Model-Based Operational Performance Evaluation of Augmented Reality Applications in Supported Employment Training

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Model-Based Operational Performance Evaluation of Augmented Reality Applications in Supported Employment Training

by

Ruo Lun Pan

A thesis submitted to the College of Engineering and Science of Florida Institute of Technology in partial fulfillment of the requirements for the degree of

Master of Science in Systems Engineering

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Abstract

Title: Model-Based Operational Performance Evaluation of Augmented Reality Applications in Supported Employment Training

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Supported employment is a service provided by social enterprises to help persons with disabilities (PWD) to assimilate into their work environment and maintain their jobs for as long as possible. Social enterprises that provide such services are able to receive incentives from the government but they still rely on a limited funding. Augmented reality (AR) has been tested in various fields such as remote support and training employees, including PWDs. This thesis aims to evaluate the operational performance of augmented reality in supported employment using a model-based systems engineering approach paired with a simulation model. The simulation model evaluates three different scenarios including in-person, AR, and hybrid support with different parameters such as number of coaches, lifespan of AR device.

The results from the simulation model shows that the implementation of AR in supported employment has the potential to enhance the efficiency of training while also reducing operational cost. It is not realistic to fully implement AR in supported employment because some people may not be able to use the devices depending on their personal conditions. The implementation of AR in a hybrid mode is cost-effective and has the potential to increase training efficiency or coverage as compared to hiring an additional coach.
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Dedication

To family and friends.
Chapter 1
Introduction

There is an uprise in promoting work from home or remote work since the COVID-19 pandemic started in late 2019. Remote work has been enabled by many different technologies and also led to an increase in popularity for some software and or hardware devices that supports remote work. Augmented reality is one of the technologies that has a rise in popularity; it is not a new technology and also has been brought up every now and then since it has been invented. Currently, there is an increasing popularity with augmented reality in multiple different fields such as medical, aerospace, manufacturing, gaming for different purposes including employment training, remote support, etc. [1]–[3]. Such technology has also been tested to help persons with disabilities (PWD) in terms of education and employment training [4], [5].

Supported employment is a mode of employment designed to assist PWDs with job placement and training provided by social enterprises [6]–[8]. Social enterprises that provide supported employment are able to receive incentives from the government, but the service has to be sustainable because the fundings tend to be low. Since augmented reality has already been used and tested to provide employment training and remote support, in some cases to assist person with disabilities. It may be able to effectively help these social enterprises to provide supported employment to PWDs while reducing the operational cost.

In order to determine whether the implementation of augmented reality will have a positive impact on supported employment training, the performance must first be analyzed. Here, a model-based systems engineering approach is used in a social enterprise context. The current supported employment system is analyzed as-is in terms of the operation and different use cases. Next, the to-be system is analyzed in a similar approach. This addresses the system configuration that is required to support the supported employment mission and sustainment of the system during the training operation. The systems engineering approach also helps in uncovering and establishing the requirements based on the emergent system
properties. The purpose for doing so is to reduce the risk when a new technology, in this case augmented reality, is first implemented for supported employment.

The system model created using systems modeling language (SysML) is used to view how each entity reacts with each other. For example, the relationship between the supported employment coach and the PWD employee, as well as the achievement center, or social enterprise, and the employer. On the other hand, a simulation model is developed using Python language to specifically simulate what the operational performance of the system is like before and after the implementation of augmented reality. Different scenarios/setsups are tested using the python simulation model including full implementation of AR, in-person support, as well as hybrid support where both in-person and AR are implemented. Different parameters are also used in these three scenarios such as the levels of demand, number of coaches, and the lifespan of the AR device.

The purpose of this thesis is to determine if it is worth it to implement AR in supported employment and identify the operational performances of the different supported employment scenarios such as the training coverage and how each scenario differs in terms of the annual operational cost.
Chapter 2
Literature Review

Supported Employment

Person with disabilities often face difficulties when searching for jobs due to their personal conditions and other factors such as lack of skills. Supported employment is a mode of employment designed to assist persons with disabilities to assimilate into their work environment.

Statistics of Persons with Disabilities

Person with disabilities, or PWD, are less likely to be employed as compared to those without disabilities [9] and approximately 43.7 percent of PWDs who were not employed claimed that they have barriers prohibiting them to employment [10]. The types of barriers that stops them from being employed could range from reasons of their own disability, lack of education or training for the job, special needs for the job, as well as lack of transportation to the employment site. About 13.8% of PWDs requested some changes in their work environment to improve their job performance, this includes new/modified equipment, workplace, policies, tasks, schedule, job structure, training, etc. 31% of the PWDs age 25 and over reported a barrier to employment has a bachelor’s degree or higher, while 50.4% has something less than a high school diploma [10]. Although PWDs face difficulties when searching for employment, they often times tend to be employed. According to data prior to the COVID-19 pandemic in 2019 from the U.S. Bureau of Labor Statistics (BLS) [9], there are approximately 30.3 million PWD in the U.S. civilian noninstitutional population who are of age 16 and over. In this 30.3 million PWD population, about 79.1% of the population are not in the labor force, 19.1% are employed and with the remaining 1.7% being unemployed. The percentage of this employed population decreased to 17.9% during the COVID-19 pandemic in 2020 [9].

The data that is reported to the BLS in 2021 shows that for the PWD population that is not in the labor force, about 87.1% had prior work experience. This percentage is lower as
compared to the data from 2019, 88.6%. The reported data also shows that among the PWDs not in the labor force, those with prior work experience increased with age, and those who had a higher level of education tends to have prior work experience [10].

There are career assistance programs available for PWDs to help them with their employment. According to the BLS data in 2021, 5.7% of PWDs used career assistance programs in the past five years to help them train for their job. This data is decreased from 6.5% in 2019 prior to the COVID-19 pandemic. Data shows that PWDs tend to be more likely to have used some sort of career assistance program when they are unemployed as compared to those who are employed or not in the population that are in the labor force. The percentage for the unemployed PWD population to have used a career assistance program is 24% as compared to 7.9% for those who are employed, and the 4.5% for the remaining who are not in the labor force [10].

**Employment for Person with Disabilities**

PWDs often work with and are employed by social enterprises [8], which are businesses that has a goal to serve a economic purpose while also pursuing a social objective. Although these social enterprises employ many PWDs and their primary purpose is to serve an economic goal, they are not charities. The difference is that social enterprises often generate a revenue through their activities and a fraction of their revenues are used to support social causes. These social enterprises broaden the employment options for PWDs and two most popular modes for social enterprises to provide employment options to PWDs are sheltered employment and supported employment.

Sheltered employment is devoted exclusively for PWD training, prevocational services, and for-profit work. It is a type of employment that is center-based and happens in a segregated facility dedicated to PWDs. It is one of the popular modes to provide employment opportunities for PWDs [6], [7], [11]–[16]. This type of employment has proven in Spain to remove the employment barriers for PWDs because compared to normal companies, the jobs they provide to PWDs tend to be more stable and they are able to receive public subsidies since they are helping the society [14]. According to Inal et al. [7],
France and Switzerland are both countries where sheltered employment is popular and Switzerland has one of the highest rates of employment for PWDs specifically. These sheltered employment centers typically provide either transitional employment or extended employment. The difference between transitional employment and extended employment is that transitional employment provides hands-on training experiences that the PWD can use at another employment site. Extended employment is more of a permanent placement where the PWD is hired as an employee and earn a living wage in the center [6], [11].

Though sheltered employment is popular and has many benefits for PWDs, it also has its downsides. For example, it may have a negative effect on the life quality of PWDs if it is not properly managed. It may also reduce the opportunity for PWDs to gain their living freely [7]. This is mainly caused by the employment centers not willing to let go of their best performance PWD workers to the open market because the centers themselves are typically managed by for-profit social enterprises. Letting their best PWD performers go may negatively impact the social enterprise. Hence, when these sheltered employment social enterprises are not managed properly, it may take away the fundamental right of PWD to work equally as others [17].

Another popular employment mode provided for PWDs is called supported employment [7], [11], [13], [18]–[32]. This type of employment is able to mitigate the negative aspects and issues of the other popular employment mode, sheltered employment, and it allows PWDs to make a living while working in an open, inclusive, and accessible work environment just like every other person. The way that supported employment works is that each PWD works in a regular work environment and they are assisted with ongoing support provided by social enterprises. PWDs in supported employment often works in positions that are suitable for their person conditions while receiving training at the job site to help them maintain their jobs [7], [19], [20], [22]. There are a total of five main components to supported employment, which includes job assessment, job development, job placement, job site training, and on-going support [7]. Studies have shown that PWDs with intellectual and developmental disabilities (IDD), and autism spectrum disorders (ASD) benefits and sees the most improvements on their employment outcomes [11], [13],
Some of the negative sides of supported employment as compared to unsupported employment is that individuals with cerebral palsy tend to earn less and have lower working hours [26].

PWDs in supported employment are often accompanied by a supported employment specialist or coach on the job site. The supported employment coaches are professionals who assists PWDs regarding job placement, traveling, skills development, and on-going assessment [7]. As the PWD gains more experience and becomes more comfortable with their job, the coach would gradually decrease the training hours as well as their presence and interaction with the PWD [31]. The ultimate goal of these supported employment coaches is to train the PWD to be as productive and competent as possible with their job so that they can perform like other employees without disabilities [20], [32].

The benefits and cost-effectiveness vary from different locations and agencies. Although this model of employment is favorable, seen in multiple examples, and overall cost effective, there are, however, situations when supported employment is unfavorable. Cost effectiveness of supported employment tend to be more when employees are individually placed instead of group placement [33]. Supported employment also cost only about a third of the cost of sheltered employment and gradually decreases even more when the PWD employee gets more comfortable and gains more experience on their job. On the other hand, sheltered employment tends to have slight increments with cost over time [18]. Overall, supported employment model performs better than sheltered employment in terms of cost over the entire employment cycle and it returns benefits to the contributing taxpayers. On another note, supported employment does not have the identical benefits uniformly, it tends to differ across states and it may even be costly to use supported employment in some places. This means the process of supported employment can still be improved and optimized to make it more sustainable [34].

The social enterprises that provide supported employment are qualified to receive government incentives, but still has to be financially sustainable because they are for-profit organizations. According to Latimer et al. [35], the average indirect cost of supported
employment accounts for 20.8% of the total annual cost, while the remaining 79.2% are
direct cost such as payroll, occupancy, transportation, etc.

**AR Applications**

Augmented reality (AR) is a type of technology that has the capability to overlay
digital information or objects onto the real world. These type of information or objects can
be images, audios, text, and videos that links the virtual world with the real world [1], [4],
[36]. The concept of augmented reality entered the public’s view when the science fiction
TV series Star Trek was aired in 1966. Two years later, this sci-fi technology that used to
exist solely on TV screens came to life when Ivan Sutherland and his team at Harvard
University and Utah University developed a prototype. It was a display that can be
mounted on people’s heads equipped with a piece of transparent screen that can display
simple computer drawings. This is considered as the first example of both augmented
reality (AR) and virtual reality (VR) [4]. However, the term augmented reality (AR) was
not coined until 1992 when researchers, Tom Caudell and David Mizell, at Boeing
developed the first AR application to overlay information to help assemblers with cable
wiring [4], [37]. Although technology has advanced tremendously since Sutherland and his
team developed the first AR prototype, the basic underlying components of an AR device
remained unchanged [4].

Since the introduction of the augmented reality concept, it has been tested and
implemented in many different fields and quite a lot of research has been published over
the years. Some of the fields that have implemented AR are education [4], [38], [39],
manufacturing and maintenance [3], [40], [41], aerospace [42], [43], and medical [2], [44].
Augmented reality has also been used to enhance the knowledge and skills of the
workforce, some of these applications involve training individuals, some of whom may be
disabled, to assimilate and develop necessary skills for the job [3], [36], [37].

**AR & VR Differences**

Many people are confused about AR and VR because both uses very similar devices. In the
research field, it remains a controversial topic when it comes to which has a higher term, is
AR a type of VR or vice versa. The key difference between the two is that VR is a simulation of a computer generated, imaginary environment. Once an individual puts on a VR headset, he or she has then entered the virtual world because the real world can no longer be seen with the headset on. This virtual environment may be further enhanced through various touch and motion sensors, or control devices, to elevate the experience in the virtual world. On the other hand, AR adds virtual objects to the real world instead of replacing it with complete digitized images [4].

**AR in Education Field**

According to Lee, AR has a bright future for both education and training. It provides an interactive education where it can engage a student with its rich contents of 3D environments and models. It also has the benefits of simplicity where it is easy to provide experiences for learners to accept knowledge and skills. There is also potential in improving the quality of information. For example, information for historical heritages can be connected by Geo tags. Lastly, AR can also promote the efficiency and effectiveness of education with its rich contents that can be provided at the right time and place [38].

Köse and Güner studied the use of augmented reality to provide education to special-need individuals as a type of learning material. AR technology allows people to create educational content even on the phone and many contents are already available on the internet. Although the use of AR in education focused on STEM education, it shows promising results for special needs education and it could assist individuals with special needs to overcome the learning barriers [4].

AR has also been utilized to enhance the learning of sign language. Ekhsan and Khairi et al. designed and developed an application for normal people to learn sign languages in a more engaging way. They concluded that it provides learners with positive implications because it helps them learn on their own. It has the potential to benefit the community of hearing-impaired people and their families.
AR in Manufacturing and Maintenance Field

The use of augmented reality is quite popular in the field of maintenance and manufacturing, one example being in assembly lines where workers would have to put different parts together in order. It is capable of annotating parts in real time for equipment maintenance with positional frames, arrows, and texts [40]. In general, AR is beneficial in that it reduces the time of reaction and time to complete a task, it also reduces travel cost since remote training is made viable [3]. An assembly line assisted by AR shows more benefits when the tasks are more difficult with unclear assembly positions. However, it does not lower assembly times by a significant amount when the tasks are more intuitive and repetitive [41].

AR in Aerospace Field

The aerospace field often has many complex procedures when it comes to aircraft operations and maintenance tasks. Augmented reality has been tested and studied for these tasks on the ground and even applications in the outer space. Aircraft technicians often need instructions along with their sides when performing their job tasks. Traditional methods of training aircraft technicians have proven to be effective, however it may not be able to keep up with trends in the future aviation industry. AR is a potential new instruction delivery system that may assist with job trainings and tasks of aircraft technicians to maintain a high safety standard to keep accidents as low as possible. It could also reduce the cost of training and retraining because the job itself can be served as a training medium [42].

In the aircraft design phase, augmented reality is also used to visualize things that are difficult to present such as physical properties. When designing an airplane cabin, customers are most often actively involved because they want to assess different alternatives and select things that goes into the final design of the product. It is very useful for visualizing computational fluid dynamics (CFD) data inside the cabin. This is a much more cost effective way as compared to implementing a physical mockup to simulate the properties. On top of that, it combines the cabin real space, allowing the user to view the pressure values in different areas in the aircraft. Another area that AR is used for the design
phase on an aircraft is the cockpit. The cockpit has an enormous number of controls and displays which requires designs that take into account of the functionality, ergonomics, and safety. Augmented reality has proven to be a useful tool in the early design phase to collaborate in the layout of the cockpit for the goal of a good human-machine interface [42].

AR has also been studied for use in the outer space onboard the International Space Station (ISS). The European Columbus module is a part of the ISS and it is a complex system that requires many maintenance tasks. The study shows that AR is able to reduce the amount of workload for astronauts onboard when performing maintenance tasks by augmenting service information on their headsets [42].

AR in Medical Field
The medical field, AR is a technology that has been brought up often. Some of the usage include promoting surgical autonomy overseas, building overseas capacity, and making sure the clinical and educational infrastructure is sustainable. A 13-month study on the use of augmented reality as an educational platform for cleft surgery was conducted and found that it is a promising way to build a sustained capacity of cleft care in overseas areas that are under resourced. It allowed more experienced surgeons regarding cleft surgeries to connect with clinicians overseas and provide a remote and interactive presence to guide the operation. This helps both parties because it enabled experts to be able to proctor using AR because often times they do not have the opportunity to participate in outreach initiatives due to time and budget. For the less experienced surgeons overseas, it helps them gain confidence to perform the surgery instead of referring patients. This is a way to transfer knowledge and skills remotely [44].

In the surgical world, the most popular training method is “learning-by-doing” paired with “on-the-job-training.” Surgeons have been searching for other means of practice that are more precise and stimulating when they started using real life simulations and practical skills sessions to hone their surgical skills. The barriers of using AR have lowered since it is becoming more cost effective and affordable. In the field of cardiac surgery, it leads
young surgeons to a repetitive learning experience in surgical teaching, which improves the efficacy and saves cost in the long term [2].

AR Helping People with Disabilities

Studies have already been conducted by researchers to determine how augmented reality can benefit the community of people with disabilities in terms of job opportunities. A group of researchers in Brazil studied the use of AR to help hearing-impaired people to develop skills necessary for job positions in an assembly line that manufactures computers. In Brazil, the hearing-impaired population is approximately 9.7 million. Many of the job positions specifically for people with disabilities are unfilled due to lack of skill. Augmented reality is used as a medium for seminars because it allows the learners to be hands free while following their instructions from tutors that helps them develop their skills. It has shown to be a low cost way to deliver skill development [5].

Another research group from Singapore studied the use of AR to provide vocational training for people who are mentally disabled. It is difficult for people with cognitive impairment to obtain a job because they often lack attention, memory, problem solving skills, and social cognition due to neurological, psychiatric and developmental conditions. Their chances of employment could be increased through vocational training to boost their social interactions. Although there are existing services that provide vocational trainings, but there remain complexities in setting up simulations for a real job. As compared to VR, AR retains spatial awareness for its users which gives them some security. The result of the study shows that AR is a motivational and engaging method to provide vocational trainings to people with cognitive impairments. It also helped pinpointing the specific weaknesses of the user and allowed the therapists to provide additional assistance [36].

MBSE in Similar Domains

The complexity of systems proliferated over the years as the advancement of technology surged. This led to the transition to model-based systems engineering (MBSE) by systems engineers from document based approaches in a way to redefine the way of systems development [45], [46]. Although engineers have used different shapes and forms of
models in centuries, MBSE is a revolutionized approach to view a system. The term MBSE was first introduced in 1993, which involves different concepts like mathematical theory of systems coupling, algebraic relationships, and the requirement’s mathematical structure. After years of development and improvement, it now focuses on requirement elicitation, trade studies, design, analysis, and verification and validation through a formal use of models, over the life cycle of a system. Over the years of engineering with models, the process often includes multiple models and has assumptions that are inconsistent and underlying semantics. All of these issues were once brought up while using computer-aided systems engineering and concurrent engineering still remains. One benefit that MBSE provides as opposed to the two previously is that all of the information that is related to the system is stored in one central location that is configuration managed [46], [47]. This helps in transparent tracing all the elements of the model, such as requirement and the reasons of the system. MBSE is currently still in its early stages and there are active pursuits in the field of aerospace industry [46]. While some argue there are many benefits from using MBSE, others also say claim that there is no empirical evidence showing the benefits of MBSE and also not implying that it is disadvantageous. They claim that the benefits of MBSE needs to be formally measured by researchers instead of informally observed by practitioners [45].

MBSE with Trade Analysis and Cost Analysis

MBSE are used in many different fields and Leserf et. al proposed to do trade analysis on Autonomous Unmanned Aerial Vehicles. Autonomous Unmanned Aerial Vehicles are usually used for intelligence, surveillance and reconnaissance missions. It is crucial that reliability of the hardware is considered and have a high priority because communication to ground control is not always guaranteed, hence onboard processing and decision-making is a necessity. MBSE approach can be used for trade off analysis using different MBSE language. For systems modeling language (SysML) specifically, a group of researchers proposed new stereotypes, which are decision points, global constraints and optimization context, that extends the initial system model without any variants for the purpose of trade-off analysis [48].
In this particular case, the SysML model is extended into a CSP optimization problem (CSMOP) and solved using different solvers. What is unique about this research is that this approach allows to model the whole problem at the SysML model level. This means that it is not required to manually connect the SysML model to the optimization solver. According to the researchers, this is helpful during the early stages of design and development when there is still a large space for exploration. Ultimately, it makes the exploration of design space more efficient and assists in reducing the number of solutions [48].

Another research team from Spain also used MBSE applied to trade-off analysis in the medical field. The micro-electromechanical systems (MEMS) technologies that are used in new sensors and actuators are getting more and more complex. These products are starting to get to a level of complexity where systems engineering approaches are needed, which used to be only needed for large projects, and this need in the biomedical field is projected to increase in the upcoming future. The powering of such implantable devices is one of the crucial steps during the phase of research and development and it is important to determine the best technology for this purpose. This is often done based upon prior experience and sometimes paired with a weighted approach, which is not a very efficient way because the process requires a large amount of data that needs a more complex and systematic approach to select the best option. Hence, MBSE was chosen as a way to systematically optimize the process for trade-off analysis [49].

The researchers concluded that MBSE combined with trade-off analysis is a very good engineering practice to select the best technology for a specific problem. It helped the research team to identify the which level of the system should the trade-off analysis be done in. This aided the identification of system building blocks and the functions that needs to be implemented to solve the problem of transferring energy wirelessly and harvesting energy within a patient’s body. The results were verified by comparing to other researchers’ results as well as publish literatures.

Overall, the use of MBSE in the early phase of the development cycle has the potential to reduce the time and cost for development. This is achieved by having preparation before
the product is built, which includes understanding, prioritizing and evaluating the requirement implementation. Since the model is reusable, organizations can actually save more time and cost when model assets are part of an initial building block a design work. The model based structured approach improves the quality of systems specifications as compared to document based approaches. There are also less errors due to ambiguous, inconsistent, incomplete or incorrect requirements since the engineering team can have a better understanding of the behavior of the system. This saves time and cost since it prevents the problems from surfacing late in the development cycle [50].

MBSE can also be used for the purpose of cost analysis to prevent and or reduce the risk of development cost increase over the products life cycle. In the field of aircraft development, the complexity of the development processes as well as the aircraft’s subsystems are always increasing. This is partly due to the necessity of safety improvement for the aircraft, which requires operations and perspectives from different stakeholders. Often times these development activities are difficult to manage because so many stakeholders play a role in the development process and this requires an effective cost analysis before anything can be done in order to prevent budget overrun. Wang et. al proposed to use a model-based systems engineering approach to support the development process, as well as the cost for research and development of the aircraft. The model was able to not only support the cost analysis for the aircraft development from a static perspective, but also from a dynamic perspective. The MBSE approach was able to help analyze the development process and decrease the risk of project failures due to exceeding the budget constraints. [51].

MBSE SysML Models and Simulation Models
A central system model is used to perform all the engineering activities in MBSE and this has been proven to time effective and precise [46], [47]. The activities that are included in this model may consist of specification, design, integration, validation, to the operation of the system. Some of these tasks can be done quite effectively using SysML proposed by the object management group (OMG), however, there remains other activities that are still performed using system models that are specific to their domain. These outlier activities include initial problem domain perception, requirement management, or performance
evaluation. There are other commercial systems engineering tools and software suites that are capable of integrating with SysML models to enhance the features such as simulation, computer aided design (CAD), product life cycle management (PLM), requirement engineering, etc. The evaluation of a system’s performance is usually performed by simulation [47].

Since systems performance evaluation is an essential activity of systems engineering principles, researchers believe there is a need to transition SysML models to executable simulation models [47], [52]. Kapos et. al integrated a simulation-based testing in MBSE that uses SysML to simulation model transformations with query/view/transformation relations (QVT-R). QVT-R is a declarative variant of QVT language, which is not defined as a single language but three languages in a set that provides various transformation features. This is also one of the main reasons why it has not been thoroughly exploited yet. The team of researchers concluded that QVT-R is an adjustable and an infrastructure that enables the building of SysML-to-simulation model transformations. It does not matter even if the domain-specific system characteristics, requirements of simulation model initialization, and components of simulation library are different. However, there still remain some factors that can still be further researched into, for example, different simulation approaches to exploit generality as well as applications in the domains that are appropriate.
Chapter 3
Problem Definition

The Brevard Achievement Center (BAC) is a non-profit organization that provides services like supported employment to person-with-disabilities (PWD) in the Brevard County area. Their goal is to assist disabled individuals to be successful with their job and ensure they can maintain their job for as long as possible. The organization is underfunded by the state and it is costly to provide the supported employment services under the current system. BAC is responsible for providing a coach/trainer for every PWDs and all the training is done on-site and in-person currently. This limits the ability of BAC to provide good coverage for all PWDs because traveling to various locations within the country where each PWDs are employed is very time-consuming.

The way the current system works is that each PWDs are placed at specific locations and job positions by BAC that are suitable for each of their personal conditions. On-going support for the PWDs is provided by BAC starting from a couple of hours a day and slowly decreasing to a couple of hours a week depending on the level of experience. The coach travels to where the PWD is employed and provides training from hand over hand prompting to managing difficult conversations with either customers or co-workers. This type of training is proven to help the individual to assimilate into their work environment and maintain their job. It is highly possible for the PWDs to lose their jobs without this type of support and training.

The inefficiency of the current system lies in the transportation component and reducing this may help BAC to provide more coverage and maybe reduce the operational cost of supported employment. In order to achieve this, a new tool must be implemented to change the way the current system works. Augmented Reality (AR) is a tool that has the potential to reduce the time for transportation, allowing the coach to provide training in their own office while the PWDs are equipped with AR devices. This allows the coach to potentially provide more training coverage and increase the efficiency of supported employment.
Before implementing such technology in this field, it needs to be analyzed and compare it to the current method to find out whether it will actually improve the coverage and how it would affect the cost.

**Objectives**

There are three main objectives for this research. These objectives will lead to a better understanding of the problem and whether it is feasible to implement augmented reality in supported employment.

1. Model the architecture and behavior of the supported employment training system using SysML.
2. Develop a simulation model of the supported employment training system using the SysML representation.
3. Establish the key factors that influence the effectiveness of the implementation of augmented reality for supported employment.
Chapter 4
System Model

The model of the system is generated using Cameo Systems Modeler and captured using Systems Modeling Language (SysML).

As-Is System

Figure 1 below shows the context of the supported employment service. The context consists of the achievement center (AC), family members of the employee, the employer, the employee, and the career service. The supported employment coach is part of the achievement center.

![System Context Diagram]

**Figure 1: System Context**

The use case diagram of pre-employment under the current system is shown in Figure 2. In the pre-employment process, the achievement center first assigns a coach for the potential employee. This assigned supported employment coach will then collaborate directly with the individual employee and their family members to evaluate and determine their skills, interests, barriers to employment, desired work, and what kind of support they need. Next, the coach and the career service work directly with the employee during the process of support application for employment.
During post-employment, the supported employment coach, employer, and employee are tightly correlated with each other during the employment period. Figure 3 shows the use case diagram for post-employment. The first two activities in post-employment include preparing training and providing initial training, where all three parties participate. Then, the supported employment coach and the employee complete the rest of the activities. This includes requesting coach assistance, performing employee supervision, providing continuous support, and transporting to the employment site. It is important to note the transportation component in this scenario because it is the major component that the implementation of augmented reality will try to reduce.
Figure 3: In-person Post-employment Use Case Diagram

To-Be System

Similar to the previous section, this section is the model for the pre-employment and post-employment use case after the implementation of augmented reality. Figure 4 shows the use case diagram for pre-employment with implementation of augmented reality. The only difference in the pre-employment use case between the as-is system and the to-be system is that there is additional AR training for both the SE coach and the employee. This ensures that both parties will know how to operate the augmented reality device and reduce the difficulties during its use.
In the post-employment for the to-be system, transportation to the employment site is eliminated, shown in Figure 5. However, with the introduction of augmented reality devices, there is a need to maintain the AR device before the end of the entire supported employment training and return the AR device to BAC. Augmented Reality devices are used during the initial training, request coach assistance, perform employee supervision, and provide continuous support.
Although it is ideal to implement augmented reality throughout the program, it is not realistic. This is due to several reasons such as some individuals may not be able to use the AR device, and some employment sites may prohibit the use of AR devices due to privacy reasons. The hybrid support is a combination of both in-person support and AR support. Which means that for the use case, there will still be a component for transportation and also the use of AR. This adds some complexity since both methods are used simultaneously.
Chapter 5
Simulation Approach

A discrete event simulation is developed in python to analyze and compare the operational performance of the different scenarios. Figure 6 shows the major components of the simulation. It is composed of five major parts or modules, demand generation, in-person support AR support, hybrid support, and model metrics. Hybrid support is a scenario where in-person support and AR support coexist and shares the same functions.

![Diagram of simulation components]

**Figure 6: Components of the Simulation**

Table 1 shows the parameters of the simulation. Some of these parameters are obtained from the stakeholder, Brevard Achievement Center. Examples of these parameters include the demanded training hours for the PWD, the coach rate, and training session times. The billable rate is a crucial factor that was provided by the BAC. According to the BAC, they receive $9.05 per 15 minutes of training, which translates to $36.2 per hour of actual training. This means that the BAC does not get reimbursed for the time spent traveling to the employment sites. The other parameters are assumed values and can be changed from one run of the simulation to another. This allows the simulation to run through different scenarios and yield results that can be used to compare and see the extreme cases.
### Table 1: Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum weeks</td>
<td>50</td>
</tr>
<tr>
<td>Percent of new PWDs</td>
<td>20%</td>
</tr>
<tr>
<td>Percent of PWDs that can use AR</td>
<td>50%</td>
</tr>
<tr>
<td>Demanded training hours for new PWD in one week</td>
<td>6-10 hours</td>
</tr>
<tr>
<td>Demanded training hours for old PWD in one week</td>
<td>2-6 hours</td>
</tr>
<tr>
<td>Coach Rate</td>
<td>$17</td>
</tr>
<tr>
<td>Work hours / Day</td>
<td>7 hrs</td>
</tr>
<tr>
<td>Session time for new PWD</td>
<td>2 hrs</td>
</tr>
<tr>
<td>Session time for old PWD</td>
<td>1 hr</td>
</tr>
<tr>
<td>Percent of AR failure in 1 year</td>
<td>20%</td>
</tr>
<tr>
<td>AR life of AR failed before life span</td>
<td>0.5 year</td>
</tr>
<tr>
<td>AR unit cost</td>
<td>$1100</td>
</tr>
<tr>
<td>Wi-Fi cost / month</td>
<td>$70</td>
</tr>
<tr>
<td>Percent of PWD require Wi-Fi</td>
<td>50%</td>
</tr>
<tr>
<td>Number of AR sets for LOW demand</td>
<td>15</td>
</tr>
<tr>
<td>Number of AR sets for MEDIUM demand</td>
<td>20</td>
</tr>
<tr>
<td>Number of AR sets for HIGH demand</td>
<td>25</td>
</tr>
<tr>
<td>Vehicle degradation cost / mile</td>
<td>$0.56</td>
</tr>
<tr>
<td>Software cost</td>
<td>$12 / month/ PWD</td>
</tr>
<tr>
<td>Number of replications for simulation</td>
<td>10</td>
</tr>
<tr>
<td>Number of years for simulation</td>
<td>5</td>
</tr>
<tr>
<td>AR life</td>
<td>1,2,3,4 years</td>
</tr>
<tr>
<td>Low Demand Range</td>
<td>15 +/- 2 PWD/Week</td>
</tr>
<tr>
<td>Medium Demand Range</td>
<td>20 +/- 2 PWD/Week</td>
</tr>
<tr>
<td>High Demand Range</td>
<td>25 +/- PWD/Week</td>
</tr>
<tr>
<td>Number of coaches</td>
<td>1,2,3</td>
</tr>
</tbody>
</table>

Moving on to a component that enhances the simulation, real world locations. Since in-person support requires the coach to travel from one employment site to another, using real locations in the Brevard Country helps to make the simulation more realistic regarding the travel time and travel distance done by the supported employment coaches.
Figure 7: Locations Used in Simulation

Figure 7 is a map of the Brevard County labeled with eighty locations of various supermarkets, drugstores, and selected offices. A csv file containing the information regarding these locations such as distance between each location and estimated travel time is used in the simulation. Note that the Brevard Achievement Center is centrally located in the map, this is where each training tour begins every day.

Demand Generation Module

In the demand generation module, several things are generated to initialize the simulation. First, the total number of PWDs in the week is generated. Which is then separated into new and old PWDs depending on the percentage of new PWDs set. The default percentage of new PWDs is set to 20% of the total PWD for the week. The employed location of the
PWD is randomly generated with an assigned number, which correlates to a realistic location within Brevard County. Then the weekly demand is generated for each new/old PWD, which has different hours of demand per week depending on their level of experience for the job. The less experienced, new PWDs, require 6 to 10 hours of training per week with a 2-hour training session. On the other hand, the more experienced, old PWDs, require 2 to 6 hours of training per week with a 1-hour training session. This in turn determines the number of visits the coach needs to make for each PWDs in a week. There can be a maximum of five visits for each PWDs in a week because the assumption is that a PWD will only receive one training session a day. To prevent the visits from cluttering at the beginning of the week, an array is used to determine which day the visit is scheduled. First, an array of five zeros is generated simulating the five working days in a week. Next, the number of visits is filled for the week with the demanded hours depending on the type of PWD. For example, if there is a total of three visits for an old PWD, that means the coach will visit the PWD 3 days out of the five working days with a 1-hour training session for each day, totaling 3 hours of training for the week. The array will then look like [1 1 1 0 0]. This shows that the visits are all cluttered at the beginning of the week. The array is shuffled to eliminate the clutteredness at random, resulting in a more distributed visit for the week, for example [1 0 1 0 1]. To accommodate the different scenarios in this simulation, the number of PWDs that are able to use the augmented reality devices is also determined in this module of the code. The setting for AR users in a week is 50%, which means 50% of the PWDs are AR capable, while the rest are not. This is then used to determine how many old/new PWDs are capable of using the AR device within the group of AR-capable PWDs. These PWDs are then assigned with an AR device; the number of AR devices is limited depending on the predetermined maximum PWD in a week. These data are then stored in a pandas dataframe ready to be used in the next simulation module.

**In-Person Support Module**

The next three modules of the simulation code are specifically for the three different scenarios of the supported employment. First, is the in-person support, second is the AR support, and lastly is the hybrid support. For the in-person support simulation, the code
reads in the record generated by the demand module. It starts the simulation by looping through the number of weeks, then by days in the week, and the available coaches to fill in the available coaching hours with the requested demand hours. The simulation does this by looping through the demand record, which is stored in a Python dictionary. It first verifies if the conditions are matched, for example, the coach availability, the week, and day in the demand record should match up with the current week and day of the simulation. The coach will only service the demand if it satisfies the condition where there are enough available hours from the coach and that the added session time along with the travel time to the employment site would not exceed the coach's availability. If such is exceeded, it would move on to the next condition and check if it is possible to satisfy half of the demanded hours. The location of the PWD employment site is also taken into account to determine the miles and time traveled by the coach. This is later used to calculate the vehicle degradation cost, which is an important cost component for the in-person support. The data for total service time, total distance traveled, and total travel time is accumulated for each week, and lastly added for each simulation cycle. Inefficiencies such as paperwork, or anything that is required before the training session is accounted for by generating a random time between 7 and 15 minutes. Once the demand has been serviced, it would be marked with the number 1 so that the code would skip this demand when going through the record of demands.

AR & Hybrid Module

The AR support module is remarkably similar to the in-person support module but without the transportation component. This means the code does not need to check the location for information such as travel time and travel miles. The added component for the AR module is the replacement of AR units. This replacement is determined by the useful lifespan of the AR device. For example, with a three-year useful lifespan for the AR devices over 5 years of simulation, the unit must be replaced one time. It is assumed that 80% of the AR devices will last for the entire lifespan, while the rest, 20% of the AR devices, will have a useful lifespan of half a year. The hybrid support module is a combination of the previous two simulation module. The code here needs to identify which demand is AR or in-person.
and whether the AR demand is assigned an AR device or not. The in-person scenario in the hybrid support module is identical to the in-person module. The only difference is that it needs to verify if the demand is in fact an in-person demand. If it is not an in-person demand, it would be passed on to the AR support scenario. Then it would determine if the PWD associated with the demand has received an AR device or not. If it has received an AR device, it would then be serviced as an AR demand. Otherwise, it would be served as an in-person demand if there are enough available hours from the coach.

Model Metrics Module

The final module in the simulation is the model metrics. It is a module used to report the collected data as well as calculate some of the metrics and output it into a python dictionary, which in turn is finalized and exported as a .csv file using python pandas. There is a total of thirty-five metrics that are exported in the final results file. These are the total metrics that are simulated for one year, which include the number of new and old PWDs, total demanded hours, the total number of requested training, the amount of new/old PWD that are not served, the total unserved hours, training coverage, coach utilization, average annual cost, etc. A summary of the different model metrics is listed in Table 2.

Table 2: Summary of Model Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Num New PWD</td>
<td>Total number of new (less experienced) PWDs</td>
</tr>
<tr>
<td>Num Old PWD</td>
<td>Total number of old (more experienced) PWDs</td>
</tr>
<tr>
<td>Total Demand</td>
<td>Total demanded hours</td>
</tr>
<tr>
<td>Num Request</td>
<td>Total number of training requests</td>
</tr>
<tr>
<td>New Unserved</td>
<td>The number of new PWDs remained unserved</td>
</tr>
<tr>
<td>Old Unserved</td>
<td>The number of old PWDs remained unserved</td>
</tr>
<tr>
<td>Unserved Hours</td>
<td>Total demanded hours that are unserved</td>
</tr>
<tr>
<td>Half Serve Hours</td>
<td>Total demanded hours that are partial/half served</td>
</tr>
<tr>
<td>Num Unserved</td>
<td>Total number of PWDs that remained unserved</td>
</tr>
<tr>
<td>Num Served</td>
<td>Total number of PWDs that are served</td>
</tr>
<tr>
<td>AR Served</td>
<td>Total AR PWDs served and received AR device</td>
</tr>
</tbody>
</table>
## Metric

<table>
<thead>
<tr>
<th>Metric</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR Unserved</td>
<td>Total AR PWDs that remained unserved and received AR device</td>
</tr>
<tr>
<td>No AR Served IP</td>
<td>Total AR PWDs that did not receive an AR device and are served in-person</td>
</tr>
<tr>
<td>No AR Unserved</td>
<td>Total AR PWDs that did not receive an AR device and remained unserved</td>
</tr>
<tr>
<td>IP Served</td>
<td>Total IP PWDs served in-person</td>
</tr>
<tr>
<td>IP Unserved</td>
<td>Total IP PWDs that remained unserved</td>
</tr>
<tr>
<td>Total Unserved Hrs</td>
<td>Total hours that remained unserved</td>
</tr>
<tr>
<td>Num Half Served</td>
<td>Number of PWDs that are partially served</td>
</tr>
<tr>
<td>Num Full Served</td>
<td>Number of PWDs that are fully served</td>
</tr>
<tr>
<td>% Half Served</td>
<td>Percentage of PWDs that are half served</td>
</tr>
<tr>
<td>Request Coverage</td>
<td>Coverage of the received training request</td>
</tr>
<tr>
<td></td>
<td>(Completed request / Total request)</td>
</tr>
<tr>
<td>Training Coverage</td>
<td>Coverage of demanded training hours</td>
</tr>
<tr>
<td></td>
<td>(Completed training hrs / Demanded training hrs)</td>
</tr>
<tr>
<td>Service Time %</td>
<td>Percentage of time when coaches are training PWDs</td>
</tr>
<tr>
<td></td>
<td>(Training time / Total work hours)</td>
</tr>
<tr>
<td>Travel Time %</td>
<td>Percentage of time when coaches are traveling to the site</td>
</tr>
<tr>
<td></td>
<td>(Traveling time / Total work hours)</td>
</tr>
<tr>
<td>Coach Utilization</td>
<td>The utilization ratio of coaches</td>
</tr>
<tr>
<td></td>
<td>(Total work hours / available coach hours)</td>
</tr>
<tr>
<td>Total Work Hours</td>
<td>Total hours when coaches are working</td>
</tr>
<tr>
<td></td>
<td>(Service + Travel)</td>
</tr>
<tr>
<td>Tot Service</td>
<td>Total time coaches spent training PWDs</td>
</tr>
<tr>
<td>Tot Travel</td>
<td>Total time coaches spent traveling to employment site</td>
</tr>
<tr>
<td>Tot Distance</td>
<td>Total distance traveled by coaches</td>
</tr>
<tr>
<td>Avail Coach Hrs</td>
<td>Total available training hours from coaches</td>
</tr>
<tr>
<td>Total Cost</td>
<td>Total cost to provide supported employment</td>
</tr>
<tr>
<td>Unit Cost</td>
<td>The average cost to provide training to one PWD</td>
</tr>
<tr>
<td>Billable Hrs</td>
<td>Total training hours provided to PWDs</td>
</tr>
<tr>
<td>Revenue</td>
<td>Revenue from providing supported employment</td>
</tr>
<tr>
<td>Profit</td>
<td>Profit from providing supported employment</td>
</tr>
</tbody>
</table>

The cost components for the different scenarios like in-person and AR are different. While all scenarios have the coach’s salary as a component, the in-person scenario mainly differs in that it requires a vehicle degradation cost, the AR scenario takes into account the
technologies that are required to implement AR such as software and hardware. The cost components of the hybrid scenario are a combination of both the in-person and AR scenario.

Simulation Model

The four modules mentioned previously are composed to make up the final supported employment simulation model that has three different scenarios, in-person support, AR support, and hybrid support. The simulation changes its parameters for every run and each run simulates five years of supported employment activity. The parameters that change include the useful life of the AR device, levels of demand, and the number of coaches. The useful lifespan of the AR device is a parameter that ranges from one to four years. The level of demand is the number of PWDs per week, which is 15, 20, and 25, representing the low, medium, and high demand accordingly. For each replication, the maximum number of PWDs per week may fluctuate from the set number of PWDs by +/- 2. For example, this means for low-level demand with a set number of PWD of 15, the maximum number of PWD per week can fluctuate between 13 and 17 for each replication. The number of coaches is another parameter that changes during the simulation and it ranges from one coach to three coaches. The simulation ran for a total of ten replications.
Chapter 6
Results & Discussion

The results of the simulation were exported into a csv file that contains all the metrics produced by each run of the simulation. The simulation results were averaged for each replication that has the same simulation parameters, which is then used to produce the plots to visualize the data. Table 3 shows all the different scenarios that have been tested in the simulation model. There are a total of ten replications, each replication goes through low, medium, and high level of demand. In each of these scenarios, the maximum number of PWDs per week varies ±2 depending on the level of setting. Then, the number of coaches and the lifespan of the AR devices are varied between one to three and one to four. Each of the scenarios are simulated for five years.

Table 3: Simulation Scenarios

<table>
<thead>
<tr>
<th>Replications</th>
<th>Level of Demand</th>
<th>Max PWD/Week</th>
<th>Number of Coaches</th>
<th>AR Lifesanp</th>
<th>Years of Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep 1</td>
<td>Low</td>
<td>15</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>21</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>25</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td>Rep 2</td>
<td>Low</td>
<td>14</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>19</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>26</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td>Rep 3</td>
<td>Low</td>
<td>16</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>19</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>23</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td>Rep 4</td>
<td>Low</td>
<td>14</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>21</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>23</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td>Rep 5</td>
<td>Low</td>
<td>15</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>18</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>26</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td>Rep 6</td>
<td>Low</td>
<td>16</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>21</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>26</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td>Rep 7</td>
<td>Low</td>
<td>14</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>20</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
</tbody>
</table>
### Replication Levels of Demand

<table>
<thead>
<tr>
<th>Replications</th>
<th>Level of Demand</th>
<th>Max PWD/Week</th>
<th>Number of Coaches</th>
<th>AR Lifespan</th>
<th>Years of Simulation</th>
</tr>
</thead>
<tbody>
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</tr>
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<td>14</td>
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<tr>
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<td>1-3</td>
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<td>1-4</td>
<td>5</td>
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<tr>
<td>Rep 10</td>
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</tr>
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<td>Medium</td>
<td>20</td>
<td>1-3</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>25</td>
<td>1-3</td>
<td>1-4</td>
<td>5</td>
</tr>
</tbody>
</table>

### Demand vs Available Hours

Figure 7 is the plot of demanded hours vs. the available coaching hours. Each datapoint is the average of result of the simulation under the same parameters. The utilization ratio of the coaches is calculated by dividing the demanded hours and the available coaching hours. It is directly related to the demanded hours and inversely related to the available hours. This means the utilization ratio increases as the demanded hour increases and decreases as the available hours increases. It shows how much the coaches are occupied by the demanded supported employment trainings. The size and shade of the datapoint on the plot is also directly related to the utilization ratio to give a clearer picture of how each scenario differs from one another.

The available hours are determined by the number of coaches over the simulated years. For example, there is a total of 8750 available hours over the course of 5 years with one coach. As can be seen, the available hours are distributed almost identically for each scenario that has the same number of coaches. As for the demanded hours, it is determined by the level of demand depicted by the label shown on the datapoint low, medium, or high, followed by the maximum number of PWDs per week set for the simulation. The demanded hours increase as the level of demand is higher and the diagonal line is the threshold at which the coach is over or underutilized. The upper left portion of the plot has a utilization ratio.
greater than one, which means the coaches are over utilized. On the lower right portion of the plot is the scenarios when the coaches are under-utilized.

Figure 8: Demanded Hours vs. Available Coaching Hours

A three dimensional representation of demanded hours vs. available coaching hours with the utilization ratio is shown in Figure 8. The surface plot is shaded similar to Figure 7 to show the various levels of utilization. Identical to the previous plot, the utilization ratio peaks at the lowest available hours and highest demanded hours. According to the Brevard Achievement Center, medium level demand with approximately 20 PWDs per week is the most likely scenario. Hence this is chosen for the main scenario for analysis and the other
two demand levels are used for comparison and determine what happens in the extreme cases.

![Demand vs. Available vs. Utilization Ratio](image)

**Figure 9: Demanded Hours vs. Available Coaching Hours vs. Utilization Ratio**

After a close look on how utilize the coaches are under the different levels of demand, next topic is to analyze and understand how much of an effect, if there is any, does the lifespan of the augmented reality devices play on the annual cost for supported employment when AR is implemented.
Effect of AR Device Lifespan on Annual Cost

The lifespan of the AR device should have an effect on the annual cost for supported employment, but it is also crucial to determine if this effect is significant enough to change to cost dramatically. The range for the AR lifespan is one to four years and this is used to compare how it changes the cost. The simulation assumes that 20% of the AR devices fails prematurely, which means that these devices fail before their lifespan. These devices are set to fail within half a year instead of the full lifespan. The remaining 80% are fully functional up to their intended lifespan. Each of the AR devices cost $1100 and the amount of AR devices is determined by the level of demand. In this case, since the medium level demand is being analyzed, there is a total of twenty AR devices.

The total cost of the AR devices is calculated by determining the number of times the units need to be replaced within the simulated years. These units are comprised of the units that last the entire intended lifespan, and those that fails prematurely, which has a lifespan of only half a year. To determine the number of times the units need to be purchased in the years of simulation, the year of simulation is divided by the useful life of the units. It is then multiplied by the number of units, either it lasts the entire lifespan or fails prematurely, and lastly multiplied by the cost of a single unit. The total cost of AR units is then found by adding up the cost to purchase AR units and the cost to replace the AR units.
Figure 10: Average Annual Cost vs. AR Life in Medium Demand Setting

Figure 10 is a plot that shows the change in average annual cost when the useful life of AR devices is increased from one year to four years, assuming a medium level demand. The annual cost is averaged for different number of coaches as well as the different replications of the simulation. As can be seen from the plot, the slope of the average annual cost drops rapidly from a lifespan of one year to two years. After the lifespan of two years, the slope of the average annual cost gradually reduces as the lifespan increases. For analysis purposes, a lifespan of three years for the AR devices is chosen for the scenarios. It may be seen as a diminishing return as the lifespan of the AR devices increases because the rate of decrease for the average annual cost is decreasing.

After taking a macro view of how the useful lifespan of the AR devices affect the average annual cost, it is crucial to analyze at a closer look and see how the cost compare in the different scenarios. The cumulative distribution function (CDF) of the annual cost for the three different scenarios are plotted for comparison.
In Figure 11, the CDF of cost for hiring one coach to provide supported employment is compared between in-person, AR, and hybrid scenarios. In this case, the in-person support dominates the other two scenarios in cost. This means that the implementation of augmented reality can not be justified because the gain in efficiency is not enough to overcome the cost of vehicle travel for the in-person support. Hybrid support is dominated by both in-person support and AR support in this case. It’s cost also has more spread compared to the other two scenarios. One key point that needs to be kept in mind is that the Hybrid support has the same amount of AR devices as the AR support scenario. Which means that it will always cost more than both AR support and in-person support because it
is a combination of both types of support. In other words, hybrid support always carries the cost of additional AR units even if they are not used. This is a significant disadvantage for hybrid support when only the cost is being used for comparison.

**Figure 12: CDF of Annual Cost with Two Coaches and 3-Year AR Life**

Figure 12 shows similar results but with an additional coach hired. This changes the results since the additional coach is able to increase the available hours and provide more training coverage. In this plot, the 100% AR support began dominating the other two scenarios; there are still some overlapping with in-person support. Hybrid support remains to be the least effective approach when comparing under the cost metric. The domination of AR
support in this case shows that if supported employment with AR implementation is able to provide an adequate amount of coverage, which is enough to overcome the cost of vehicle travel for in-person support, it becomes effective.

Figure 13: CDF of Annual Cost with Three Coaches and 3-Year AR Life

In Figure 13 where three coaches are hired, the cost benefit of AR support has completely overtaken in-person support. Even the hybrid support has started overlapping with in-person support and may even be more efficient in some situations. However, the hybrid support scenario still remains with more variability as compared to the other two scenarios.
Overall, the results show that with increased number of coaches, the cost benefit of augmented reality support becomes more feasible and viable. Increasing the number of coaches also means increasing the coach availability, in other words, the training coverage. AR support needs to have enough coaches to conduct the training, otherwise its potential could not be unleashed.

**Trips, Mileage & Emissions of In-Person Support**

The implementation of augmented reality in supported employment training has some other benefits other than the cost and potential coverage increase. It is possible to reduce the risk for coaches and also take a part in protecting the environment with the elimination or reduced transportation after implementing augmented reality. The time that the supported employment coaches spend on traveling to the PWD’s employment site is reduced, which also reduces the potential risk of running into a car accident. This also saves time and cost because it may result in the vehicle being out of service for some period and the training coverage will not be maintained at the same level. The reduction of transportation and trips to the employment site also reduces the number of emissions.

In Figure 14, the number of trips and miles traveled varying the number of coaches is shown in three different scenarios in medium demand level. The complete AR implementation eliminates the transportation component of supported employment, hence the data for trips and miles traveled is zero. Looking at the hybrid support and in-person support, the implementation of AR support reduced the number of trips and miles traveled by the coaches.
Figure 14: Trips & Miles vs. Number of Coaches in Medium Demand Setting

The amount of emission in one year is shown for the different scenarios in Figure 15. The emission is directly related to the miles traveled for each scenario. It is calculated by multiplying the miles and the amount of tailpipe CO₂ emissions per mile, 404 g/miles, produced by a typical passenger car. The amount of emission reduction is significant even when AR is not implemented completely. The emission level is reduced by half or more in hybrid mode. For example, the number of emissions is reduced from a little over 30,000 kilograms to 15,000 kilograms with three coaches.
Figure 15: Emission vs Number of Coaches in Medium Demand Setting

The comparison between the different scenarios under the metrics of trips and emissions, AR support and hybrid support is clearly the winner. Although the number of emissions reduced is insignificant to the total amount of emissions produced by some other activities, it may still produce an impactful result if more achievement centers adopt the use of augmented reality to provide supported employment.

Multi-Objective Analysis

Previously, the term training coverage has been mentioned a few times, but what is it exactly and how does the implementation of augmented reality affect this metric. This is further analyzed to provide more detail comparison and see how training coverage and the annual cost relate. Does a higher training coverage means more money needs to be spent? Or is it possible that there is a middle ground where a high enough training coverage is achievable while keeping the cost low?
The cost and coverage varying the level of coach utilization is shown in Figure 16. The plot can be separated into two areas by the utilization ratio. The area under 1.0 utilization is undersaturated, whereas over the 1.0 utilization is the oversaturated area. The utilization increases with the demand and decreases with the number of coaches. When it is undersaturated, it means that there is not enough demand for the number of coaches. On the other hand, oversaturated means that the demand exceeds the availability provided by the number of coaches. From the plot, it is clear that the implementation of AR improves the training coverage as compared to in-person support. In high utilization conditions, in-person support is more cost effective. This may be due to the low number of coaches limiting the potential of AR support. In the scenario of AR support, cost increases as more AR devices are purchased. However, purchasing it does not guarantee that it will be used because it may be limited by the coach availability.

Figure 16: Cost & Coverage vs. Utilization Ratio
Overall, Figure 16 shows that augmented reality is most cost effective when approaching capacity. This means it is most beneficial when there are enough coaches to provide training, so that the AR devices are actually utilized, otherwise it is just a burden to the system.

Figure 18 is the multi-objective plot assuming a three year useful lifespan for the AR devices. It shows each scenario on the plot as a data point, with the y-axis being the training coverage and the x-axis being the average annual cost. The dashed line at 80% is the targeted training coverage. The data may seem to be a little scattered all over the place, however, it is actually an interesting plot when taking a closer look. A more detail for comparison within the same scenario can be found in the appendix section, this includes the cost and coverage vs number of coaches, or level of demand.

![Figure 17: Multi-Objective Plot](image-url)
All the datapoints have been colored to differentiate the three different scenarios and labeled with text stating the level of demand, followed by the number of coaches and the utilization ratio of the coach.

Figure 18 is the annotated version of the multi-objective plot. The utopia point, best results, happens on the upper left hand corner of the plot where training coverage is maximized and average annual cost is minimized. The datapoints are grouped into three main sections where the lower left is the case where one coach is hired, the middle section is two coaches hired and the upper right section is three coaches hired. Since medium level demand is the main focus, the datapoint for this level of demand is connected based on their scenarios, types of support.

Figure 18: Multi-Objective Plot Annotated
As can be seen from the annotated multi-objective plot in Figure 18, the complete adoption of AR support is able to offer a better coverage at a lower cost compared to the other two scenarios. Even with hybrid mode, although it is at a disadvantage when there is only one coach available, it shows potential to improve coverage at a lower cost compared to in-person support when there are enough coaches to provide an adequate amount of coverage to overcome the cost of AR acquisition.

![Figure 18: Multi-objective plot showing AR support with complete adoption offering better coverage at a lower cost](image)

*Figure 19: Comparing AR with 2 Coaches and In-Person with 3 Coaches*

After comparing the cost and coverage between the different types of supports, next task should be to analyze the differences in cost and coverage between different number of coaches across the scenarios. Figure 19 shows an enhanced view to compare AR support with two coaches and in-person support with three coaches. Glancing at the plot, the
coverage that is achieved by AR support with two coaches is slightly higher than in-person support with three coaches, however, the cost difference between the two is approximately $40,000. This gives AR support more advantage when looking at it from the point of coverage and cost. Hybrid support with two coaches provides less coverage than in-person support with three coaches, but it still cost approximately $30,000. When looking at hybrid support and in-person support both with three coaches, hybrid support is able to provide a higher coverage, above 80%, with only a slight cost increase.

Table 4 shows the raw data for the multi-objective plot. These data will be used to determine how much exactly does AR improve the coverage and what the cost differences are. The percent difference is calculated to show the comparison between the different scenarios.

<table>
<thead>
<tr>
<th>In-Person Cost</th>
<th>In-Person Coverage</th>
<th>AR Cost</th>
<th>AR coverage</th>
<th>Hybrid Cost</th>
<th>Hybrid Coverage</th>
<th>Scenario Description</th>
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<tr>
<td>$ 130,325</td>
<td>90%</td>
<td>$ 108,484</td>
<td>98%</td>
<td>$ 127,353</td>
<td>94%</td>
<td>L3: 0.55</td>
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<td>$ 135,035</td>
<td>71%</td>
<td>$ 115,084</td>
<td>96%</td>
<td>$ 139,229</td>
<td>86%</td>
<td>M3: 0.78</td>
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<td>93%</td>
<td>$ 95,285</td>
<td>81%</td>
<td>L2: 0.83</td>
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<td>85%</td>
<td>$ 147,465</td>
<td>70%</td>
<td>H3: 0.99</td>
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<td>$ 90,302</td>
<td>48%</td>
<td>$ 85,334</td>
<td>73%</td>
<td>$ 103,157</td>
<td>60%</td>
<td>M2: 1.17</td>
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<td>52%</td>
<td>$ 58,741</td>
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<td>$ 55,584</td>
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<td>$ 66,190</td>
<td>30%</td>
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<td>$ 62,014</td>
<td>29%</td>
<td>$ 73,499</td>
<td>23%</td>
<td>H1: 2.97</td>
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The improvement from in-person support with two coaches to AR support with two coaches is calculated assuming a medium demand.

\[
\text{Coverage Difference: } AR_{M2\text{Coverage}} - IP_{M2\text{Coverage}} = 73\% - 48\% = 25\%
\]

\[
\text{Percent Difference in Coverage: } \frac{\text{Coverage Difference}}{\text{Percent } IP_{M2\text{Coverage}}} = \frac{25\%}{48\%} = 52\%
\]
Changing from in-person support with two coaches to AR support with two coaches improves the coverage from 48% to 73%, that is a 52% improvement. Next, the cost for these two scenarios is compared to see if implementing augmented reality requires a significant investment.

\[ \text{Cost Benefit of AR: } AR_{M2\text{Cost}} - IP_{M2\text{Cost}} = 85,334 - 90,302 = -4,968 \]

\[ \text{Percent Difference in Cost: } \frac{-4,968}{90,302} \times 100 = -5.5\% \]

When looking at the cost between the two scenarios, implementing AR is able to reduce the cost by approximately $5,000 per year, that is a 5.5% reduction in cost per year.

Next, the case where the two different scenarios with different number of coaches will be compared for medium level demand. As mentioned previously, the coverage between in-person support with three coaches and AR support with two coaches is very similar. Here, a more detailed analysis between the two are shown to see exactly what the differences are.

\[ \text{Coverage Difference: } AR_{M2\text{Coverage}} - IP_{M3\text{Coverage}} = 73\% - 71\% = 2\% \]

\[ \text{Percent Difference in Coverage: } \frac{\text{Coverage Difference}}{\text{Percent IP}_{M2\text{Coverage}}} = \frac{2\%}{71\%} = 2.8\% \]

As can be seen from the calculations, the coverage difference between the two scenarios here is only 2%. AR support is able to provide a 2.8% increase in coverage while having one less coach compared to in-person support. So how much different is the cost between the two scenarios?

\[ \text{Cost Benefit of AR: } AR_{M2\text{Cost}} - IP_{M3\text{Cost}} = 85,334 - 135,035 = -49,701 \]

\[ \text{Percent Difference in Cost: } \frac{-49,701}{135,035} \times 100 = -36.8\% \]
Fully implementing AR with two coaches compared to in-person support with three coaches has the potential to reduce the operational cost by $49,701 per year. This is a 36.8% reduction in cost per year.

Although the complete implementation of AR has a lot of benefits, such as providing more training coverage and reducing the operational cost, it is not realistic to completely eliminate in-person support. Hence, hybrid support combining both AR technology and in-person support may be a more realistic approach. Next, the hybrid support and in-person support are compared with more details like what has been done previously.

In-person support and hybrid support with two coaches in medium demand level is first compared here in terms of coverage and cost.

\[
Coverage\ Difference: HY_{M2\ Coverage} - IP_{M2\ Coverage} = 60\% - 48\% = 12\%
\]

\[
Percent\ Difference\ in\ Coverage: \frac{Coverage\ Difference}{Percent\ IP_{M2}\ Coverage} = \frac{12\%}{48\%} = 25\%
\]

The difference in coverage is 12% after implementing a hybrid support. The percent difference between the two difference is a 25% increase in coverage. Next, the affect in operational cost is compared.

\[
Cost\ Benefit\ of\ Hybrid: HY_{M2\ Cost} - IP_{M2\ Cost} = $103,157 - $90,302 = $12,855
\]

\[
Percent\ Difference\ in\ Cost: \frac{12,855}{90,302} \times 100 = 14.2\%
\]

Although it has benefits to implement a hybrid support from a training coverage point of view, the operational cost is increased by 14.2% from $90,302 for in-person support with two coaches to $103,157 for hybrid support with two coaches. Keep in mind that the amount of AR devices purchased for hybrid support is identical to full AR implementation. This means that there may be some excess AR units not being used. The cost may be decreased if the amount of AR units can be optimized.
Next, the coverage and cost difference for in-person support with three coaches and hybrid support with two coaches is analyzed with medium level demand. From the multi-objective plot, the coverage of hybrid support with two coaches is less than the coverage of in-person support with three coaches. However, the cost for the hybrid support is less than that of the in-person support. Is this cost benefit worth the amount of training coverage it provides?

\[ \text{Coverage Difference: } HY_{M2 \text{Coverage}} - IP_{M3 \text{Coverage}} = 60\% - 71\% = -11\% \]

\[ \text{Percent Difference in Coverage: } \frac{\text{Coverage Difference}}{\text{Percent IP}_{M3 \text{Coverage}}} = \frac{-11\%}{71\%} = -15.5\% \]

The difference between hybrid support with two coaches and in-person support with three coaches is 11\%, it is a 15.5\% reduction in coverage from the three-coach in-person support.

\[ \text{Cost Benefit of Hybrid: } HY_{M2 \text{Cost}} - IP_{M3 \text{Cost}} = $103,157 - $135,035 = -$31,878 \]

\[ \text{Percent Difference in Cost: } \frac{-31,878}{135,035} \times 100 = -23.6\% \]

The difference in operational cost per year is $31,878. Implementing a hybrid support with two coaches can reduce the cost by 23.6\% per year compared to in-person support with three coaches. To determine if hybrid support is worth implementing, amount of dollars spent for one percent of coverage is calculated.

\[ \text{Two Coach Hybrid Coverage Cost: } \frac{$103,157}{60\%} = $1719 \]

\[ \text{Three - Coach In - Person Coverage Cost: } \frac{$135,053}{71\%} = $1902 \]

The cost per percent coverage for hybrid support with two coaches is $1719, whereas the cost per percent coverage for in-person support with three coaches is $1902. This shows that the hybrid support is actually cost beneficial since it cost less to provide the same amount of coverage.
Table 5 shows a summary of the results for changing the scenarios assuming a useful lifespan of 3 years for the AR devices. The scenario name is abbreviated by the support type, level of demand and the number of coaches. For example, the scenario with AR support, medium level demand and 2 coaches is abbreviated as (AR M 2C) as seen on the first row in the table. The percent differences are related to the change in scenario shown by the arrow in the scenario column.

### Table 5: Summary of Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Percent Cost Difference</th>
<th>Percent Coverage Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP M 2C → AR M 2C</td>
<td>-5.5%</td>
<td>52%</td>
</tr>
<tr>
<td>IP M 3C → AR M 2C</td>
<td>-36.8%</td>
<td>2.8%</td>
</tr>
<tr>
<td>IP M 2C → HY M 2C</td>
<td>14.2%</td>
<td>25%</td>
</tr>
<tr>
<td>IP M 3C → HY M 2C</td>
<td>-23.6%</td>
<td>-15.5%</td>
</tr>
</tbody>
</table>

Overall, the implementation of augmented reality has the potential of increasing the training coverage or efficiency as compared to hiring an additional coach. The cost difference is significant enough for social enterprises like Brevard Achievement Center, which provides services with limited funding.

### Influential Variables on Cost and Coverage

There are quite a few simulation variables or parameters that affects the annual operational cost and training coverage for the different supported employment scenarios. These include the number of coaches, AR device lifespan, and the number of AR devices.

The number of coaches directly influences the both the annual operational cost and the training coverage. Three different scenarios of one coach, two coaches, and three coaches were tested in the simulation and all the coaches have a fixed salary. The number of coaches significantly affects the training coverage depending on what level of demand it has to serve. When AR support is implemented with a limited number of coaches, the full potential of AR is not shown because PWDs could not receive the training due to coach
availability. This typically happens when there is only one coach and it is also the scenario where in-person support tends to outperform AR support in terms of cost.

As discussed previously, the AR device lifespan is an influential factor for the annual operational cost. Four different lifespans of one year, two years, three years, and four years were tested in the simulation and the results were plotted to see how much it affects the annual operational cost. The result shows that the cost decreases as the lifespan of the device increases. However, there is a diminishing return because the rate at which the annual cost decreases also decreases with the lifespan.

The number of AR devices is another factor that has a great impact on the annual cost of the supported employment with AR support and hybrid support. In the simulation model, the number of AR devices is limited and depends on the level of demand. Each AR device is assigned to a PWD, this means that if a PWD did not receive a device, the training would either has to be performed in-person or cancelled. The number of AR devices are the same for both full AR support and hybrid support. This gives the hybrid support a disadvantage because the AR device may be purchased but not used because the PWD may require in-person support. This has a significant impact on the annual operational cost for hybrid support because it needs to carry the cost of AR purchases without it being used to the full potential.

Profit Sensitivity & Break Even Analysis

Social enterprises or charity organizations that provide supported employment services typically are able to receive incentives from the government. However, these incentives are often times low in funding. It is crucial to investigate how these types of support breaks even in terms of cost and perform a sensitivity analysis on the billable rate for the coaches.

Figure 20 shows the sensitivity of the profit by varying the billable rate per hour of coaches for the scenario of medium demand with one coach. The range of the billable rate starts from twenty dollars an hour to fifty dollars an hour. The average annual profit is calculated by multiplying the billable rate and the annual billable hours. Billable hours are defined as the actual training time provided to the PWDs. This excludes time for travel, inefficiencies,
etc. In this case, AR support breaks even the quickest, followed by in-person and hybrid support. It is important to note that the hybrid support is at a disadvantage and this may be caused by the cost of AR purchases lowering the cost effectiveness of the system.

Figure 20: Profit Sensitivity and Break Even for One Coach in Medium Demand
Figure 21: Profit Sensitivity and Break Even for Two Coach in Medium Demand

Figure 22: Profit Sensitivity and Break Even for Three Coach in Medium Demand
Figure 21 and Figure 22 each shows the profit sensitivity for two coaches and three coaches in medium level demand. It is clear that with the increasing number of coaches, the potential of the AR implementation begins to show. Both AR support and hybrid support begins to break even at a lower billable rate as compared to in-person support. This is because the implementation of AR technology allows the trainings to be more efficient and allows the coaches to spend more time on training instead of traveling to the employment sites, which could take up a significant amount of time.
Chapter 7
Conclusions & Future Work

Supported employment is crucial for persons with disabilities because it significantly affects their employment outcomes. Social enterprises or charities such as Brevard Achievement Center provide supported employment services but it is costly and the funding from the government is limited. Hence, the provided service must be sustainable in order for such organizations to continuously serve their communities. Augmented reality is a technology that has many potentials and may still require people to discover its benefits. It may help to improve the cost-effectiveness of low funding programs such as supported employment and potentially increase the training coverage.

The SysML model of supported employment helped capture the systems specification and behaviors of the three different scenarios including in-person support, AR support, and hybrid support. The simulation model developed in Python is then used to analyze the operational performance of each scenario including important metrics such as training coverage, annual operational cost, etc. The results of a five-year simulation for each different scenario changing parameters such as the levels of demand, number of coaches, and the lifespan of the AR devices, is then consolidated and plotted to visualize the differences. The changes in the cost and coverage varying the levels of demand and number of coaches are also calculated and presented.

This thesis confirms that augmented reality technologies have the potential to benefit supported employment if a three-year lifespan for the AR devices is achievable. The implementation of such technology in this field has already been widely tested and has proven to be effective. The simulation results showed that AR has the potential to increase coverage when conditions such as the number of coaches are remained the same. Also, it is more cost-effective to implement AR in supported employment to achieve a similar coverage or increase training efficiency instead of hiring an additional supported employment coach. This is significant for social enterprises that provide supported
employment services with a limited funding. Overall results indicate that the implementation of AR is most effective when the system is approaching its service capacity, whereas in-person is more effective when the demand significantly exceeds the service capacity. Though, this is due to the fact that there are not enough coaches to provide the adequate number of services, leaving many of the purchased AR devices unused. This may be further researched to determine the optimum number of AR devices for each scenario. The AR implementation has many benefits; however, it is not realistic to fully implement AR in supported employment, meaning it could not one hundred percent replace human interaction in this field. There are several reasons such as new PWDs with less experience will need to be trained in-person, some PWDs may not be able to use the AR devices depending on their personal conditions. Prescription glasses and user acceptance of the AR devices are also factors of interest that may hinder the proposed system. Hence, there needs to be a hybrid mode where both in-person support and AR support are simultaneously implemented. This allows the system to be more flexible and tend to the less experience PWDs or PWDs with conditions that prohibits them from using AR devices with in-person support. On the other hand, AR support can be used for the more experienced PWDs while also saving some in cost for the organization that provides the supported employment service.

The results are summarized in bullets listed below:

- AR technologies have the potential to benefit supported employment if a three year lifespan is achievable for the AR devices
- 100% full implementation of AR is unrealistic due to factors such as disability conditions and user acceptance, hybrid mode is more favorable
- Hybrid mode is able to reduce half of the emissions produced by in-person support
- AR is most effective when approaching service capacity, whereas in-person is more effective when demand significantly exceeds the service capacity
- AR solution is capable of enhancing training efficiency as compared to hiring additional coaches
There are several possible improvements that can be done for the simulation model presented in this thesis. Since the simulation model assumes a first come first serve scenario, it did not take into account of optimizing the travel routing for the coaches when transporting to the employment site. In future studies, this may be optimized similar to a traveling salesman problem. Another improvement that can be done to the simulation model is to simulate backlogged request. This may further affect the results of the simulation because the coaches would then be able to service the “lost” demands once they have more availability. Apart from improvements on the simulation model, the implementation of AR needs to be field tested in a small batch by Brevard Achievement Center so that the simulation results can be validated.

The future work that can be done are summarized below:

- Enhance simulation model by optimizing travel routes of the coaches
- Enhance simulation model by adding backlogging feature for requested demands
- Field test supported employment with the implementation of AR devices in a small batch
References


Appendix

Coverage & Cost vs. Number of Coaches

Low Level Demand

Demand Level: L; AR Life: 1 Year

Demand Level: L; AR Life: 2 Year
Medium Level Demand

Demand Level: M; AR Life: 1 Year
M*A1

Demand Level: M; AR Life: 2 Year
M*A2
High Level Demand

Demand Level: H; AR Life: 1 Year
H*A1

Demand Level: H; AR Life: 2 Year
H*A2
Coverage & Cost vs. Level of Demand

One Coach Scenario

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**Number of Coaches: 1; AR Life: 1 Year**

*1A1*

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**Number of Coaches: 1; AR Life: 2 Year**

*1A2*
Two Coach Scenario

Number of Coaches: 2; AR Life: 1 Year

Number of Coaches: 2; AR Life: 2 Year
Three Coach Scenario

Number of Coaches: 3; AR Life: 1 Year

Number of Coaches: 3; AR Life: 2 Year
Annual Cost vs. AR Life