College of Engineering and Applied Sciences

WESTERN MICHIGAN UNIVERSITY

Connectivity Between Battle Creek Transit and Battle Creek Veterans Affair's Medical Center using Autonomous Shuttles

Report by

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Abstract

Autonomous vehicles have the potential to increase mobility for individuals that don't have access to public/private transportation. This technology allows these individuals to traverse to different destinations without the need for human/machine interaction between the passenger and the vehicle. VAMC Battle Creek possesses an ICE shuttle that picks up and drops off employees and guests within their campus for them to be transported. Nevertheless, this gas shuttle has limited operating hours and doesn't provide connectivity with the Battle Creek Transit after 4:00 pm. Therefore, to increase transportation and hours of operation these individuals, an electric autonomous shuttle was proposed for this project. This electric autonomous shuttle will operate 12 hours for it to be available for incoming employees and guests that use the Battle Creek Transit bus, and people that live on campus. The 12-passenger autonomous shuttle proposed for this project is capable of accommodating wheelchair users and people wanting to traverse within the campus or making a connection to the Battle Creek Transit bus. The integration of autonomous shuttles to VAMC Battle Creek has positive social and environmental effects. This technology will increase the connectivity to the hospital and access to the hospital's campus. Furthermore, the increased hours of operation of the autonomous shuttle will encourage more disabled veterans to schedule appointments with the VA hospital and will also encourage the employees to take public transportation instead of driving their vehicle. The autonomous shuttle will operate on-demand and will possess a ride-hailing system capable of scheduling trips. A brief cost analysis was performed to contrast the potential benefits of switching the current service to an electric autonomous shuttle. Also, an energy consumption analysis was performed using Autonomie and MATLAB, to compare the energy drawn from both shuttles (ICE and electric shuttle). Results indicate that the autonomous electric shuttle is cost-effective and provides more overall benefits to the community and the aforementioned institutions.

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Project Purpose and Direction

Battle Creek Transit and our team at Western Michigan University (WMU) are attempting to show the connectivity between their public transportation system with sustainable autonomous mobility at the Veteran's Affair Medical Center (VAMC) Battle Creek. The purpose of the project is to demonstrate that Battle Creek is moving forward toward electrification and autonomous technology. The design and video of this project will help with future proposals, grants, and other funding opportunities to bring their city into the future using fully electric autonomous shuttles. There are other benefits to come from this project as in, relationships with the local Universities for future research, possible network connection with other mobility commercial businesses that want to work with Battle Creek Transit and/or WMU.

Figure 1: Olli Autonomous Shuttle used for the simulation.

Our team at Western Michigan University has been working with Autonomous mobility for the last year, 2019, receiving a grant from Michigan Department of Transportation (MDOT) for the Michigan Mobility Challenge along with other businesses like Pratt and Miller who was the lead for that project with WMU's assistance. The team was able to build, and test pilot a wheelchair-accessible shuttle around WMU for a pilot program to see how people with and without disabilities thought of having an autonomous shuttle on campus. The pilot program was a success and the public was excited to have it around campus. The Energy Efficient Autonomous Vehicle Lab, (EEAV) Lab, WMU team was awarded another Planet M Michigan mobility challenge for 2020. We must develop an Autonomous shuttle from the airport to downtown Detroit [1, 2].

This UIDC project will consist of informing, educating the public, and the government, that sustainable autonomous mobility is the way of the future. The autonomous shuttle used for the simulation and report can be seen in figure 1. This project will reveal that the attendance to the VAMC in Battle Creek increases over time with the use of autonomous shuttle being implemented as well as decrease the number of vehicles that need to be driven to the VAMC Battle Creek. The fluid connection between Battle Creek Transit and VAMC Battle Creek is the main goal of the simulation which will be used as needed for Battle Creek transit purposes. We are hoping to continue our relationship with Battle Creek Transit to help each other exceed toward electrified autonomous mobility.

Motivation

There are multiple reasons that give us motivation for this project. The most important reason is to show that Battle Creek Transit has complete connectivity to VAMC Battle Creek which can be seen in figure 2. The simulation focuses on the entrance of the hospital to show the connection between the Battle Creek Transit and the VAMC Battle Creek. This will help with commuting to and from the hospital regardless of employment at the facility. The AV shuttles will help decrease the need to drive to the facility given the drastic weather conditions the hospital faces due to the region it is in. The employees or visitors can take the local bus transit to the hospital and then use the on-demand AV shuttles on the facility well after the hours of operation. The main bonus of this project is to help disabled veterans get to and around the hospital.

4D Model

Figure 2: BCT Bus route connectivity

Figure 3: Multiple Shuttle stops for visitors and employee's

Figure 4: Autonomous shuttle storage and recharging station.

Effects on the Built Environment

There would be little effects on the built environment since there is already an established route and benched station to wait for the autonomous shuttle which can be seen in figure 3. They currently have an internal combustion engine shuttle that uses the route and has storage for the shuttle as well. The AV shuttles will use the same route and the same storage. The only change would be the implementation of the charging stations for the shuttles. This would be placed inside the garages for each shuttle as seen in figure 4.

The batteries will be large enough to support one day of driving with the charge it will receive overnight in the garage. The charging time overnight can be reduced if there is a wireless charging station at fixed points along the route. This would increase the cost of the charging station yet decrease the size of the battery. There would be infrastructure costs for implementing multiple wireless charging stations. There would be construction at first which would limit the route that can be driven either by an internal combustion engine (ICE) or the AV shuttles.

A typical 2kWh charger will be enough for charging the batteries for less than 12 hours to receive a full charge. Having the smaller charging system, the hospital can use the already in place electrical system to charge their shuttles without having to upgrade the wiring and fuses to handle the increased output of the charger.

Effects on Social and Environmental Sustainability

Social Sustainability

There are positive effects on social and environmental sustainability concerning this project. This project will increase the connectivity to the hospital and increase access to the hospital's campus. The large campus takes time to get around and can be very confusing to anyone not familiar to the area. Figure 5 shows the current hospital ICE shuttle that is on-demand with a phone call to the transportation services on site. The times of service are only Monday through Friday from 7:30 a.m. to 4:00 p.m. which is less than the operational hours of the Battle Creek Transit.

Figure 5: Internal Combustion Engine (ICE) transportation shuttle.

The Battle Creek Transit bus operates Monday through Saturday. During the week, the times are from 5:15 a.m. to 5:15 p.m. and on Saturday times are from 9:15 a.m. to 4:15 p.m... There is a time difference of 3 hours a day during the week between Battle Creek's operational

hours and the hospital hours for their ICE shuttle. The Autonomous shuttle can operate during the same time as the BCT bus route which will increase the time people can use the shuttle service. Having the increased hours of operation of the AV shuttle will encourage more disabled veterans to schedule appointments with the VA hospital and will also encourage the employees to take public transportation instead of driving their vehicle. The AV shuttle would have an on-demand feature where anyone can hail the ride-sharing shuttle to take them to a location of their choice [3].

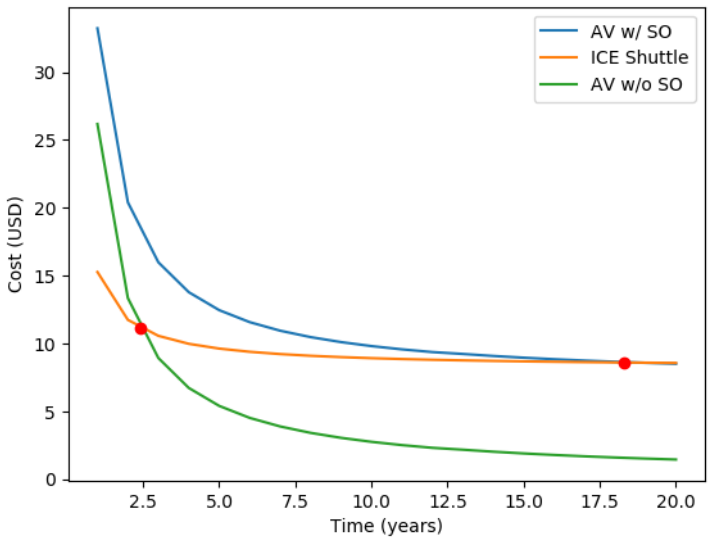

Figure 6: Cost per-mile for the ICE shuttle and the AV shuttle with and without a service operator.

Our team at Western has done a cost analysis from the 2019 Michigan mobility challenge which can be seen in figure 6. The figure shows that there is a high initial cost from the shuttle compared to an ICE shuttle, and it also shows that the cost of having a safety driver. The safety driver would be there to make sure the initial pilot goes well and can slowly decreasing safety operators over time. The safety drivers will stop after a few weeks depending on the requirement or implementation of the autonomous shuttles [4].

Environmental Sustainability

The implementation of the autonomous shuttle will decrease the amount of emission pollution contributed by the veteran's transportation service, employees, and veterans going to and around campus. With the increase in connectivity, the hospital using the AV shuttle decreases the need to take private transportation to and from the hospital. People that work or visit the hospital can take advantage of the AV shuttle to increase mobility around campus. Employees can ride share more due to the connectivity of BCT buses and carpooling with other fellow workers.

Energy Analysis

The energy analysis was done using Autonomie simulation software in conjunction with MatLab. There are some assumptions that are being made to begin the calculations for each

vehicle. We assumed the same route for each vehicle along with a continuous operation for the total hours purposed. The time assumption for the current ICE shuttle is 9 hours. The operation time for the AV shuttle will be 12 hours since that is how long the BCT route operates its buses. The AV shuttle will have a larger battery capacity of 16kWh and have a 2kWh charger stated before. The charging time should on take a maximum of 8 hours [5].

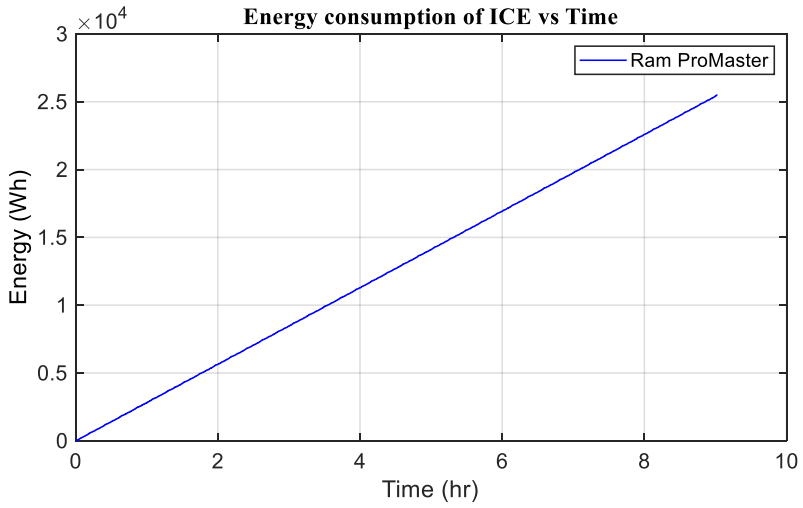

Figure 7: Energy consumption of ICE shuttle for drive cycles around the VAMC Battle Creek Route.

We made sure to use the same specification for the current ICE Shuttle that the Hospital currently uses to make sure our analysis is as accurate as possible. When analyzing the data from Autonomie, the energy consumption was the most import information relevant to this project. Driving a consistent route all day for their operating hours the energy consumed each day is approximately 26.3 kWh. Figure 7 illustrates the energy consumption of the ICE shuttle throughout the day. Figure 8 shows the power distribution, it also shows the efficiency and the losses in each component. There is more moving part in an ICE shuttle which makes the efficiency at 36% total output from the ICE.

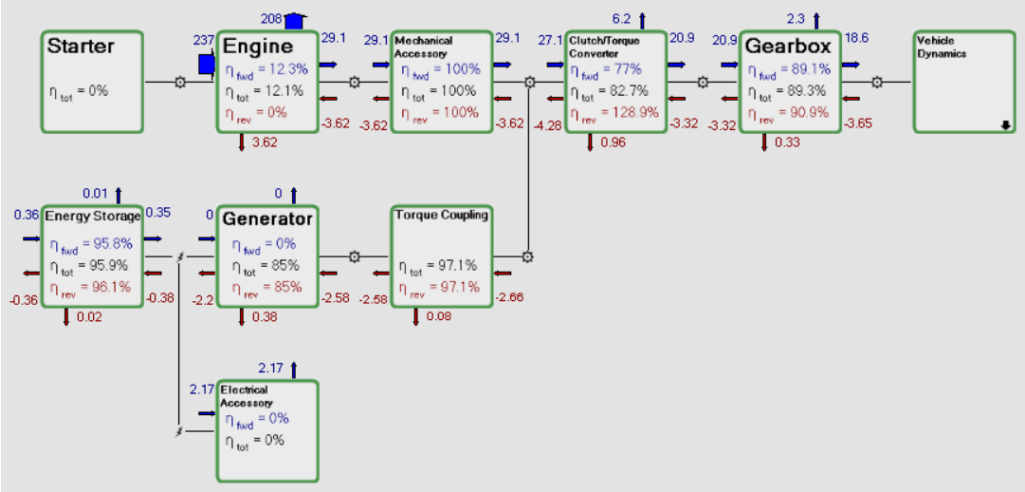

Figure 8: Energy distribution in current ICE shuttle

Analyzing the energy consumption of the battery electric autonomous shuttle we can see from the graph in figure 9 That the total energy consumed for 12 hours are approximately 13.3 kWh. The power distribution for the BEV autonomous shuttle has far less components and has a high efficiency of 95% since electric motor is more efficient that conventional ICE as seen in figure 10. The efficiency is assumed in the program for the ICE and EV motor.

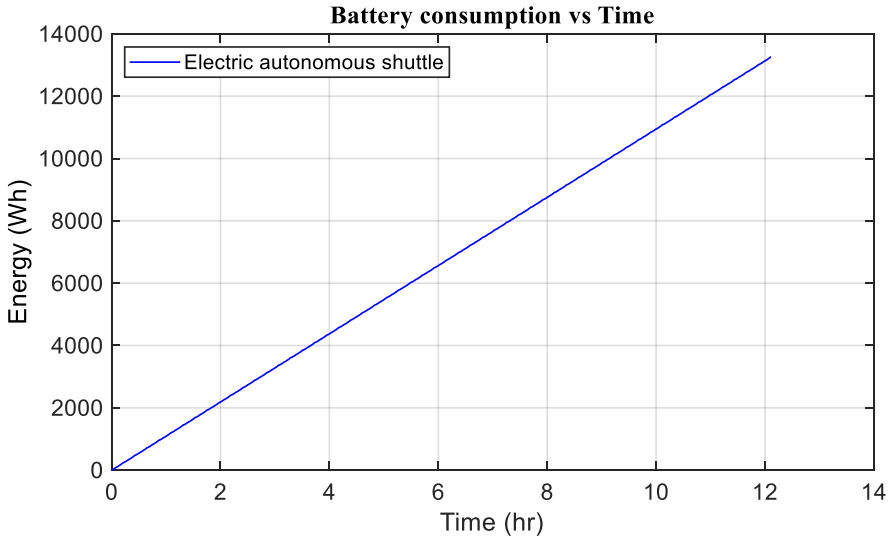

Figure 9: Energy consumption of the BEV autonomous shuttle for drive cycles around the VAMC Battle Creek Route.

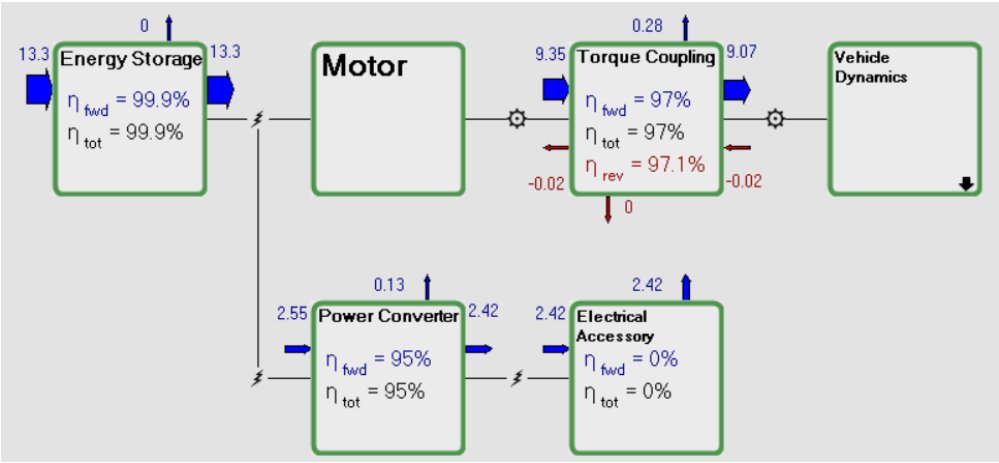

Figure 10: Energy distribution for BEV autonomous shuttle.

Conclusion

The team at WMU have met with our sponsor Battle Creek Transit several times to make sure we cover their needs for this project. The simulation is a good visualization tool for them to use for future proposals. The simulation illustrates the connectivity with the hospital using the Ollie electric autonomous shuttle. The increased hours of operation by switching from the conventional ICE to the BEV autonomous shuttle helps increase connectivity with BCT and VAMC Battle Creek. There is a 3 hour increase everyday Monday through Friday as well as adding a whole day by adding Saturday's operation for another 7 hours. There is an increase of 22 hours of connectivity to the hospital a week.

The increase in hours of connectivity will encourage more veterans to schedule appointment or get certified for service-related disabilities and medical assistance. This increase of hours will also encourage employee's that live in Battle Creek to commute using BCT public transportation or carpool. Having the shuttle operate during their new times employees can take the AV shuttle around the campus since there are severe weather condition in Michigan. The increased mobility to, from, and around the hospital, will decrease the need for added vehicles around which will help decrease the emissions.

The implementation of the AV shuttle will be quite easy due to the infrastructure currently in place. There are plenty of bus stops around campus as well as plenty of storage. Since the 2 kWh battery charger does not take any extra improvement to the current electrical system, the installation of the charger will be easy. The initial cost of the AV shuttles and charges will be higher than the current shuttle yet over time the cost of the AV shuttle will be less to maintain than the ICE shuttle. There are some concerns about the silence from the AV shuttle because pedestrians are worried about collisions. There are sensors on the autonomous shuttle for safety measures built in to make sure that there is not an object in its path.

The energy analysis that compares the ICE and BEV shuttle shows the saving of energy the AV shuttle saves the hospital which also correlates with the cost savings over time by using electricity from a power plant rather than using gasoline ICE. The ICE shuttle consumed 26.3 kWh whereas, the BEV shuttle Consumed 13.3 kWh, this is a savings of 13 kWh every day. The energy consumption is half the amount of energy used by a conventional IC engine. Two AV shuttle could run at the hospital and consume as much as the ICE current shuttle. This savings in energy and the related emission that come along with the reduction in conventional IC engines is a very good incentive to save money and the environment.

References

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[3] Wen, B., Gelbal, S., Guvenc, B., and Guvenc, L., "Localization and Perception for Control and Decision-Making of a Low-Speed Autonomous Shuttle in a Campus Pilot Deployment," *SAE Intl. J CAV* 1(2):53-66, 2018, https://doi.org/10.4271/12-01-02-0003.

[4] Electric Vehicle Benefits and Considerations. (n.d.). Retrieved from https://afdc.energy.gov/fuels/electricity_benefits.html

[5] Gao, Z., Lin, Z., Laclair, T. J., Liu, C., Li, J.-M., Birky, A. K., & Ward, J. (2017). Battery capacity and recharging needs for electric buses in city transit service. *Energy*, *122*, 588–600. doi: 10.1016/j.energy.2017.01.101

Appendix

Appendix A: Battle Creek Transit Bus Schedule

MONDAY THROUGH FRIDAY

	DEPART TRANSP. CENTER	DICKMAN & HILL BRADY (OB)	DEPART VA HOSPITAL (IB)	HILL BRADY & II STANLEY (IB)	DICKMAN & HILL BRADY (IB)	LIBERTY COMMONS (IB)	ARRIVE TRANSP. CENTER
	5:15	5:25	5:35	5:45	5:55	6:05	6:10
†	5:45	EXPRESS	EXPRESS	EXPRESS	EXPRESS	6:35	6:40
	6:15	6:25	6:35	6:45	6:55	7:05	7:10
	6:45	6:55	7:05	7:15	7:15	7:35	7:40
	7:15	7:25	7:35	7:45	7:55	8:05	8:10
	7:45	7:55	8:05	8:15	8:25	8:35	8:40
	8:15	8:25	8:35	8:45	8:55	9:05	9:10
	9:15	9:25	9:35	9:45	9:55	10:05	10;10
	10:15	10:25	10:35	10:45	10:55	11:05	11:10
	11:15	11:25	11:35	11:45	11:55	12:05	12:10
	12:15	12:25	12:35	12:45	12:55	1:05	1:10
	1:15	1:25	1:35	1:45	1:55	2:05	2:10
	2:15	2:25	2:35	2:45	2:55	3:05	3:10
	2:45	2:55	3:05	3:15	3:25	3:35	3:40
	3:15	3:25	3:35	3:45	3:55	4:05	4:10
	3:45	3:55	4:05	4:15	4:25	4:35	4:40
	4:15	4:25	4:35	4:45	4:55	5:05	5:10
	5:15	5:25	5:35	5:45	5:55	6:05	6:10

SATURDAY

DEPART TRANSP. CENTER	DICKMAN & HILL BRADY (OB)	DEPART VA HOSPITAL (IB)	HILL BRADY & II STANLEY (IB)	DICKMAN & HILL BRADY (IB)	LIBERTY COMMONS (IB)	ARRIVE TRANSP. CENTER
9:15	9:25	9:35	9:45	9:55	10:05	10;10
10:15	10:25	10:35	10:45	10:55	11:05	11:10
11:15	11:25	11:35	11:45	11:55	12:05	12:10
1:15	1:25	1:35	1:45	1:55	2:05	2:10
2:15	2:25	2:35	2:45	2:55	3:05	3:10
3:15	3:25	3:35	3:45	3:55	4:05	4:10
4:15	4:25	4:35	4:45	4:55	5:05	5:10

OB--OUTBOUND IB--INBOUND

Appendix B: Map of BCT Bus Route