Economic Impact of adopting Assistive Technologies on Quality Adjusted Life Years and Work Productivity

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Background: Electrical Engineering (Bachelors), Marketing & Operations Research (Masters), Applied Economics (PhD)

Professional Experience: 10 years at Kansas State University, teaching graduate and undergraduate courses (Economics); Citibank (sales)

Research Interests: Applied economic research in the areas of agricultural trade, food policy, organic markets, mobile computing, accessible and assistive technologies, teaching pedagogies, and faculty development.

Professional Activities: Active in securing US federal grant funding ($2M), publishing articles in academic journals, presenting in national/international conferences, and serving as a reviewer/panelist and consultant for US federal agencies/federally funded projects.

Current Projects

- <u>Circular Space Materials Economy</u>: Economics of incorporating sustainable material management practices in composite materials for space vehicles

- <u>Environmentally Sustainable Mobile Computing</u>: Economic framework to analyze market & incentives for adoption of sustainable choices

- <u>Controlled Environment Agriculture</u>: Designing an autonomous AI/ML system for Vertical Farming to maximize production yields and food quality and minimize energy consumption and water recycling

What are Assistive Technologies?

- Concept of an item or piece of equipment that enables individuals with disabilities to enjoy full inclusion and integration in society

- Traditional assistive technologies include: white canes, screen readers, walkers, etc.

- They differ from convenience technologies in usability, economics and human considerations.

- Accessibility Vs Assistive Technologies
  - Accessibility focus on giving "similar" access capabilities to a specific device or service
  - AT is broader, with a focus on enabling core human tasks

Motivation

- Wayfinding remains a challenge for persons with disabilities (PWD)
- Many areas where GPS is unavailable or not accurate enough (indoor areas, some outdoor areas)
- Reading and following visual signs/cues remains the typical approach
  - Places PWDs at a disadvantage
    - BVI cannot see the signs
    - Inefficient for mobility impaired individuals
    - Older adults, those with cognitive or intellectual disabilities can find it challenging to comprehend some signage
    - Wayfinding in unfamiliar surroundings remains challenging even for those without disabilities
  - Exacerbated in rural and low population density areas without others for assistance
- Independence is an important quality of life criterion

Unique Approach

- Cater to needs of individuals having disabilities from a broad set, simultaneously, in addition to the general population

- Utilizing a common technology infrastructure taking a universal design approach

- Investigating resulting economies of scale and scope

- Provide applications that fill critical current gaps while retaining flexibility for the future in terms of applications and underlying technologies chosen

CityGuide Prototype

https://www.youtube.com/watch?v=5vlgEDz-L70
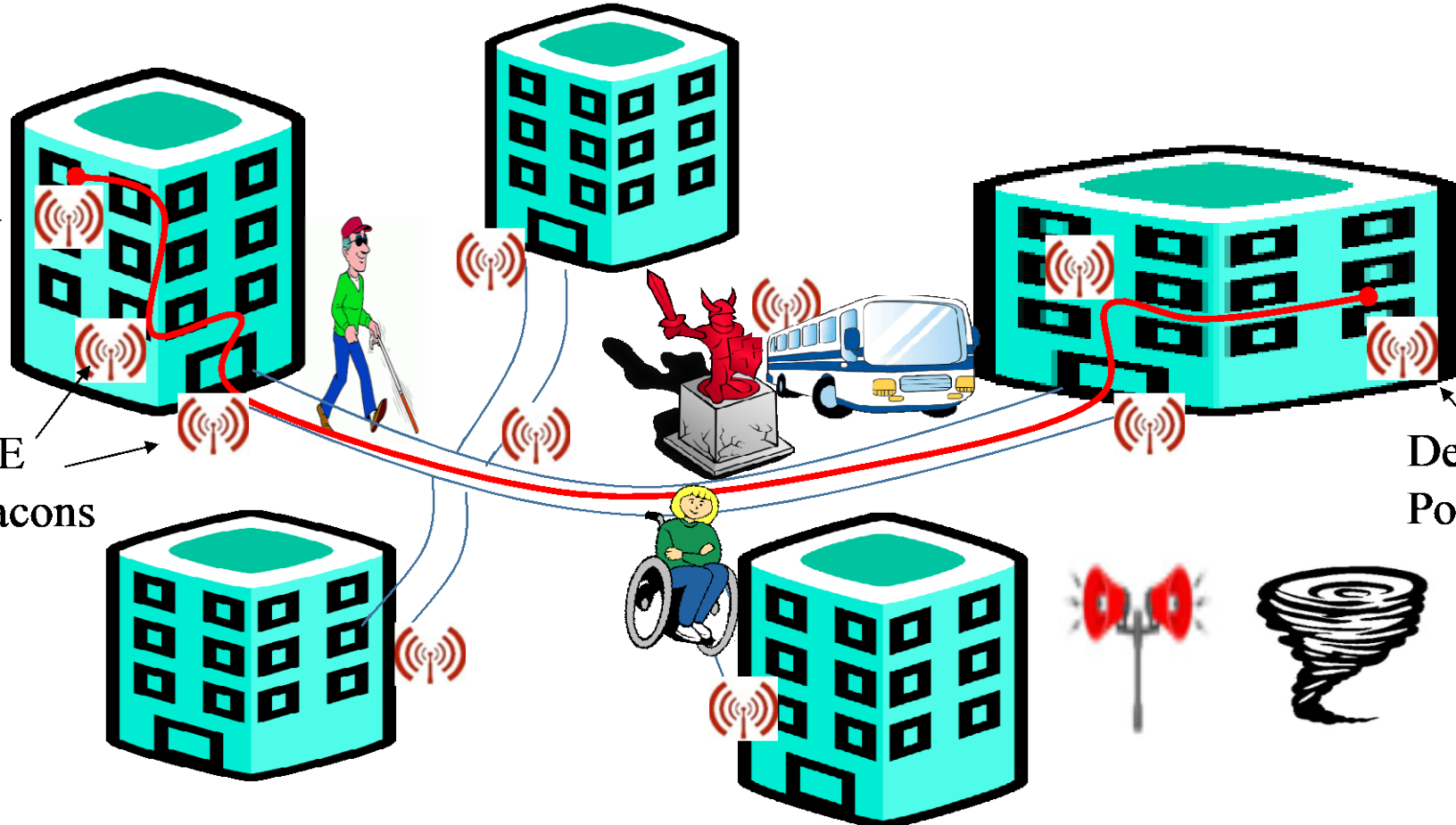
Testing with the CityGuide app for indoor to outdoor wayfinding for those with visual impairments. BLE beacons are used in indoor environments with the app seamlessly switching to GPS when outdoors.

Low-cost, easy to use and reliable Auxiliary Location-Based Services (ALBSs)

- Within indoor and outdoor environments
- Complements GPS-based systems
- Usable by individuals with disabilities and the general population

Economics: Cost-Benefit Analysis

Common survey instruments adopted for measuring health utility:

- EQ-5D-3L developed by the EuroQol Group

- Health Utilities Index Mark 3 scale (HUI3)

- SF-6D scale developed from SF-36

Other questionnaires to evaluate at-work disability and productivity loss:

- Work Limitations Questionnaire (WLQ-25)

- Workplace Activity Limitation Scale (WALS).

The most common questionnaire is EQ-5D-3L, where three levels of severity are assigned to five dimensions of quality of life, namely, mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Similarly, HUI3 considers eight attributes of 5 to 6 levels.

Objectives

Develop a unique standardized survey instrument that measures both the quality of life improvements and increases in work productivity for people with disabilities with the use of assistive technologies.

The task of Wayfinding is presented as a case study to evaluate the benefit to people with disabilities.

Contributions

- Evaluate use of instruments for AT applications

    Some evidences of using EQ-5D-3L and SF-36 in measuring AT adoptability across various domains.

- Comparative study of instruments

    Instruments are typically used in a mutually exclusive form.

- Case study of Wayfinding systems

    A smartphone based indoor/outdoor wayfinding application for PWD will be used to determine changes in health and work states.

Authors	Year	Title of Paper	Instrument Used	AT Used
Brandt, Å et al	2012	Can we rely on QALYs for assistive technologies?	EQ-5D	Various
Øksnebjerg, L. et al	2020	Self-management and cognitive rehabilitation in early stage dementia – merging methods to promote coping and adoption of assistive technology. A pilot study.	EQ-5D	ReACT app
Howard, R. et al	2021	The effectiveness and cost-effectiveness of assistive technology and telecare for independent living in dementia: a randomized controlled trial.	EQ-5D	Telecare
Vuorialho, A. et al	2012	Effect of hearing aids on hearing disability and quality of life in the elderly.	EQ-5D	Hearing Aid
Van Walsem, M. R. et al	2016	Assistive Technology for Cognition and Health-related Quality of Life in Huntington's Disease.	EQ-5D	To improve Cognition
Nollett, C. et al	2018	Pragmatic randomized controlled trial of a trauma-focused guided self-help Program versus Individual trauma-focused cognitive behavioral therapy for post-traumatic stress disorder (RAPID): trial protocol.	EQ-5D	Online Guided Self-help Program
Okullo, G. O. et al	2022	Adverse events in the treatment of motorcycle-related isolated limb injuries at a regional hospital in Uganda: a prospective clinical analysis.	EQ-5D	Various
Bray, N. et al	2019	Perceptions of the impact of disability and impairment on health, quality of life and capability.	EQ-5D	Various
Hammond, A. et al	2017	Job retention vocational rehabilitation for employed people with inflammatory arthritis (WORK-IA): a feasibility randomized controlled trial.	WLQ	VR/AR
Rebecca J. et al	2015	Hearing aid and hearing assistance technology use in Aotearoa/New Zealand.	SF-36	Hearing Aid
Thompson, W. et al	2011	Health-Related Quality of Life Among Older Adults With and Without Functional Limitations.	SF-36	Various
Pettersson, I. et al	2015	The effect of powered scooters on activity, participation and quality of life in elderly users.	SF-36	Powered Mobility Devices
Vincent, C. et al	2017	Pain, fatigue, function and participation among long-term manual wheelchair users partnered with a mobility service dog.	SF-36	Mobility Service Dogs
Arun, S. et al	2019	Rehabilitation evaluation of the newly developed polymeric based passive polycentric knee joint.	SF-36	Polycentric Knee Joint
Huang, C. et al	2017	Comparing the Chinese versions of two knee-specific questionnaires (IKDC and KOOS): reliability, validity, and responsiveness.	SF-36	Surveys
Demers, L.. et al	2008	Tracking mobility-related assistive technology in an outcomes study.	SF-36	Mobility AT Devices

Instrument Features	SF-36	EQ-5D-3L	WALS	WLQ
Questions	• Focused on Health • General health, emotional and social activities question.	• Focused on Health • Specific disability questions, and the severity of that disability based on the scale presented.	• Focused on Work	• Focused on Work • Focuses on symptoms/impacts from the past 2 weeks • Each question asks about a different aspect of work.
Format	36 questions, divided into 8 different domains	5 domains, with three different levels of responses	12 questions, 4 levels of answers	25 questions divided into 4 subscales, rating scale from 1-6
Intent	Intended for use with arthritis	Intended for use with arthritis	Intended for use with arthritis	Intended to assess various states of workplace disabilities
Accessibility	Given the simplicity of the questions, it is very accessible	Very accessible because of the ease of answer choices regarding the scale	Very accessible given the short length of the survey	Semi-accessible a bit of a longer survey but goes more in depth
Strengths	• Simple answer choices to questions makes it easier for people to fill out. • Covers a lot of ground regarding limitations of activities, and it dives into the specifics of what one has trouble with.	• More responsive to improvement/decline in people's condition in terms of mobility • The scale has "states" which are worse than death. This helps people understand the seriousness of the diseases these people have and helps professionals assist them appropriately.	• No recall period • Does not go into depth on each individual thing making it easy to understand and fill out	• Very easy to complete • Goes in depth into the areas it covers • Higher work limitation numbers, which means this survey is more sensitive
Weaknesses	• Missing values estimated through the mean of answered data in the same scale for patients with responses for at least half of the domain questions. • Given the above is true, the results may not be accurate in those cases	• Not effective for use with hearing impaired individuals • Patient excluded of specific analysis if <u>any</u> question is left unanswered.	• If 2 questions are left unanswered the patient is left out of special analysis • Does not go in depth into the problems	• With only 5 questions, it does not cover everything in which someone might need. • Uses reverse instructions which can be confusing for individuals • Not very intuitive for blind people, they may be confused with all of the different choices.

# A flowchart of the adapted survey instrument
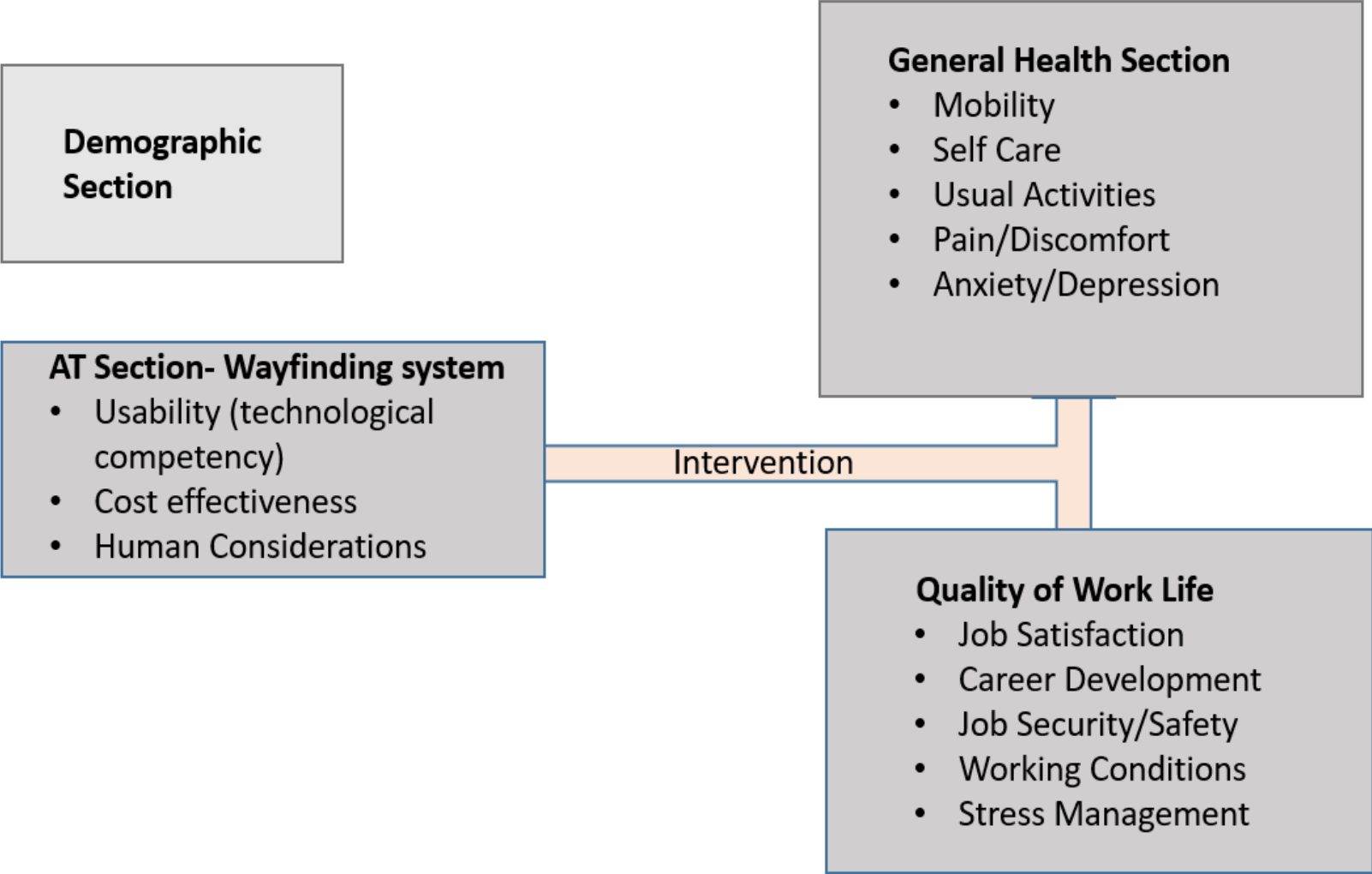
Methodology

- **QALY**: the extent to which a particular treatment or system extends life and improves the quality of life at the same time. It combines the effects of health interventions on morbidity (quality of life) and mortality (quantity of life) into a single index. QALY has been largely used by insurance providers to weigh the benefits of a drug or medical treatment for patients.

- Goal of a health utility as measured by the instrument is to measure the degree to which a particular disability negatively impacts quality of life as compared to a state of perfect health.

- Adoption of ATs are expected to change the utilities, thereby aiding in measuring changes in QALY and work productivity.

Cost-Effectiveness Ratio

Cost effectiveness ratio (CER) or cost per QALY is computed as $\dfrac{c}{(u_2\, t_2 - u_1\, t_1)}$

An intervention with a lower CER is considered to be a more cost-effective intervention. This implies lower costs and/or higher utility is desirable.
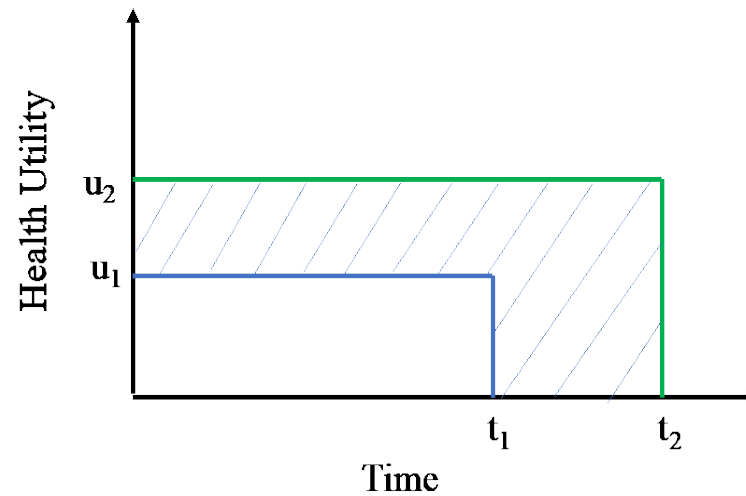
Future Work

- Administer the designed instrument to PWD – cognitive, visual, hearing, motor, older adults.

- Determine cost-effectiveness ratio.