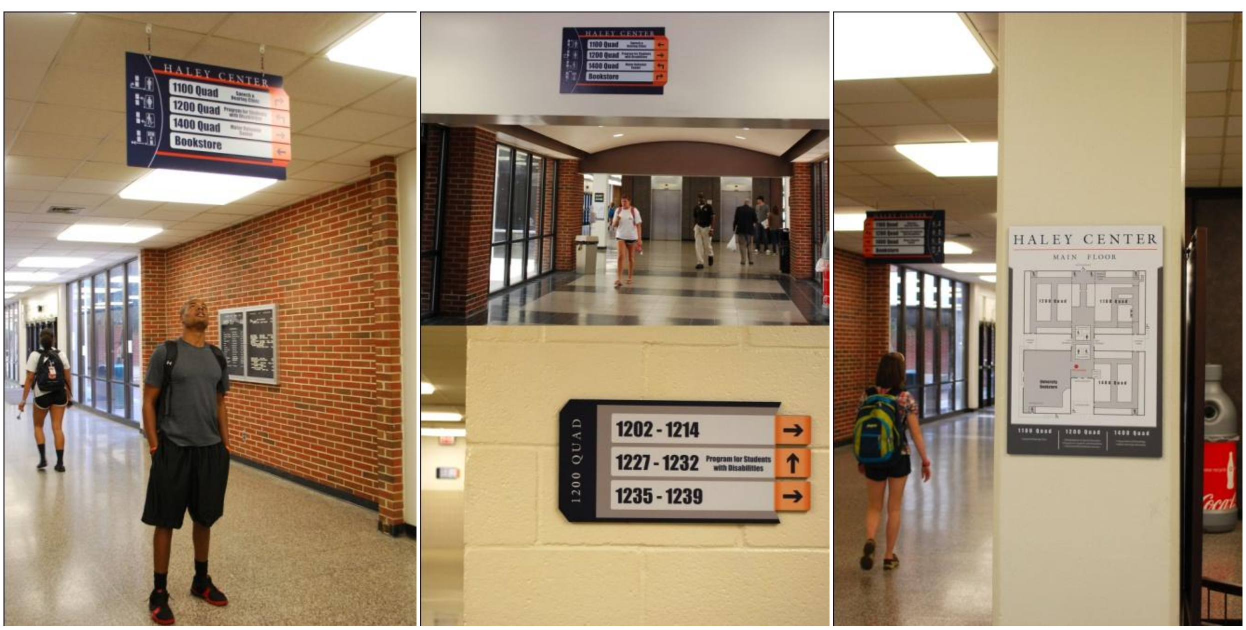


Figure 37 Examples of areas where test signage was posted



7.3 Haley Center Visitor Survey and Results

Within the week following the posting of the signs, visitors to Haley Center were randomly approached and asked to complete a one-page survey. These individuals were all contacted while on the main floor in areas where the signs were posted (it would have been very unlikely that individuals had not already passed any of the signs). In all, a total of 135 visitors completed the survey. An example of this survey is given on the next page (Figure 38), while the results of the survey questions are expressed visually in tables that follow (Figure 39 to Figure 44).

Figure 38 Haley Center survey

This questionnaire is an attempt to gather information about effective ways to distribute directional information / navigational information. Your thoughts are appreciated!

1. In the past, how have you found your destination at Haley Center?

   ○ I found my way on my own (hit or miss approach)
   ○ I asked for directions
   ○ I followed signage that was previously posted
   Other________________________

2. How often do you visit Haley Center?:

   ○ 2 times a week or more ○ 1-2 times a month
   ○ Once a week ○ Less than once a month

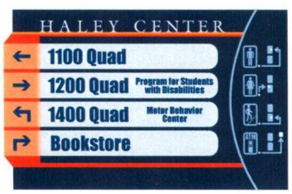
3. Please indicate your opinion regarding the following statement:

   "It is easy to find your way around at Haley Center."

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
○	○	○	○	○	○

4. Before being handed this survey, did you notice any signs like the ones seen below?

   ○ Yes
   ○ No



5. If yes, please share your thoughts about the directions posted on the signs:

   ○ Directions were helpful
   ○ Directions were unclear
   ○ I already knew where I was going (didn't pay attention to signs)
   Other________________________

6. Let's assume you are looking for a new location inside Haley Center -- but you have no idea where it is. Which of the following would you use (if it was available)?

   ○ I would look for printed materials (signs, maps) that give a general idea of the location
   ○ I would follow interactive directions sent over Wi-Fi to my smartphone / smart device that would guide me to the exact location (similar to GPS)
   ○ I would look at a map available online (pdf or other image)
   Other________________________

7. How often do you use your cell phone for more than just making calls?

   ○ 1-2 times a day ○ 6-10 times a day ○ I couldn't count - but it's a lot
   ○ 3-5 times a day ○ 11-20 times a day ○ I don't use a cell phone

Please feel free to share any thoughts/suggestions on the back of this page. Thank you!

Figure 39 The majority of visitors at Haley Center find their way on their own

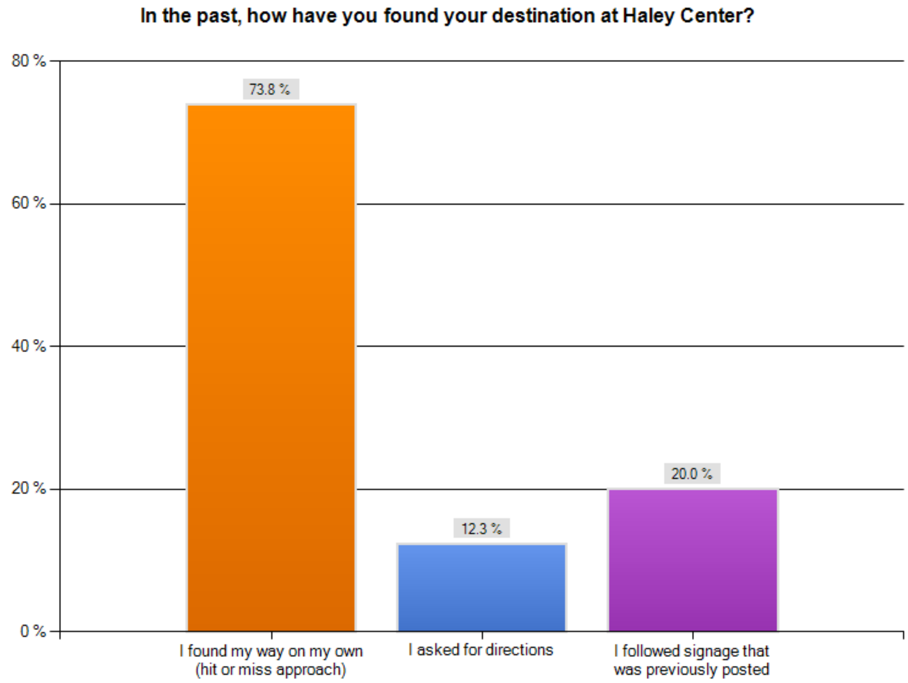


Figure 40 Most respondents visit Haley Center many times a week

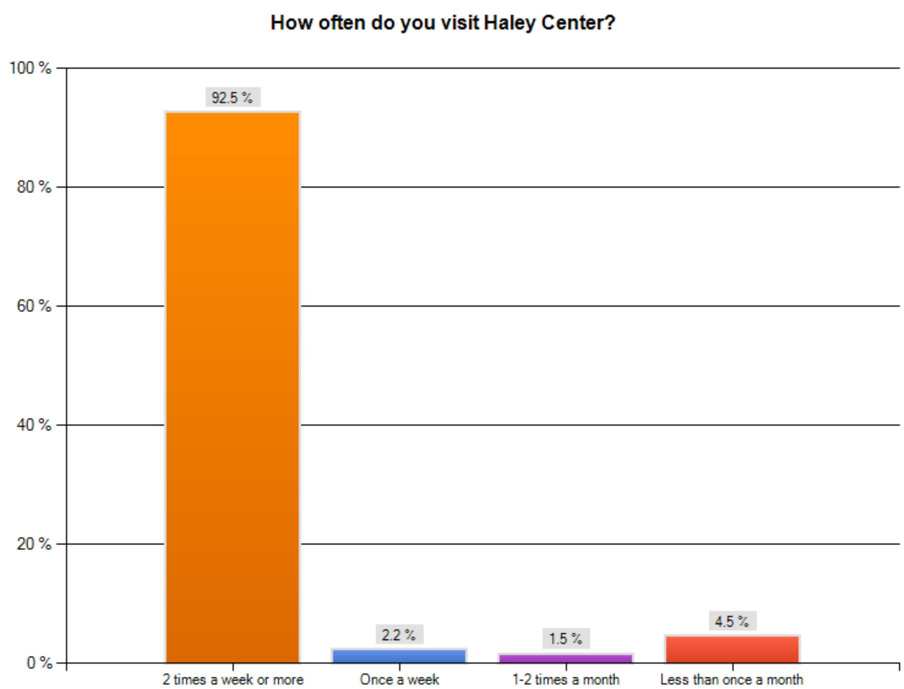


Figure 41 A majority find it is difficult to find one's way at Haley Center

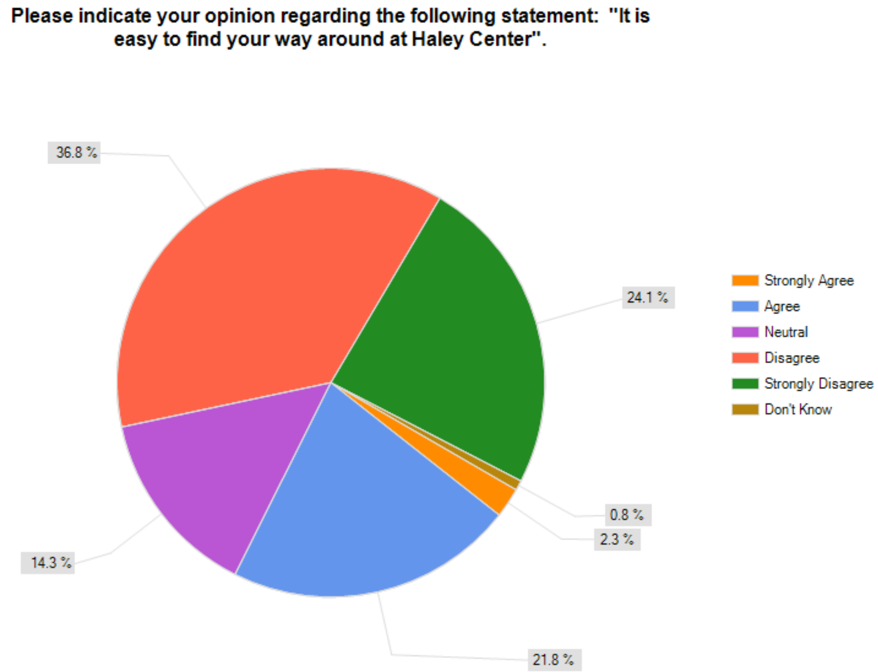


Figure 42 Over 25% of participants did not observe posted test signage

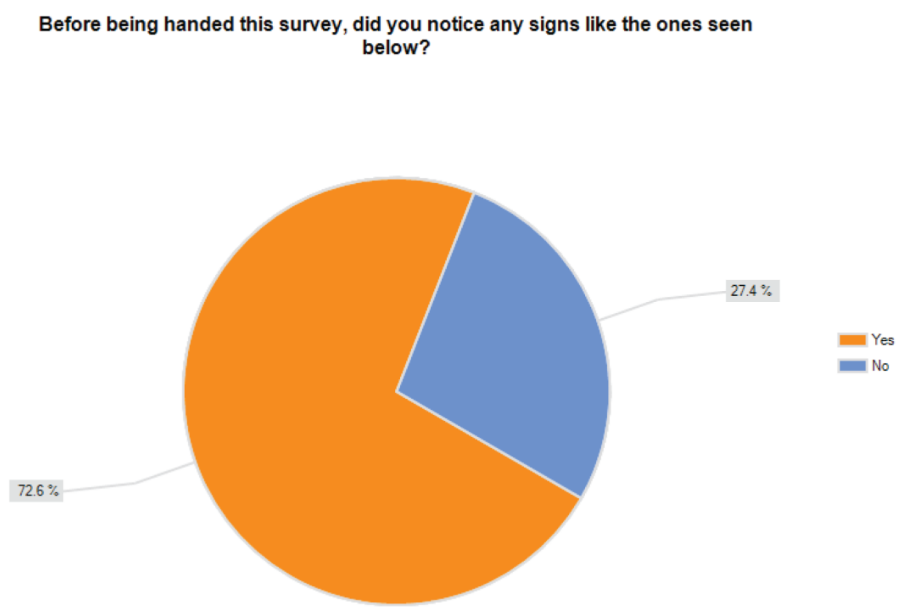
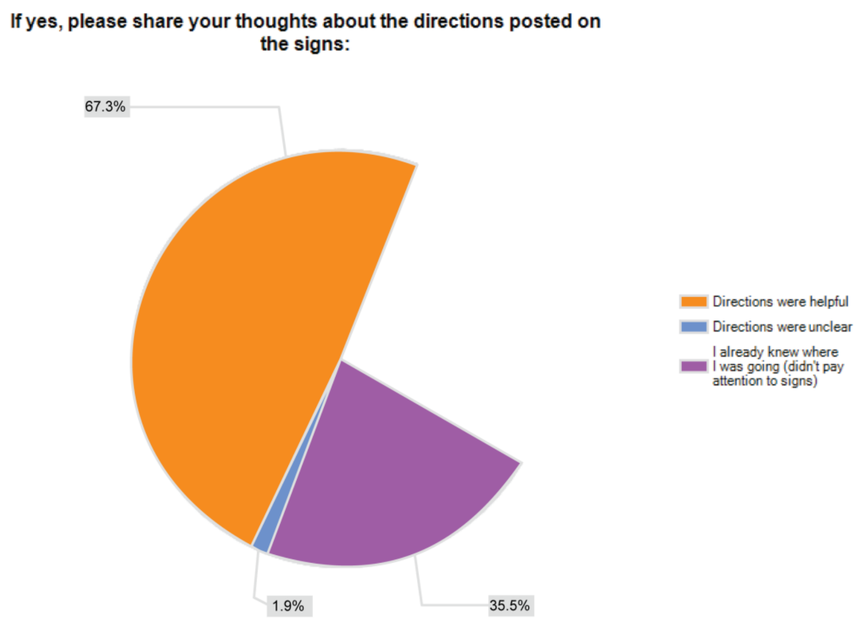
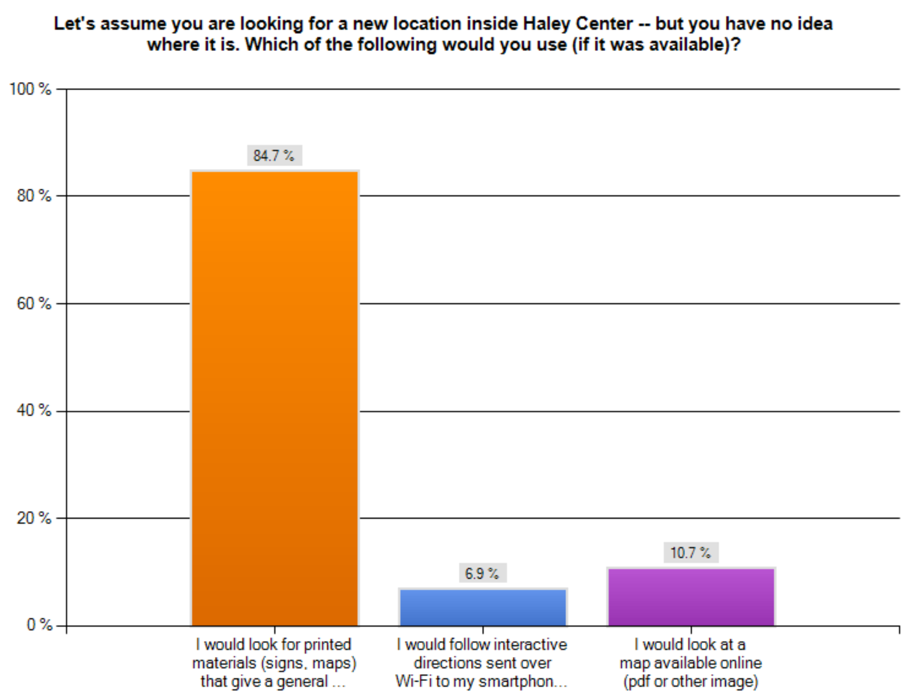


Figure 43 Many found directions helpful, many did not pay attention



:

Figure 44 Most respondents prefer signage



7.4 Survey Results Analysis

An analysis of the survey results indicates that most individuals believed wayfinding to be a challenging task at Haley Center (Figure 41 - over 60% either agreed or strongly agreed with this thought). Thus, the use of this building to determine the effectiveness of wayfinding signage would seem appropriate. The survey also indicated that an overwhelming number of individuals found their way through the building on their own. A far smaller number followed existing signage, whereas an even smaller segment asked for directions. This raises the notion that in the past, wayfinding within Haley Center may have been nothing short of an experimental approach and might be greatly improved by the addition of wayfinding aids, such as the test signage.

While over 70% of respondents noticed the test signage, over one in four did not (Figure 42). This statistic points out a major limitation of signage – the inability to be located in the "right place" at the "right time" for all individuals. For those that did notice the signs, just under 70% of respondents shared that directions were helpful (Figure 43), while 35.5% indicated that they already knew where they were going and did not to pay attention to directions (note: some respondents gave more than one answer for this question). Relatively few voiced opinions regarding whether directions on the signs were unclear.

More than 92% indicated they visit Haley Center two times a week or more (Figure 40). Participants also shared that when given three different wayfinding options, they strongly preferred the use of printed wayfinding materials (Figure 44) over looking at a map online or using interactive Wi-Fi directions sent to their phones (overall, 6.9% of respondents indicated desire for Wi-Fi wayfinding).

The survey questions were also posed to two individuals who suffer from significant vision loss. Both individuals expressed that it had been difficult to navigate their way at Haley Center when they had first come to Auburn University, but they were now used to the building (wayfinding was not so much of a problem anymore). Due to the extent of their impairments, neither was aware that test signage had been posted, although each individual had been inside Haley Center repeatedly after the new signs were displayed. Obviously, the test signage had not fulfilled any wayfinding needs for them. Both individuals, however, did express interest in the idea of Wi-Finding and stated that they would choose the same for wayfinding purposes if it was available for use.

The initial impression of the survey results would indicate that the general public finds traditional, static forms of wayfinding to be satisfactory (Figure 44). The interactive, Wi-Fi based system, on the other hand, seemed to be a novel concept that was attractive to a limited few. This could lead to the conclusion that an AT-specific device approach would be warranted, as demand for a mainstream, inclusive design-focused device might be scarce for this application. A further look at this survey, however, reveals some telling points.

7.5 Potential Survey Flaws

It became apparent that many participants suspected that the individuals administering the surveys (the author and several cohorts) had either developed the test signage or were closely associated to the individual who had done so. In fact, respondents often asked this question while completing the survey. In light of the same, it is possible that survey participants felt inclined to provide overly-positive responses because they could appreciate that someone had finally installed wayfinding aids at Haley Center, even if they did not depend on them to get to their destination.

In fact, it is certain that many respondents did not depend on the test signage to find their way. As mentioned earlier, 92.5% of respondents indicated that they attend Haley Center two times a week or more (Figure 40), and most respondents had previously found their way within Haley Center on their own (Figure 39). The conclusion here is that these participants were, at least on some level, already familiar with the layout of Haley Center. Their comments reflected this idea. One noted "but [the signs] would be helpful if it was my first time!" and another shared, "They will be helpful at the beginning of next semester for freshmen." Another remarked, "Where were these when I first came here?" These comments imply that individuals had experienced a need at some previous point, but those needs had already been satisfied before the survey was administered. Even when asked what method participants would use to find a location in the building when they had no idea where the destination was, it was apparent that many could still find their way without any external wayfinding assistance. "If given quad #, I can find" was one participant's written comment, while another shared, "[If I] know room #, I find that way by knowing which level and quadrant."

Unfortunately, timing appeared to be a major factor affecting the survey outcome. Surveys were administered mid-semester – a time when searching for new destinations in an academic building would be unlikely. Had surveys been taken at a time when individuals were seeking unfamiliar destinations, with visitors who were relatively or completely unfamiliar with the building layout, the author believes that the results of the survey may have been much different. This is not to say that interest in Wi-Finding would have increased; however, evaluations of the test signage may have been more objective. The results obtained (at least those pertaining to the test signage) appear to be more superficial than revealing about the effectiveness of the test signage.

Respondents were also asked about cell phone use (for tasks outside of making phone calls), with the expectation that increased cell phone use would correlate with an increased desire for Wi-Finding. In the end, no such correlation was noted. The absence of this relationship was compounded by the failure to directly ask respondents if they owned a smartphone. Survey wording was designed to convey that any respondent could select Wi-Finding as their preferred form of navigation, regardless of whether they owned a smartphone or not (Figure 38, question 6). This intent was apparently not understood by at least some. One respondent who had indicated a preference for signage noted, "I would use the interactive directions if I had a smartphone." Had the survey revealed who owned smartphones and which participants did not, this data could have allowed for more in-depth analysis of the survey results.

7.6 Haley Center Survey Conclusions

The foregoing concerns noted, a couple important pieces of information gleaned from the survey remain clear. One, well-implemented signage is an important aspect of wayfinding for many, and perhaps the first thing that the general public looks for when entering a large-scale, unfamiliar environment. Two, the general public may have desires for a wireless, interactive wayfinding system, but (at least in the context of Haley Center) the demand does not appear to be great.

The survey also raises more questions. In light of respondents' previous familiarity with Haley Center, their dependence upon the wayfinding system appeared to be minimal. How would individuals react in an environment where they are unfamiliar with their surroundings? Further, how might the building environment (and purpose for wayfinding) shape user needs? An examination of visitors in an unfamiliar environment would appear to answer these questions and provide the opportunity for comparison with the Haley Center survey results.

7.7 Introduction of Airport Visitor Survey

Analysis of wayfinding needs in an airport environment represents a substantial change in visitor context from that of Haley Center. It is not difficult to imagine that in many instances, airport guests may be entirely unfamiliar with the locale. Additionally, visitor entrance into the environment typically occurs at numerous points, where traditional wayfinding approaches may not be realistically capable of providing spatial orientation at or nearby every visitor entrance. Successful wayfinding in the context of an airport can also be dependent upon clear, timely delivery of information where the potential consequences of confusion and error can be large for the visitor. This may create unique, heightened wayfinding demands different from what was observed at Haley Center. A survey was created to determine user needs in airport environments. It was the author's intent to capture the needs from a broad segment of individuals and to establish visitor wayfinding demands within an airport when they are at their greatest. The survey questions are represented on the next two pages (Figure 45).

Figure 45 Airport survey

Airport navigation

I am analyzing how people use different methods to process navigational information, and how directional needs are affected by environment and context. I would really appreciate your time answering the eight questions listed here. Thank you for your help!

1. In the past, what has been your primary method for finding your departure gate at an airport?

- ◯ I followed posted signs/directions
- ◯ I asked for assistance from staff
- ◯ I used a printed map/manual provided by the airport or airline
- ◯ I printed a map before arriving and used it at the airport

Other (please specify)

2. Generally speaking, where has it been most challenging to find your departure gate?

- ◯ your home/local airport
- ◯ a connecting airport
- ◯ the airport in the city/place where you have been visiting

Why?

3. Assuming each of the following were available, please check the box(es) indicating navigational aids you would likely use when searching for your departure gate at the following types of airports (check all that apply):

	Directional signage	Directions provided by staff	Realtime, directional instructions and flight information delivered over Wi-Fi to my smartphone/device (like GPS)	Handheld manual/map obtained at airport or on airplane	An airport map I had printed myself before my arrival at the airport
Home/local airport	☐	☐	☐	☐	☐
Connecting airport	☐	☐	☐	☐	☐
Destination airport	☐	☐	☐	☐	☐

Airport navigation

4. Please rank the following navigational aids, from least preferred (1) to most preferred (5), under the assumption that you are in an airport where finding your departure gate poses the greatest challenge to you.

	1 (least preferred)	2	3	4	5 (most preferred)
Directional signage	○	○	○	○	○
Realtime, directional instructions and flight information delivered over Wi-Fi to my smartphone/device (like GPS)	○	○	○	○	○
An airport map I had printed myself before my arrival at the airport	○	○	○	○	○
Handheld manual/map provided by airport or airline onsite	○	○	○	○	○
Directions provided by staff	○	○	○	○	○

Please indicate the reason for your most preferred choice

5. What is the most common reason you fly?

- ○ Business
- ○ Leisure - I usually fly alone
- ○ Leisure - I typically fly with teens and/or adults and older
- ○ Leisure - I typically fly with others including children 12 and younger

Other (please specify)

6. How often do you fly commercially?

- ○ Once a year or less
- ○ 2-3 times a year
- ○ 4-6 times a year
- ○ 7-9 times a year
- ○ 10-11 times a year
- ○ About once a month or more

7. How often do you user your cell phone for more than just making calls? (text messaging, Internet, etc.)

- ○ 1-2 times a day
- ○ 3-5 times a day
- ○ 6-10 times a day
- ○ 11-20 times a day
- ○ 21+ times a day
- ○ I use my cell phone for phone calls only
- ○ I don't use a cell phone

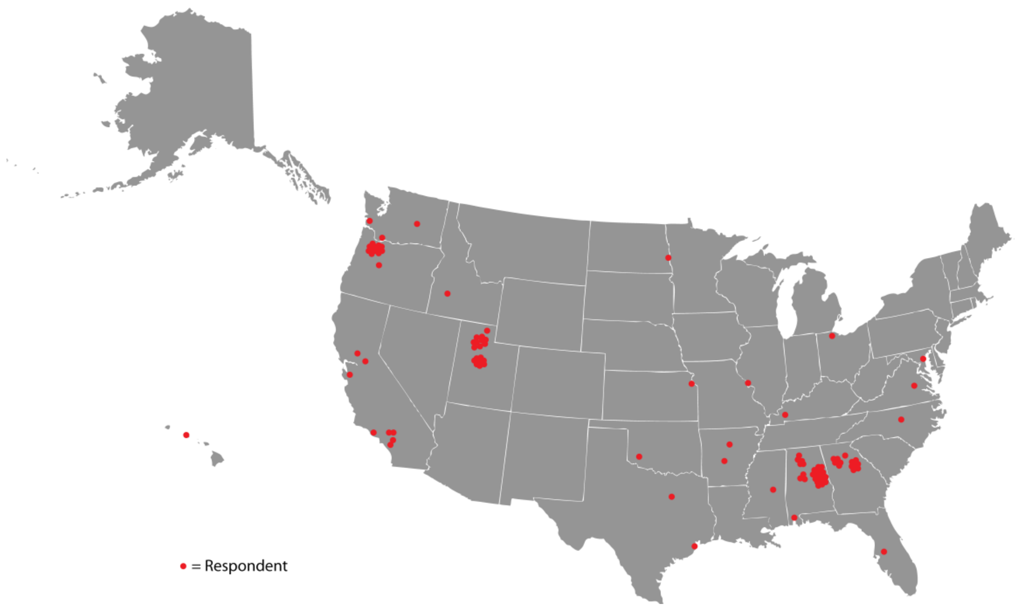
Other (please specify)

8. Do you currently own a smartphone or other portable smart device?

- ○ Yes
- ○ No

The survey was administered online (no print form of the survey was distributed). A total of 105 respondents participated, hailing from 21 different states within the U.S. (Figure 46). Three respondent locations were unknown, and three more surveys were completed by individuals located outside the U.S. (All surveys were considered in the response analyses.)

Figure 46 Survey participant distribution across the U.S.



Although there were a number of U.S. states where no respondents participated, the results gained from the survey do not indicate a correlation between respondents' home region and a preference for a particular wayfinding approach. Answers by region did not appear to exert any noticeable effect on the outcome of the survey, essentially ruling out the possibility that a troublesome airport in one locale (if one existed) might unduly influence the survey results.

7.8 Airport Survey Results

A number of questions allowed respondents to express their reason(s) for flying, the frequency of their air travels, and wayfinding preferences. Respondents were also encouraged to share thoughts, opinions, and reasons for their choices. The results are provided in Figure 47 to Figure 53.

Figure 47 Signage is the dominant wayfinding tool participants have used in the past

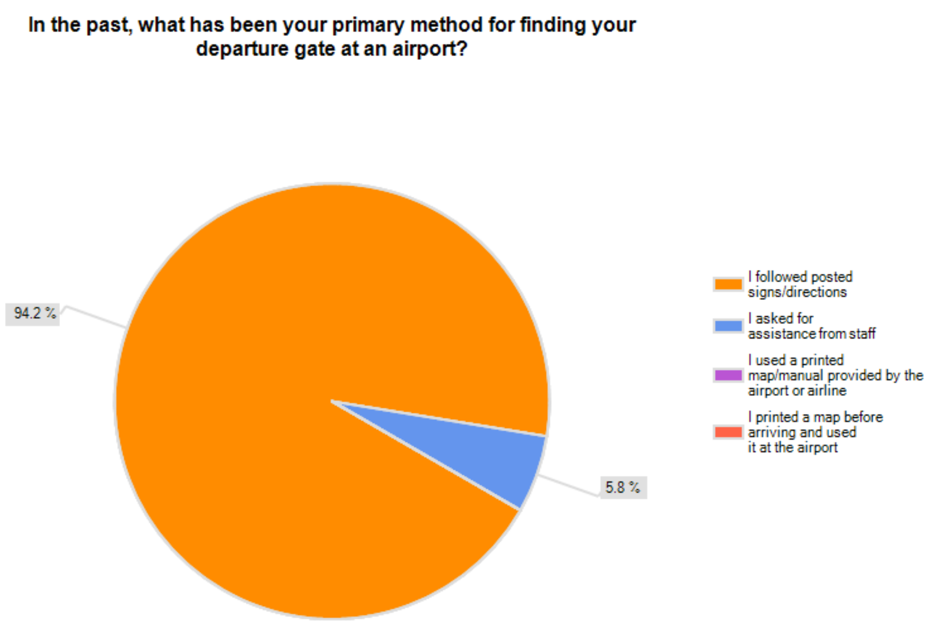


Figure 48 Respondents find connecting airports to be the most challenging

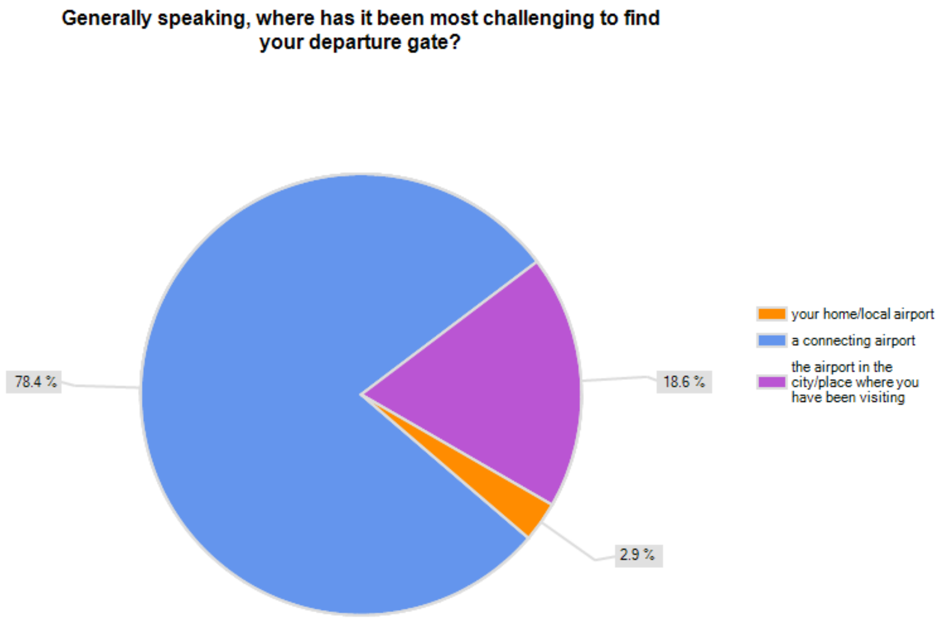


Figure 49 Signage is the primary wayfinding tool respondents desire; competitive results between information staff and Wi-Finding

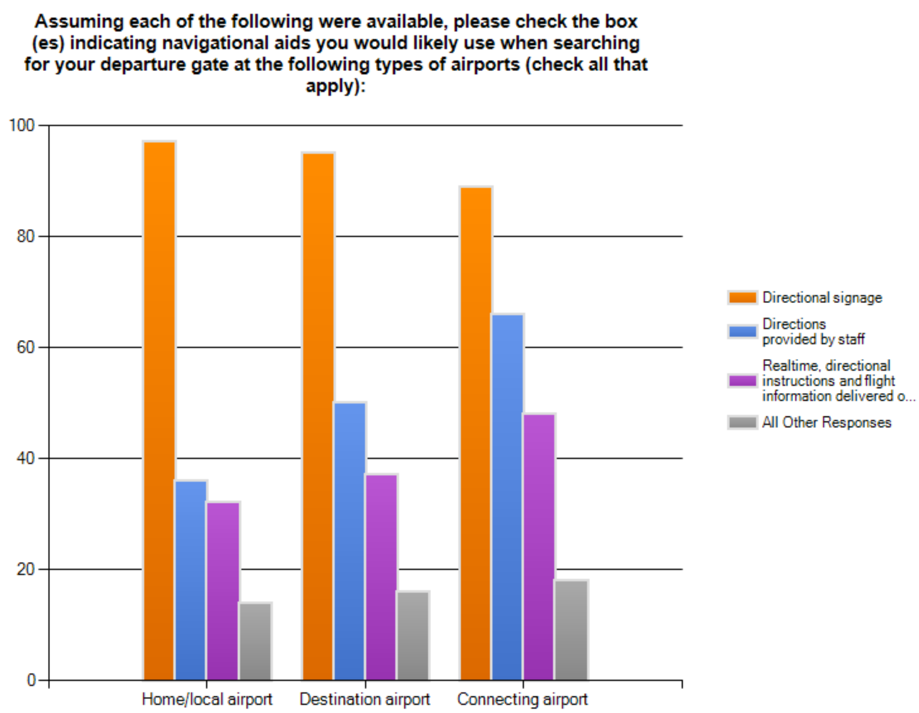


Figure 50 Respondents rank wayfinding preferences

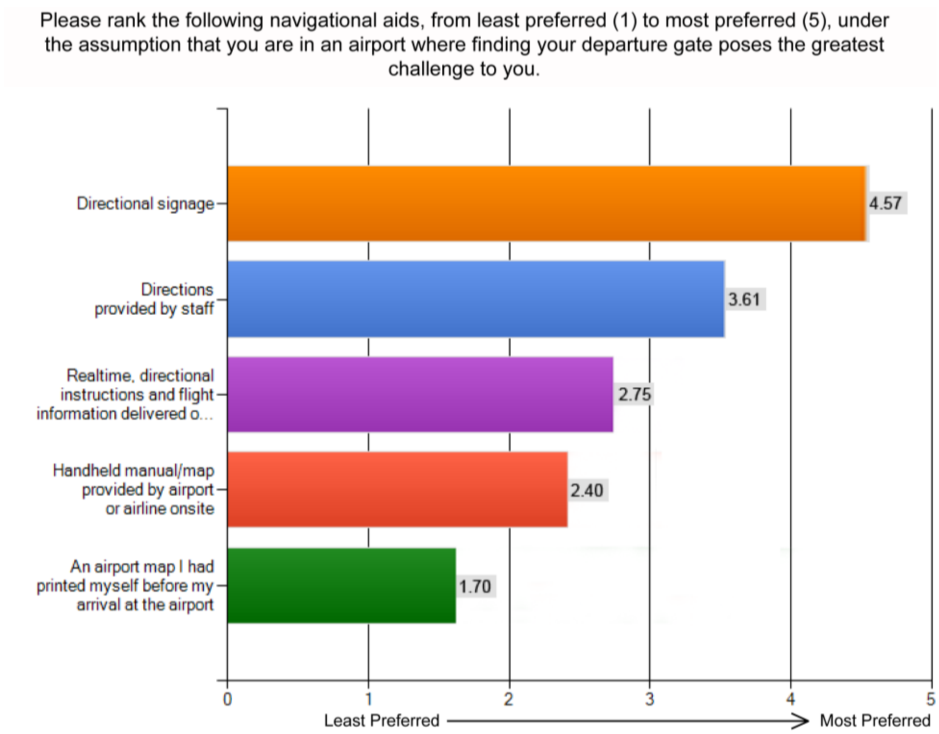


Figure 51 Survey makeup by reason for flying

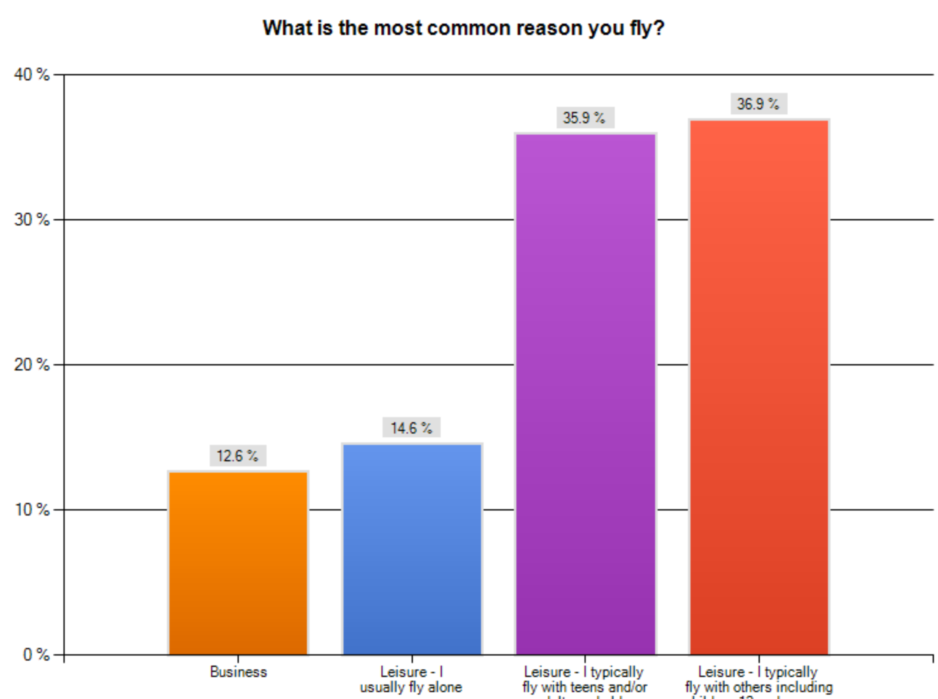


Figure 52 Survey makeup by participant flight frequency

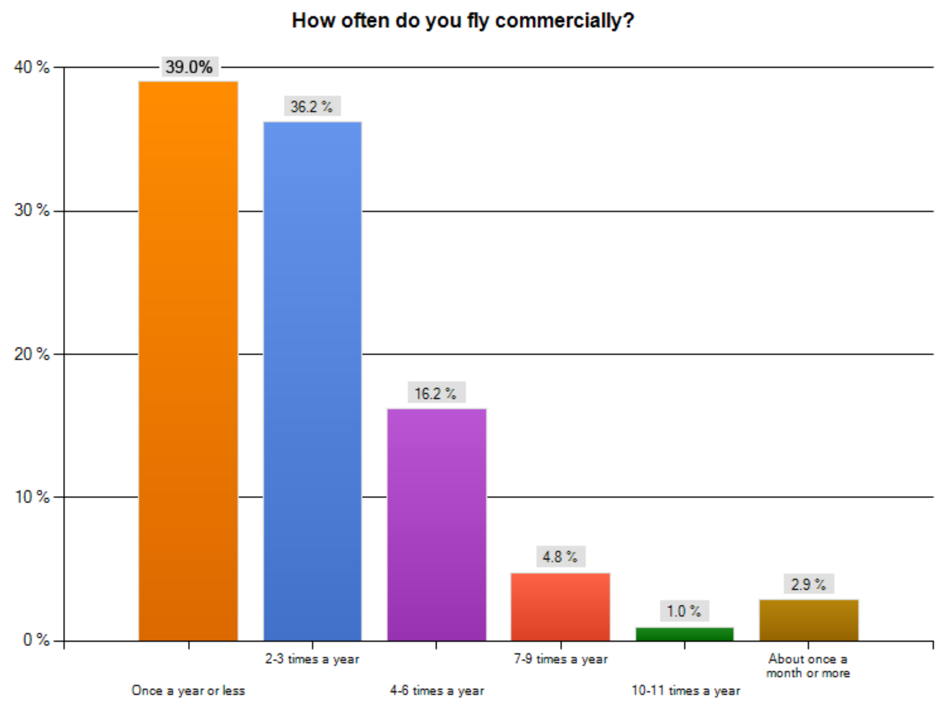
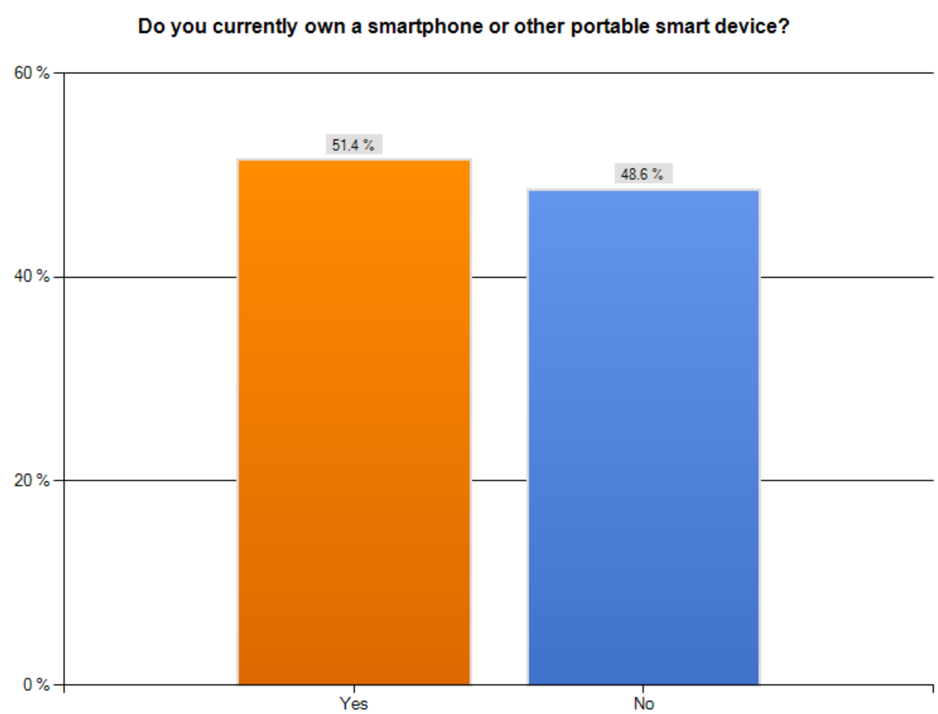


Figure 53 Participant smartphone ownership



7.9 Airport Survey Results Analysis

Though respondents expressed different reasons for flying, there appeared to be no association between travel purpose (Figure 51) and preferred wayfinding method (Figure 49, Figure 50). The same can also be said of respondents' flight frequency – there did not appear to be a link between the frequency of an individual's air travel (Figure 52) and a desire for a specific wayfinding approach.

Overall, respondents indicated that in the past, they were most likely to utilize signage to assist wayfinding in an airport, followed distantly by staff direction (Figure 47). If respondent comments are any indication, participants in the airport survey appeared to express more objective evaluations of the wayfinding options than the participants in the Haley Center survey. This could be because the airport survey participants considered themselves largely unfamiliar with their perceived airport environment(s) and more dependent upon respective wayfinding system(s), whereas Haley Center respondents by in large had not been dependent upon any wayfinding tools. Whatever the case, airport survey respondents lobbed wayfinding criticisms more freely. One commented, "Not enough signage in the boarding areas" and another indicated, "'C-1' means nothing to me if I don't know the airport layout," among many similar complaints. Spatial orientation also appeared to be a concern that signage did not always resolve. One participant shared, "…they don't always let you know by signage where the other terminals are located. Especially when you land in the middle of a large terminal." Yet another commented, "I never know where to start."

A few participants readily shared particularly troublesome airport wayfinding experiences: "Charles deGaulle airport in Paris was horrible. The signage was sparse & once you're on a shuttle train if you don't speak French you're hosed. Amsterdam airport is infinitely better...good signage". Another remarked, "Phoenix airport terminal A (I think) is difficult because it doesn't follow numerical order logically and wasn't labeled clearly." Despite these concerns, many of which dealt directly with signage concerns, survey participants still expressed a strong desire for signage, the most popular wayfinding aid indicated in the survey. This remained true regardless of the airport context considered (Figure 49).

What was not constant, however, was the level of signage's popularity among varying airport contexts. Where respondents indicated that wayfinding was a greater challenge (mostly connecting airports, as observed in Figure 48), interest in signage decreased, whereas interest in obtaining information via Wi-Fi and/or airport staff increased. In these environments, individuals often expressed that time constraints and other new variables were an added factor, creating another challenge – stress. One respondent shared the following sentiments:

> Frequently the stress of connecting flights seems to influence my ability to process information rationally. Some airports split numerical labeling in a weird way - for instance, A1-15 may be down one hallway, and A 16-32 down another, rendering sequential navigation unreliable.

This was by no means the only comment that directly or implicitly tied respondents' mental state to wayfinding needs. When asked why some airport contexts were more challenging than others, respondents directly indicated stress, or stress-related issues (being in a rush, under pressure, etc.) more often than unfamiliarity with the environment. In fact, it appears that many respondents believed that stress affected their abilities. One participant noted, "Because the layout of the connecting airport may be unfamiliar, and if I don't have a lot of time between connections, I'm probably stressed and may not see the signs I'm looking for." Another shared the following thought: "You are sometimes in a rush to make your connection and need to get the information now. If you are running close to time, in your haste you might not be able to find what is right in front of you." Bearing in mind their thoughts, it appears that stress ultimately bore an effect upon respondents' wayfinding preferences.

A further look at the topic of stress gives a clue as to why respondent needs may have been altered. The association between stress and decision-making has been studied previously, where it has been shown that stress can create distortions that impact the capacity to process information (Ozel, 2001). Stress has been shown to produce the *reflection effect* – where individuals make risky decisions when a loss is anticipated, but more conservative decisions where the potential outcome is a gain (Porcelli & Delgado, 2009). In the context of airport wayfinding, the reflection effect would dictate that where there is much to lose by way of a missed flight, individuals would tend to make riskier wayfinding choices. When an individual misses a flight at a connecting airport, or in a destination away from home, the potential for loss and discomfort is understandably greater. It may be for these reasons that in these airport situations, Wi-Finding proved more popular with respondents, perhaps because it is capable of removing an unwanted layer of decision-making from an individual whose capacity for the same may be threatened by the presence of stress.

Finally, as noted in the Haley Center survey, there was no appreciable correlation between increased cell phone use (for tasks outside of making phone calls) and an increased desire for Wi-Finding; hence, the data for that question was not used in this work. The airport survey, though, asked respondents to indicate smartphone ownership (Figure 53). A definite correlation existed between smartphone possession and an increased desire for Wi-Fi wayfinding. A side-by-side comparison of non-owners (Figure 54) and owners (Figure 55) demonstrates this:

Figure 54 Wayfinding preferences among non-smartphone owners

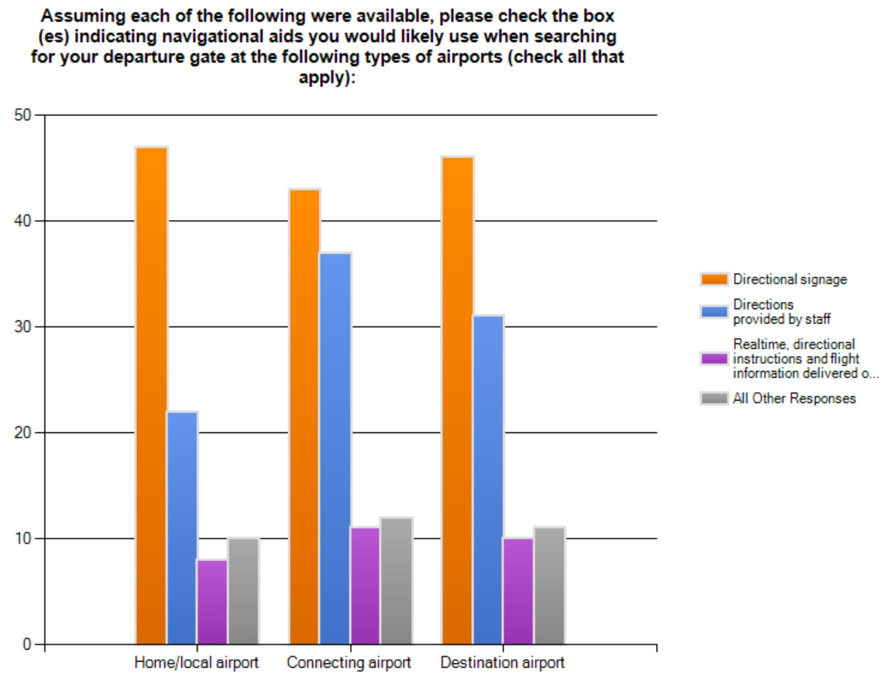
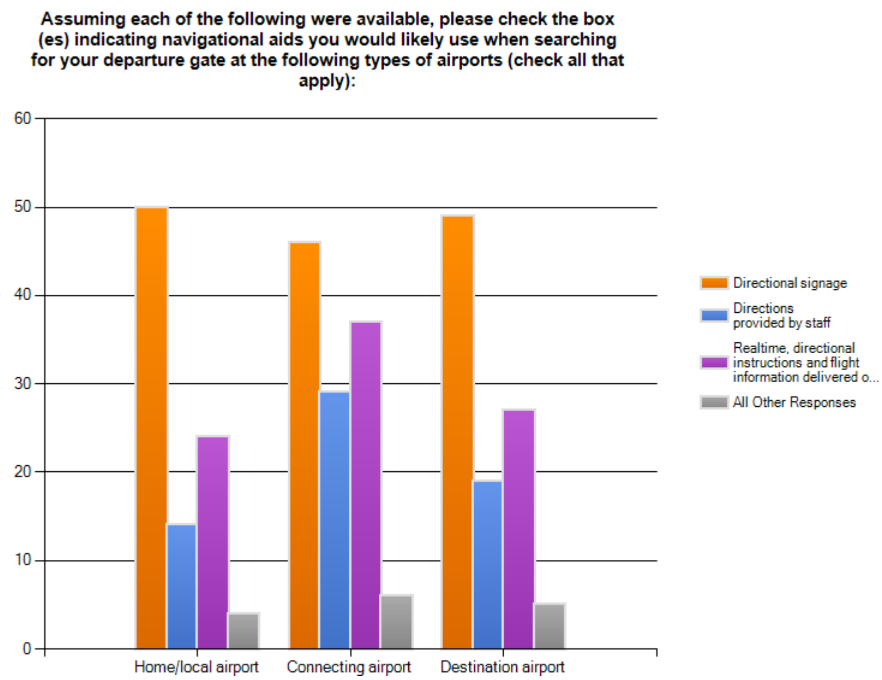


Figure 55 Wayfinding preferences among smartphone owners



As can be observed, traditional signage still remained popular among all respondents, but interest levels in the other dominant choices varied. Wi-Fi wayfinding was much more attractive to smartphone owners, especially in the context of a connecting airport, where it rivaled the interest these respondents had in signage. Non-owners, instead, favored an increased desire for information from staff in this context.

Smartphone owners also exhibited similar responses when asked to rank their interest in each wayfinding form. Whereas non-owners ranked Wi-Fi wayfinding in a virtual tie (for last place) among the wayfinding options (Figure 56), owners ranked Wi-Fi wayfinding as their second most-favored option, just ahead of directions provided by airport staff (Figure 57). Given consumer trends in the smartphone market that have been shared earlier, the author believes that interest in Wi-Fi wayfinding that was noted in this survey will likely increase as more consumers purchase smartphones.

Figure 56 Non-smartphone owners rank wayfinding aids

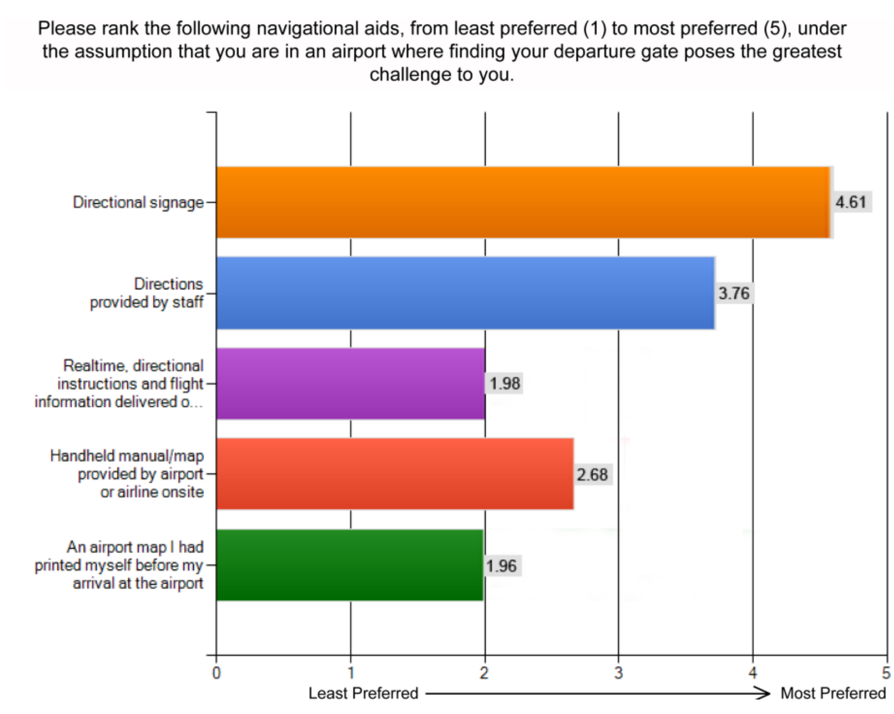
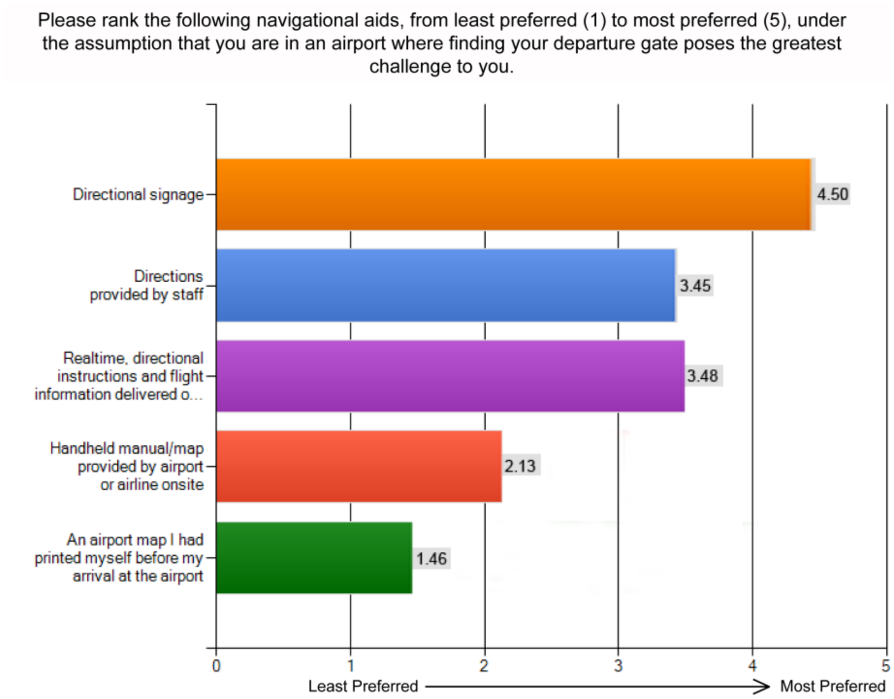


Figure 57 Smartphone owners rank wayfinding aids



7.10 Potential Survey Criticisms

Both the Haley Center survey and the airport survey asked participants' to state their inclination towards Wi-Finding. However, the description of Wi-Finding was slightly different in each survey. The Haley Center survey asked whether participants would have interest in following "…interactive directions sent over Wi-Fi to my smartphone / smart device that would guide me to the exact location (similar to GPS)." The airport survey provided the option of "…realtime, directional instructions *and flight information* delivered over Wi-Fi to my smartphone/device (like GPS)" (emphasis added). These additional words on the airport survey could have attracted additional respondent interest that otherwise may not have been there. However, one advantage of Wi-Fi is that it is certainly capable of delivering this information (and many other information forms), in addition to serving as a source of wayfinding directions.

The author does not feel that indicating these possibilities in the airport survey would be a misrepresentation of the technology.

For example, in Haley Center, Wi-Finding might be offered in addition to the ability to reserve study rooms, the ability to turn in homework, establish class attendance, or schedule a meeting with a professor by way of a smartphone application designed to offer visitors the fullest building experience possible. In an airport, Wi-Finding might be offered in an application alongside other services particular to the building, such as the ability to request wheelchair assistance or the option to alert airport staff of one's proximity to the departure gate before gate doors are closed. The author's vision of Wi-Fi uses is one that provides a variety of services to the visitor (wayfinding being just one) that allow for a more efficient interaction within the structure.

Another challenge to the airport survey focuses on respondents' historical wayfinding tendencies inside airports, which are largely unknown, other than there was a strong preference for using signage (Figure 47). Signage remained the preference, even after respondents were introduced to the concept of Wi-Finding (Figure 49). Because respondents were not asked about less-preferred methods they had used in the past, it cannot be ascertained whether any of these other methods had been displaced by interest in Wi-Finding. While this weakness is noted, there is no reason to believe that owners (previous to their smartphone purchase) would have answered any differently than non-owners. If these individuals had exhibited the same tendencies as non-smartphone owners previously (Figure 54), then the purchase of a smartphone led them to displace the desire for information from staff with a desire for information provided on their smartphone (Figure 55).

The airport survey results also appeared to be affected by the concept of stress, whereas this aspect did not seem evident in the Haley Center survey. The full impact of stress upon wayfinding is a large enough question that it cannot be analyzed extensively here. The airport survey results may therefore offer a glimpse of how stress affects user wayfinding needs, but leaves this issue open for further examination.

7.11 Survey Comparisons and Conclusions

When considered jointly, the two surveys allow for an analysis of how context shapes need. The purpose of respondents' presence within a building (in either survey environment) and respondents' mental state ultimately appeared to affect what they wanted. When unfamiliarity increased and was compounded by perceived negative consequences that could create stress, respondents indicated a greater desire for interactive approaches and less reliance upon static information provision.

Still, when considering the survey results, it is evident that most individuals would prefer traditional signage as the foundation for providing wayfinding direction. On this basis, it is anticipated that for individuals who have visual impairments (and a small portion of the general population), Wi-Finding would be the preferred wayfinding tool, whereas for most others Wi-Finding would be supplementary to signage, potentially filling in the gaps when static wayfinding forms falter. The author also feels that, as smartphone ownership increases, not only will overall interest in Wi-Finding (and/or other interactive wayfinding forms) increase overall, but may someday rival the likes of signage as the most preferred form of wayfinding (as tastes for technological approaches increase), resulting in a fulfilling interaction between visitors and their environment.

This leads back to the purpose of the surveys – identifying whether an assistive technology design is appropriate, or whether an inclusive design approach should be employed. The survey results indicate that either approach could prove acceptable, as the popularity of Wi-Finding appears to be largely dependent upon the context of the building environment. The device concept would either need to account for the needs of all (including individuals with disabilities) under an inclusive design approach, or it should consider the proposals previously stated in this work for assistive technology design, encouraging its adoption among individuals with disabilities and possibly the general population.

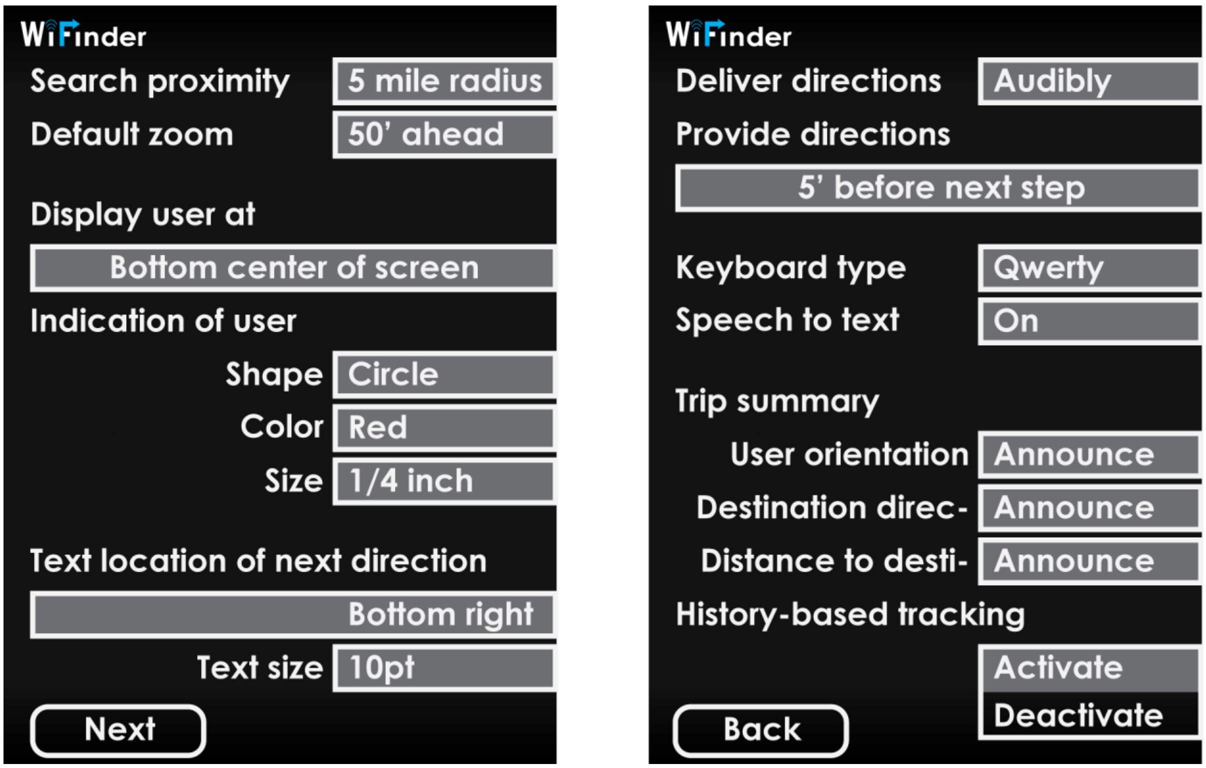
Chapter 8 Concept Design and Implementation

The foregoing chapter identified that Wi-Finding can answer the navigation needs of those who have vision loss and may also prove attractive to the general population. The implementation of Wi-Finding software (hereafter called *WiFinder*) should therefore be customizable in order to meet varying needs among all users. When considering the potential layout of WiFinder software, the author took into account that on many device platforms, inclusive design aids and hooks for AT software are already present within the device. For example, most Apple iOS and Google Android devices now ship with screen-reading software preinstalled (Kane, Wobbrock, & Ladner, 2011). Hence, the software approach conceived for WiFinder assumes that these aids are already embedded and (where necessary) have been pre-programmed to allow effective access to all smartphone software by the user. Where touch screen approaches are used, the author feels that is it sufficient to indicate that selections and inputs can be made, but it is not warranted in this work to provide the exact action (i.e., a two-finger contact approach; double-taps, etc.) because this would be dependent upon the smartphone platform in use.

8.1 WiFinder Software Customization

What may be necessary here is the explanation of additional customization and enhancements within WiFinder software itself, augmenting user abilities to successfully perform wayfinding tasks. An example of potential WiFinder customizations is indicated in Figure 58, which represents customization screens that would be found within WiFinder software. When accessed, each customization option would display a drop-down/pop-up menu, indicating selection options.

Figure 58 WiFinder customization screens



8.2 Smartphone Device Sketch Development

The author's intent is to offer WiFinder for use on any smartphone platform. However, an exemplary platform design for individuals who have vision loss was considered in order to maximize the benefits WiFinder can offer to these individuals. The author's first sketches and design aesthetics are shown in Figure 59 and Figure 60.

Figure 59 Exploratory sketches

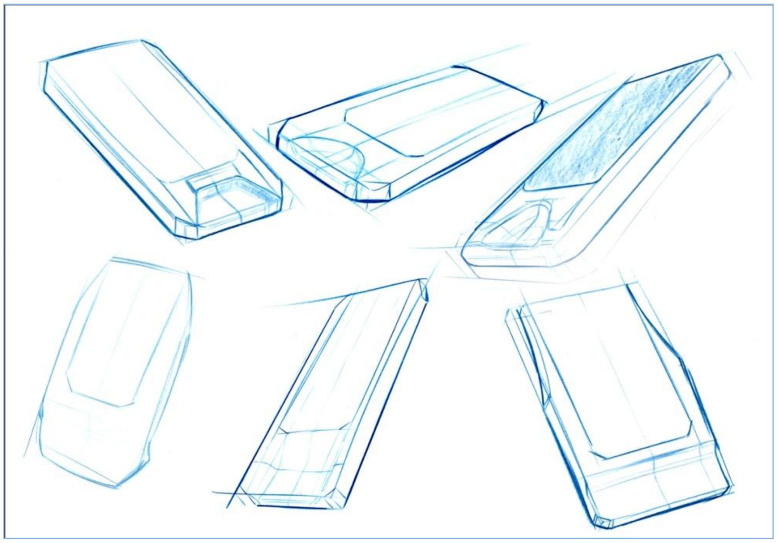
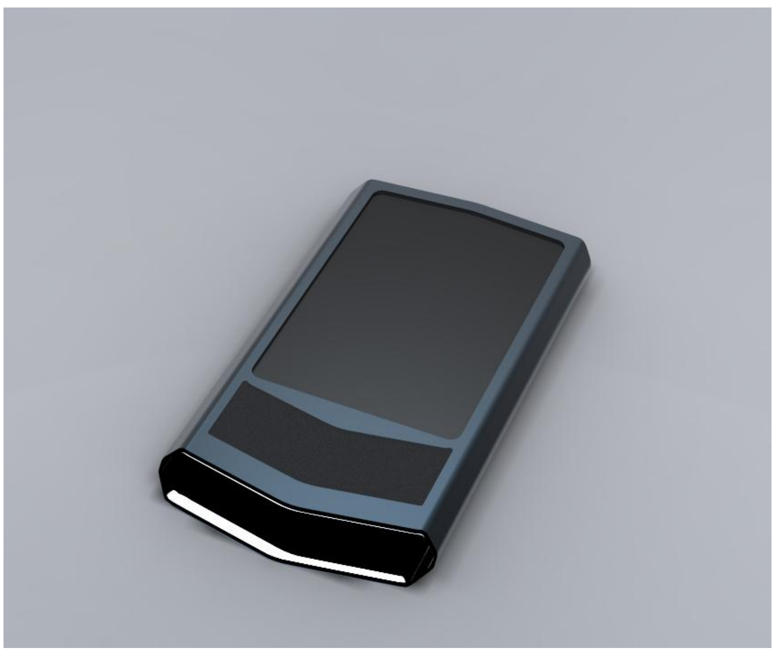


Figure 60 Form Exploration in Rhinoceros



Upon further review of the author's design approach, it was determined that screen sizes were likely insufficient to encourage use by individuals who have vision loss. This is a problem associated with many smartphones that are on the market today for many users (Squidoo, 2011). The end result is that some of these devices can be inaccessible for those who are visually impaired (IDEAL Group, 2011). One study participant who is sight-impaired also suggested larger screen sizes in the design development:

> I have become quite accustom to using my iPhone. I really like using the touch screen with Voiceover. A larger screen would be really nice to have. The larger screen would complement the needs of people with low vision as well as total blindness. (B. Urquhart, personal communication, July 4, 2011)

The author evaluated possibilities to increase screen size, while attempting to preserve a design aesthetic similar to other smartphone devices. Figure 61 and Figure 62 show further preliminary design and shape explorations that were considered:

Figure 61 Design exploration in Rhinoceros

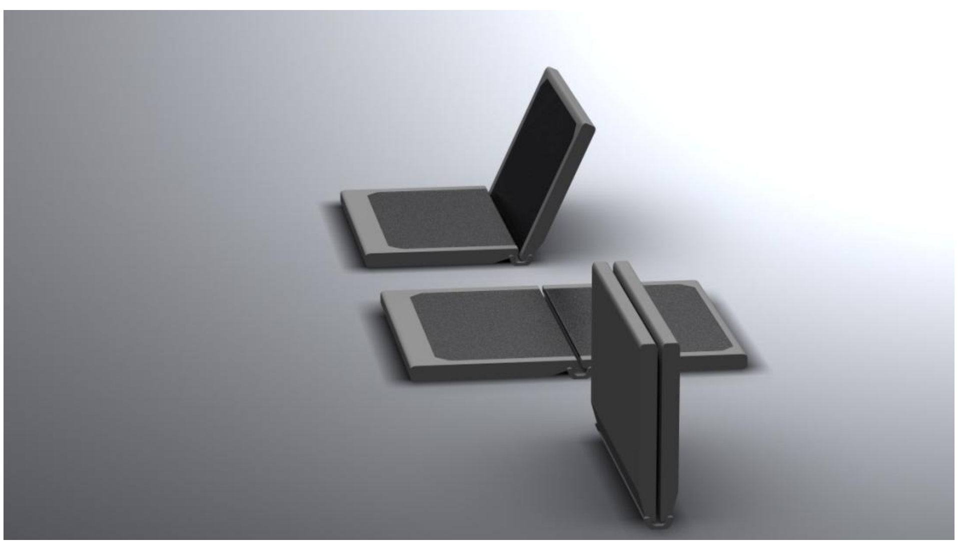
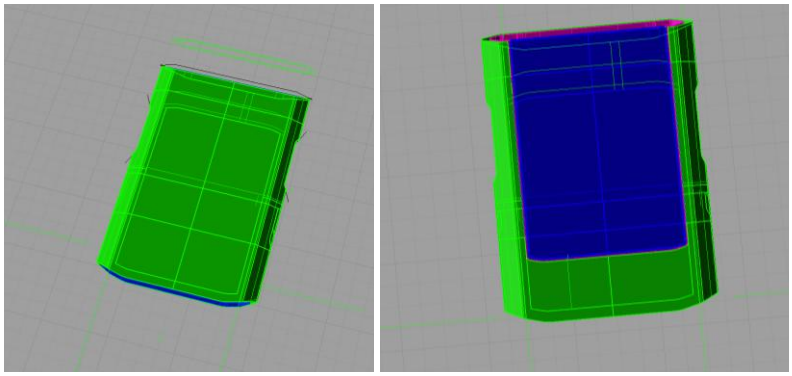


Figure 62 Concept development in Rhinoceros



8.3 Smartphone Concept Design

The author finally set upon a design (Figure 63) utilizing one primary touch screen, which may be operated in place by itself, but can also slide along a track, exposing a second screen concealed beneath the first. The two screens fit together (with a small “parting line” separating the two), forming a flush and expansive touch screen area. The total area is as large as 13 square inches, well over twice the screen area offered by most smartphones.

Figure 63 Concept design renderings in Bunkspeed Shot

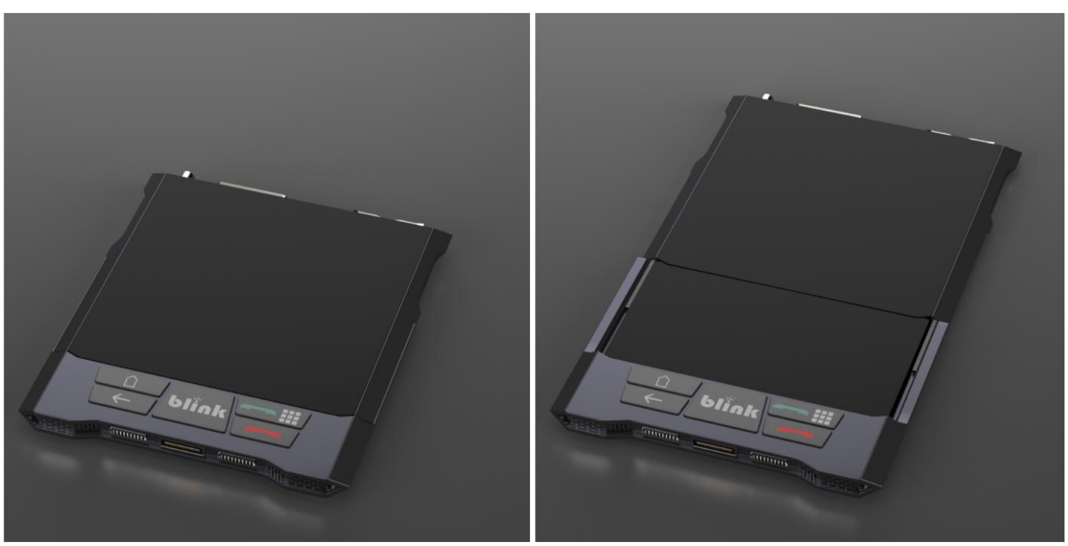
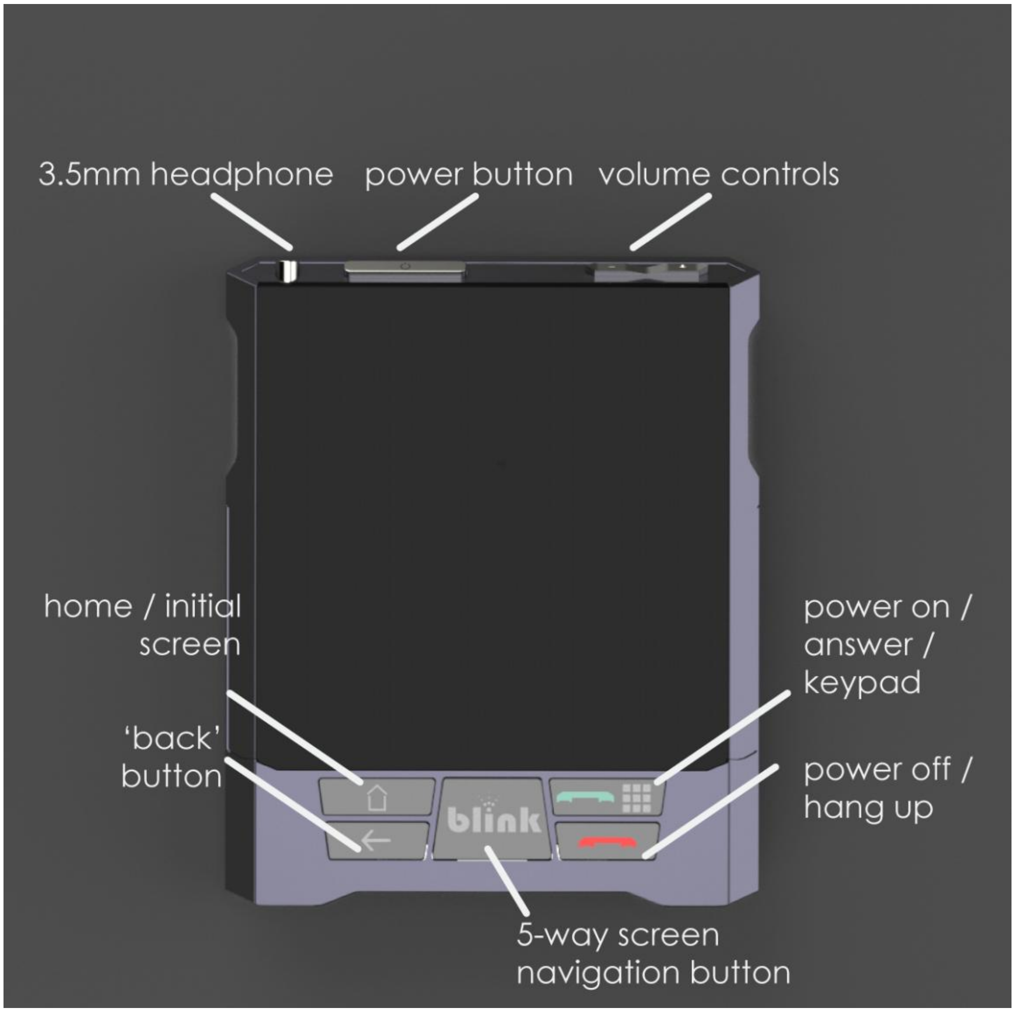


Figure 64 Explanation of design components



As seen in Figure 64, the phone (hereafter referred to as *Blink*) includes primary control buttons that have been placed on the face surface. In order to avoid unintentional activation of Blink's features (such as while feeling around for the phone), buttons were eliminated from the sides and bottom of the phone. Buttons present at the top of the phone are angled, potentially limiting inadvertent activation.

Blink also includes a couple software features displayed upon the touch screen that are intended to be present and accessible at all times (Figure 65). The first is a compass located at the top of the screen. This would allow the user to determine his/her facing direction at any point. The second, located near the bottom of the screen, is a zoom feature that would allow users to enlarge displayed touch screen information.

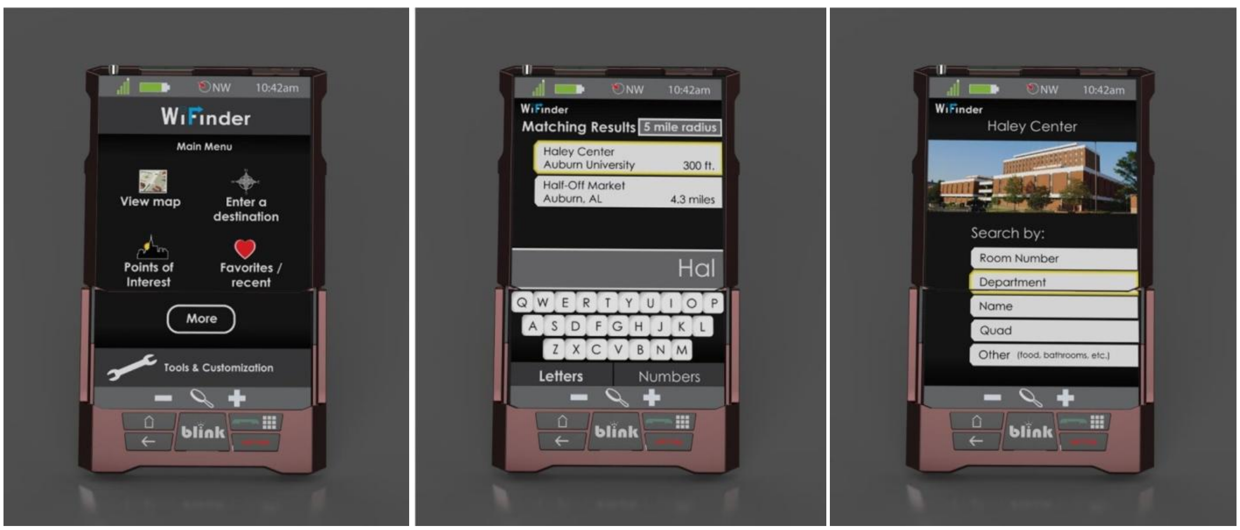
Figure 65 Compass and zoom locations on design

8.4 WiFinder App Functions

Having described the smartphone platform, the operation of WiFinder software can now be demonstrated. Upon selecting the WiFinder App, the user is brought to WiFinder's home screen – the starting point of the Wi-Finding process. Assuming that *Enter a destination* is selected, the user is brought to a screen where the user can input building information, while

WiFinder simultaneously searches for matching locations (the search proximity range being pre-selected by the user) that have previously been mapped for WiFinder use. The user is then brought to a third screen that offers in-building information previously provided by the premises operator during building mapping. This allows the user to determine the final destination within the building (for example, the opportunity to search by room number, by use type, etc.). Figure 66 depicts these steps.

Figure 66 Description of WiFinder interface



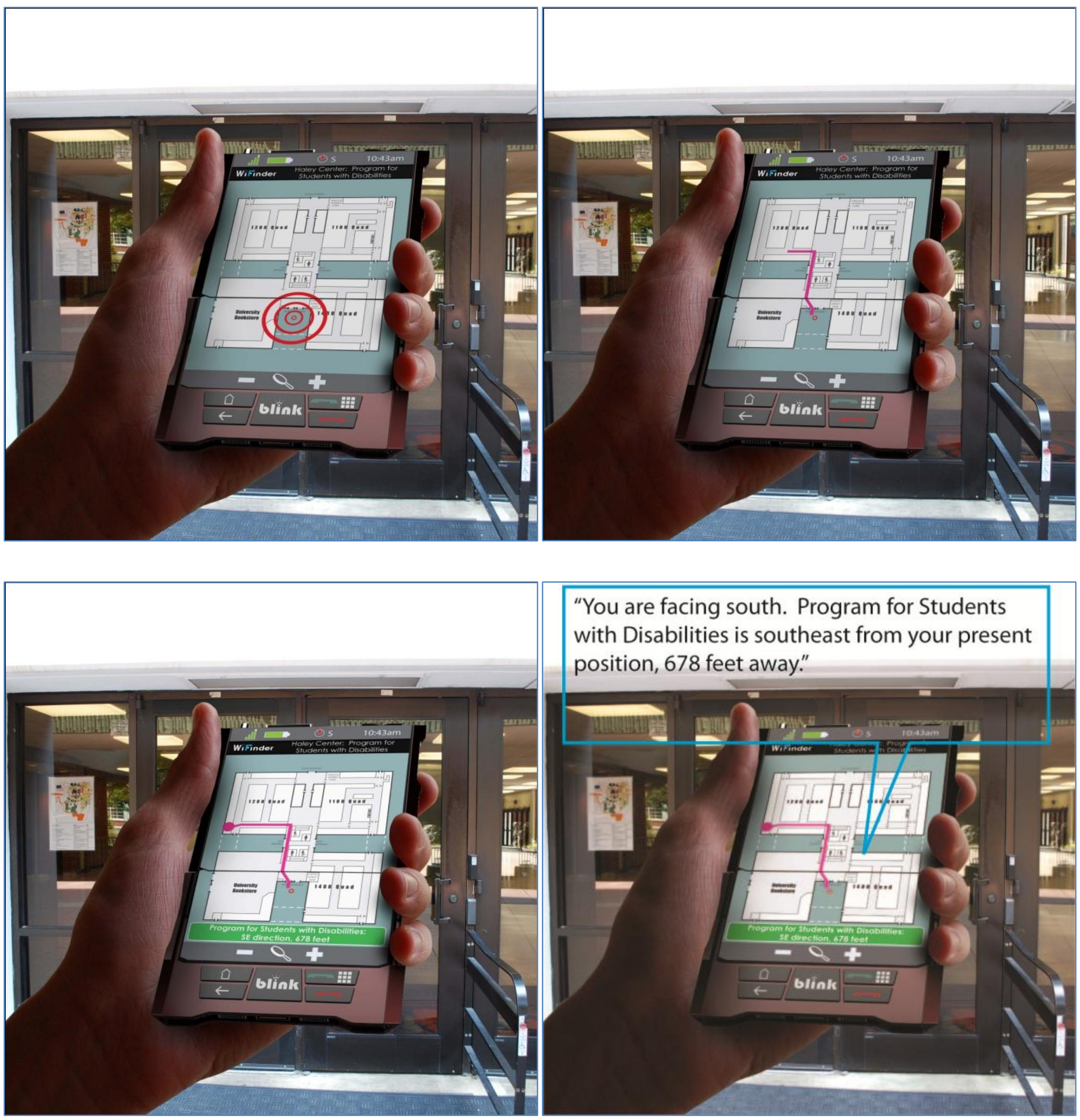
In this instance (Figure 67), while the user is offered the option of scrolling through a list of departments located in Haley Center, (s)he instead the selects (via the five-way navigation button) *Input information manually*. This selection triggers the appearance of a touch screen keyboard where letters may be input on the touchscreen or selected via the five-way navigation button. Matching department names appear, and in this case, the user indicates *Program for Students with Disabilities* as the destination goal. Destination information is offered to the user, who can then select the target to begin wayfinding procedures.

Figure 67 User process in WiFinder interface

Navigation commences with a map display of the building layout (Figure 68), where the user's location is demonstrated via concentric "bull's-eye" rings that zero-in on the user position. This provides a starting point to indicate the user's relationship to the area presented. The user's destination path is then drawn on the screen, providing an overview of the course to be followed.

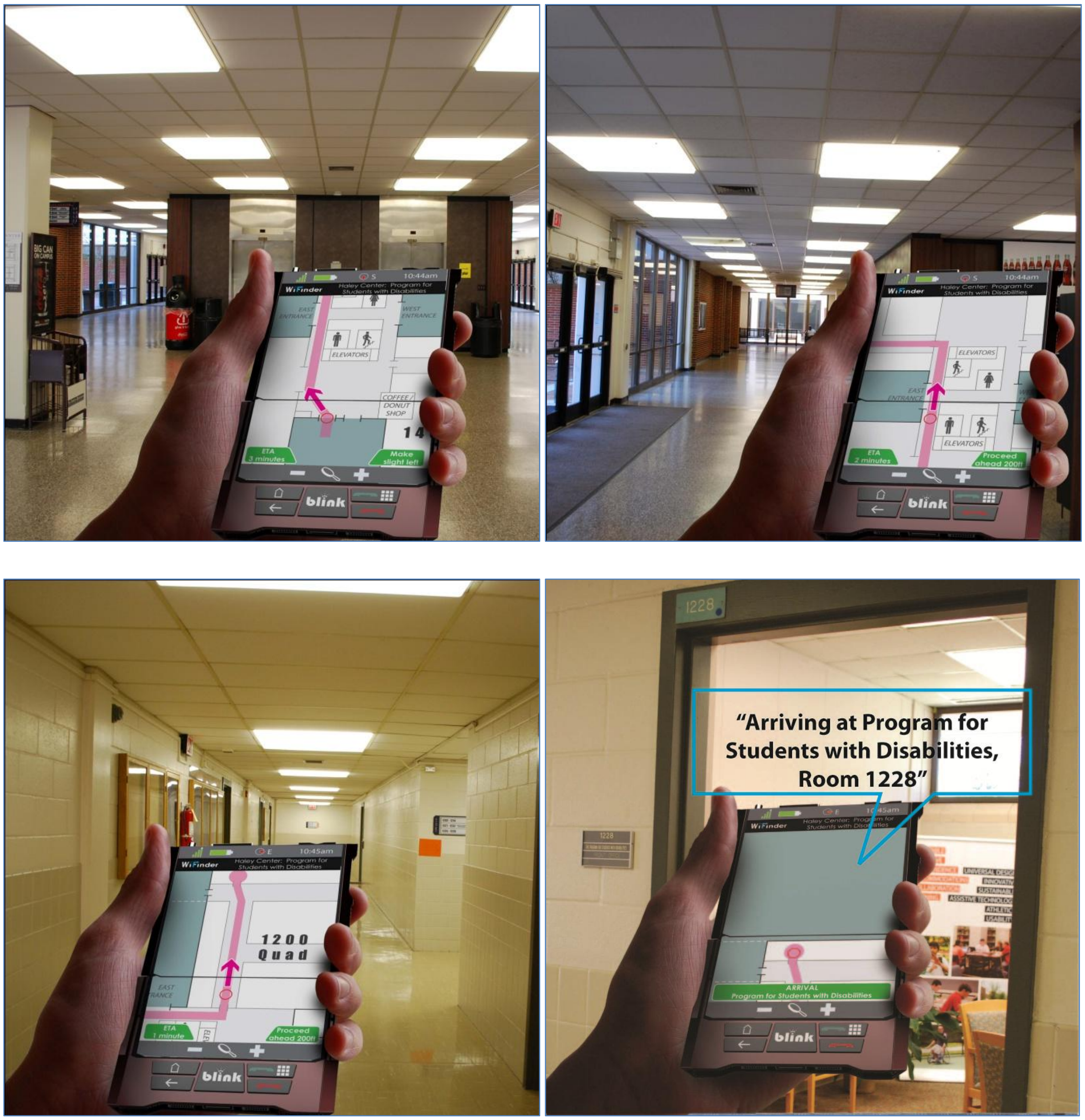
Once the path is shown, WiFinder announces the user's present direction, the direction of the destination, the distance, and the estimated travel time (according to previously selected user customizations). In addition, spatial information can be achieved as the user touches the map in any area. This triggers WiFinder to announce the area being touched, according to the level of map detail presently displayed, in an effort to familiarize the user with the layout of the building area. This is an opportunity for the user to obtain a spatial orientation with the environment.

Figure 68 Spatial orientation using WiFinder



Thereafter, WiFinder provides the user with step-by-step details of the path to follow to the intended objective (Figure 69). User surroundings are constantly updated on the map, providing for continual spatial updating. Once the destination is reached, the user is notified by WiFinder.

Figure 69 User navigation with WiFinder



8.5 Potential for increased interaction through Wi-Fi approaches

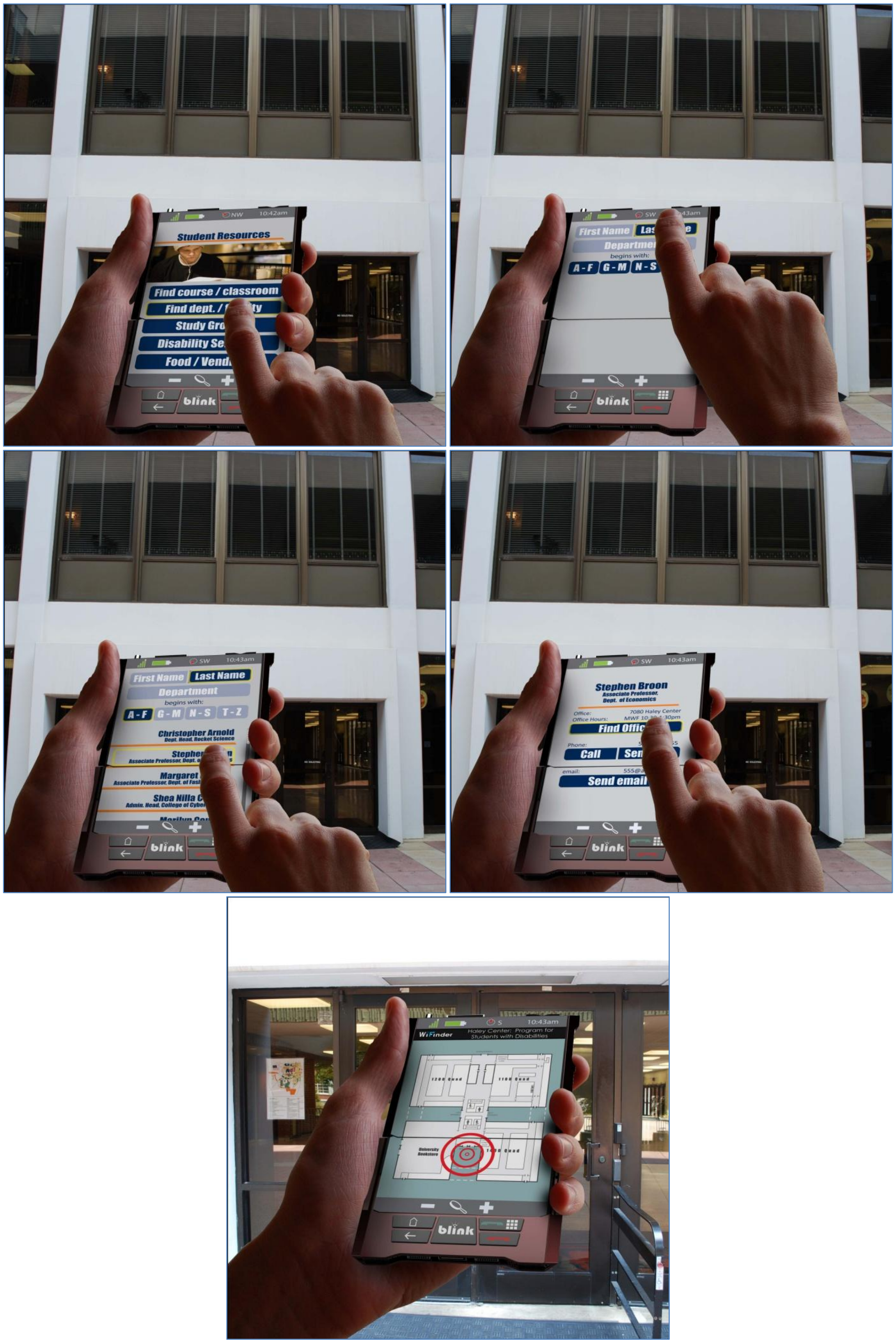
Finally, it is important to remember Wi-Fi was not initially developed for Wi-Finding purposes, but as a means of wireless network access. While the WiFinder setup demonstrated holds promise on its own, the author's vision is for WiFinder to exist as one of many services and building features that are offered to visitors to maximize the effectiveness of their visit to the location. When the user's whereabouts are known, an opportunity exists to transmit information regarding the goods and services present within the establishment. This could create a mutually beneficial relationship between visitor and premises operator. In this context, Wi-Fi network access would provide information to the user, while WiFinder would serve as an important link, connecting the visitor with the locations of various services offered. For example, within an airport, a variety of services could be delivered over Wi-Fi to users known to be within the establishment: gate information, realtime flight information, estimated check-in times, vendor services, etc. WiFinder could provide access to any one of these services should the user be so inclined.

An example of this idea process is demonstrated in Figure 70 and Figure 71. In this example, the assumption is made that a student is coming to Haley Center to speak to a professor. The user is first offered access to a number of facilities, based on his/her position on Auburn University's campus. The user indicates Haley Center, and services specific to that building are indicated.

Figure 70 Demonstration of location-based services

The user selects the services pertinent to his/her needs and locates the desired professor. Upon finding the same, the user is offered a number of options, including the ability to call the professor from that screen, send a text message, or find the professor's office. The user indicates that (s)he would like to locate the office, whereupon WiFinder commences its navigational instruction.

Figure 71 Example of wayfinding embedded within location-based services



In summation, the author believes that WiFinder is an application that could exist on its own, but would be even more effective when paired up with other building services offered to visitors. It is an important tool because it allows for an interaction, potentially resolving a number of issues for individuals who have vision loss and have found other wayfinding forms to be lacking.

8.6 Future Work

The author readily acknowledges that before a Wi-Finding-type setup can be established, a number of additional issues must be considered. For one, security and user privacy are topics that must be considered adequately in users' best interest. While it has been stated earlier that Wi-Finding directions can be delivered without "discovering" users' identities, it has also been shown that knowing a user identity could improve Wi-Finding accuracy where histories or patterns have been developed. This is a matter that must be weighed sensitively, with a great deal of deference for user desires. Further, users must be aware how and when their information might be used, should it become necessary to store the same.

Yet another issue involves the computational requirements of wireless APs. This matter has not been discussed in this work. Much of the Wi-Finding information shared here operates under the assumption that Wi-Fi APs can readily provide Wi-Finding information to users as needed. The author has no indication whether Wi-Finding would prove overly burdensome upon Wi-Fi networks or not. None of the works cited by the author shed an appreciable level of insight in this regard. However, a certain level of computational power is undoubtedly required for Wi-Finding to function effectively. In the event that a building is experiencing a high level of Wi-Fi traffic that is already consuming much of the APs' computational capabilities, Wi-Finding could add demands that might overwhelm the system, rendering Wi-Finding ineffective and slowing Wi-Fi access to a crawl. At the very least, this is a matter worth considering in order to assess its impact upon Wi-Fi traffic.

Along similar lines, smart device energy consumption is another matter to be reviewed. Many of the approaches discussed in this work would likely demand a great deal of energy from the user's portable smart device, potentially draining energy more quickly than the user would find acceptable. In this light, Wi-Finding techniques must be evaluated to determine whether any certain methods exhaust user smartphone devices too quickly to be reasonably attractive to the individual.

The implementation of WiFinder and related location-based services is another topic worthy of further discussion beyond this paper. The provision of services provided to individuals based on their location holds the opportunity to maximize visitor experiences within the environment. Knowing this information, and being able to access it via direction from WiFinder, could provide for a much more profound interaction, specifically for individuals who have vision loss, which can limit information access. The author believes that a general software template could be developed, allowing for business entities to use the same to develop information hierarchies that can be accessed and navigated by the user. This template could be updated as necessary and exist alongside WiFinder software, which might reside as one part of this system. The creation and organization of such a kit could be complex. Nonetheless, where effectively implemented, it could serve as a competitive advantage within the business sphere.

8.7 Conclusion

Ultimately, Wi-Fi is just one medium of many that allows for an interactive approach to wayfinding. There could be other developments and breakthroughs around the corner that enhance this approach or prove to be much more effective for interactive uses. Wi-Max and

Ultra Wideband technology are two examples of emerging technologies that might prove more effective for these purposes. The intent of this paper is not to declare that one method trumps all others. The author's intent has been to demonstrate that wireless, interactive wayfinding is already possible. Further, interactive methods hold a great deal of promise that static wayfinding forms may be unable to fill. The results of this study indicate that static wayfinding forms (such as signage) may always hold a place – perhaps always the most popular place – among the overall population. However, these often fall short of the needs of those who are disabled, particularly individuals who are vision-impaired. In some contexts, static wayfinding approaches may even fall short of the needs of the general population. Where a need for interaction exists, interactive wayfinding approaches based in modern technology may hold the key to efficient participation within the environment, alleviating the need for labor-intensive methods satisfied by the use of staff or others. For individuals who suffer from vision loss, interactive wayfinding technology methods may encourage an increased participation within society, resulting in greater acceptance, achievement, and personal fulfillment. Whatever the method, attaining this goal would represent a major success.

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