MDOT
Michigan Department of Transportation

BEDESTRIAN

Autonomous Delivery in Urban and Campus Environments for Michigan

Pilot Sponsored by Michigan Department of Transportation

Overview

At the time of the MDOT grant, Bedestrian was an early stage startup building an ambitious product. Specifically, Bedestrian is building autonomous robotic technology and integrating with the vehicle hardware for a fully integrated, end-to-end solution.

Our thesis was and remains that autonomous technology can augment service to underserved communities. The MDOT grant enabled significant progress in developing our solutions and acted as an accelerant for what is a very ambitious vision.

We are continuing work on the pilot that will have

our vehicles traveling outdoors - on sidewalk –

in service of underserved communities.

Overview

We coordinated with the UofM Ross School of Business which is key stakeholder on one end of our delivery pilot. Specifically, we met with the university faculties management and food services representatives that runs the Ross school's food program to discuss excess food donations to local food pantries. The local food pantries serve senior communities and other underserved areas. We focused on the pain points and identified a circuit of "pick ups" from adjacent buildings on campus with food service.

We specifically walked the grounds of the business school to understand what the potential planned path for our bots would look like. Captured some measurements. And had in-depth discussions regarding materials for interior and exterior of B2 modular trailer. We worked to schedule a follow-on session with our thermal supplier and the UofM food service staff to further define be requirements.

Executive Summary

Bedestrian has made advanced progress on the technical side, and we have successfully implemented full teleoperation and short-term path planning, we conducted multiple tests to verify constant speed at different elevations (ascending a hill and descending); resulting in full Hardware implementation and testing readiness. We also implemented the human Machine Interface aspect with full testing of Voice commands for pedestrian warning navigation. We implemented an insulation compartment for temperature-controlled food delivery.

A key learning from the MDOT program is that the work MDOT did in advance of selection - to pair municipalities and startups for joint application - was critically important. While we are certainly grateful for the opportunity to have been selected and believe we have significantly advanced the cause of mobility technology development in Michigan, we have faced time-consuming challenges relative to stakeholder engagement and alignment.

Executive Summary

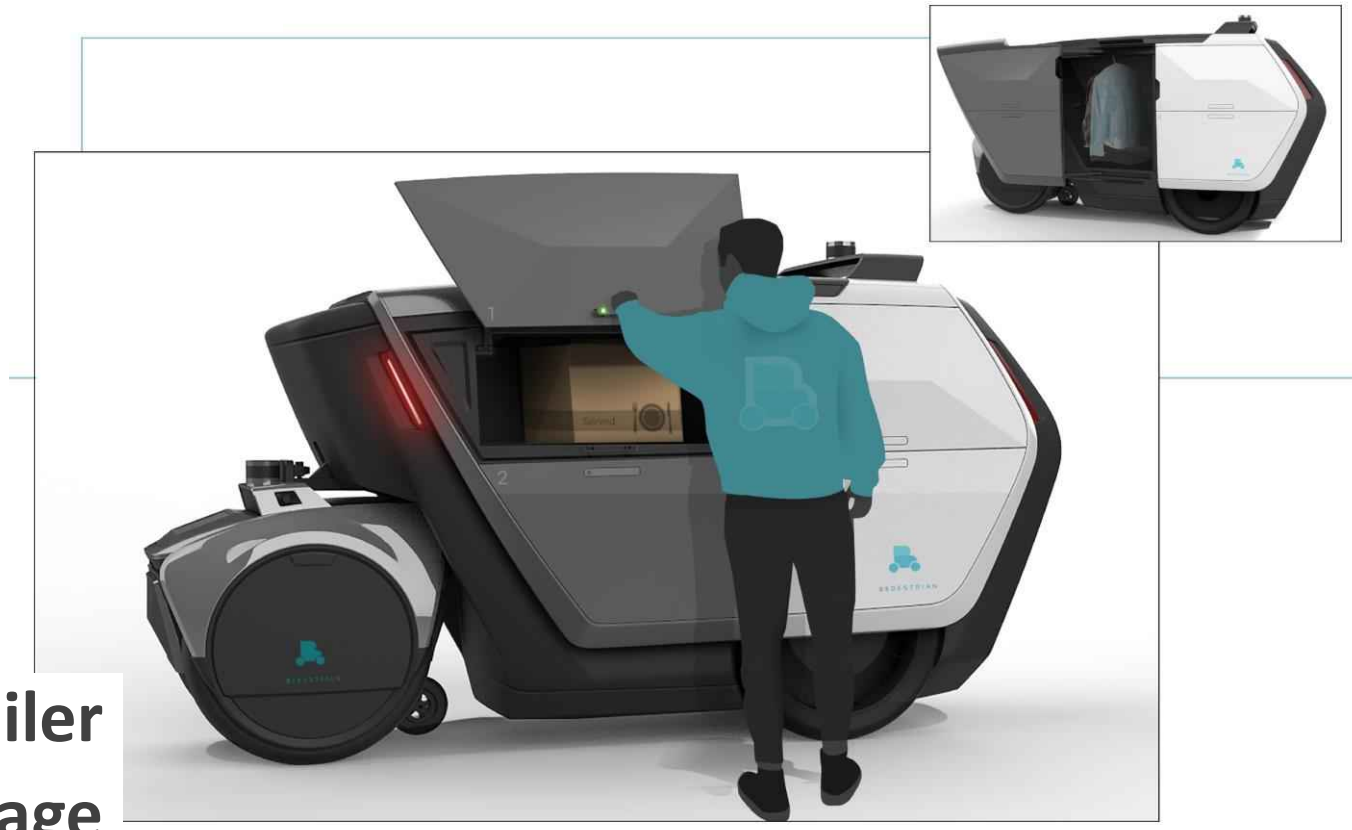
While cities across Michigan have been very welcoming and open to collaboration, their processes for decision-making and approval did not always align well to the timing and pace of a small startup. That said, we did eventually land a partnership that appears on track to be allow for successful deployment with the City of Ann Arbor.

Coordinating with municipalities, as well as, business to align a pilot has proven difficult for the first 3 cities we approached, however, we have found a path forward with Ann Arbor city in aligning a pilot with the cooperation from the university of Michigan for a pilot that address the needs of an underserved population. We reached final stages of organizing the pilot with the coordination of the city of Ann Arbor Mobility representative and University of Michigan School of business.

Autonomous Delivery Solution

Bedestrian develops and supplies a system of autonomous delivery robots

B1 Autonomous Robot
Scalable | Robust | Chatty



B2 trailer

Low cost | Modular storage

Project Tasks

Tasks accomplished highlights:

- Final Assembly
- Set a plan with Team for dedicated lanes and stations for preplanned path
- Run a manual navigation test for the pre-planned route using Cameras and LIDAR
- Engaged numerous stakeholders from City of Ann Arbor, U of M Ross School of Business and discussions with numerous community groups that provided services to underserve populations (i.e. food and shelter).
- Run a Teleoperated road test with B1 on preplanned path
- Modify Simulation and add all modifications
- Run an autonomous enclosed road test with B1

Executed Work Plan

- Complete Build/Modifications to B1 vehicle for road worthy pilot
- Suspension testing and update to match road quality
- Environmental test readiness
- Build/Modify B2 trailer for Road worth pilot
- Build/Modify B2 trailer to integrate Ross Cafeteria refrigeration and food insulation pods

*The bulk of the costs for Bedestrian are the capital costs associated with the hardware-software integration of the B1 lead vehicle and B2 trailer:

Executed Work Plan

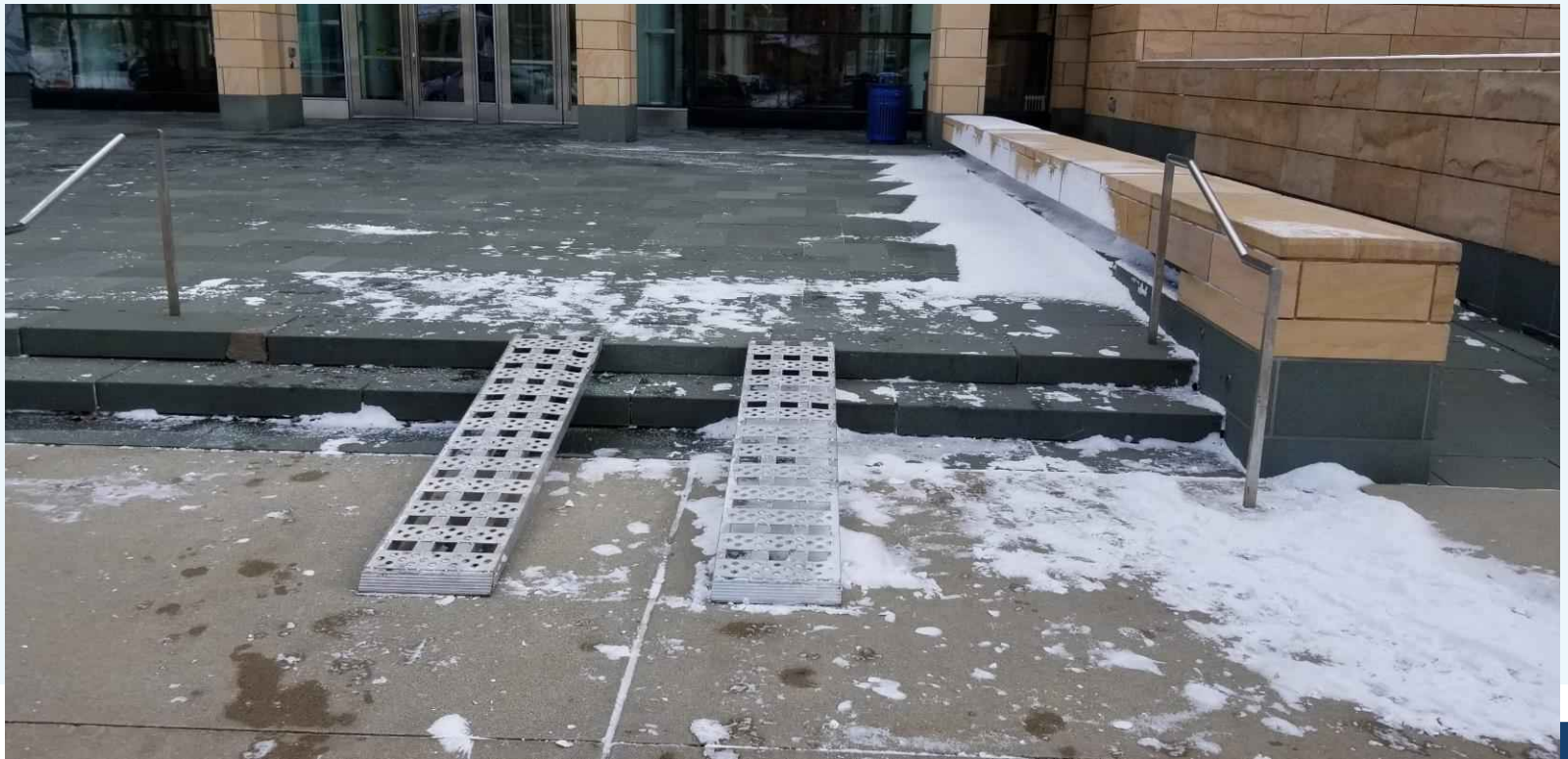
- Planning Process with stakeholders
- Demonstrate (for City) B1 and B2 system and an indoor demo
- Map pilot planned route: Navigation, High Definition image mapping
- Map entry ramps and exits
- Modify B1 and B2 per charging points infrastructure (if we use existing infrastructure)
- Set a plan with facilities and campus planner for dedicated lanes and stations for preplanned path
- Run a manual navigation test for the pre-planned route using Cameras and LIDAR
- Survey and meet stake holders for preplanned path deliveries
- Dry run for Preplanned deliveries with operating staff

Pilot Site Findings

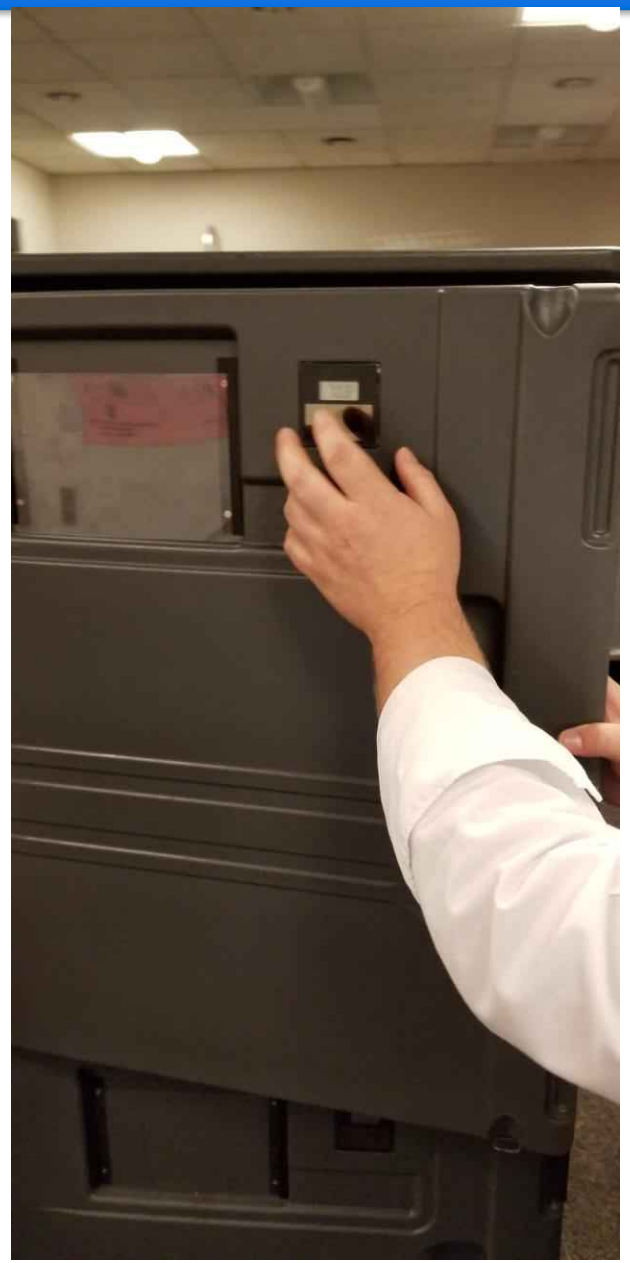
- Discovered current manual food transfer processes.
- Identified all Health Department requirements for safe transfer of foods
- Learned key pain points preventing more food donation and improved sustainability

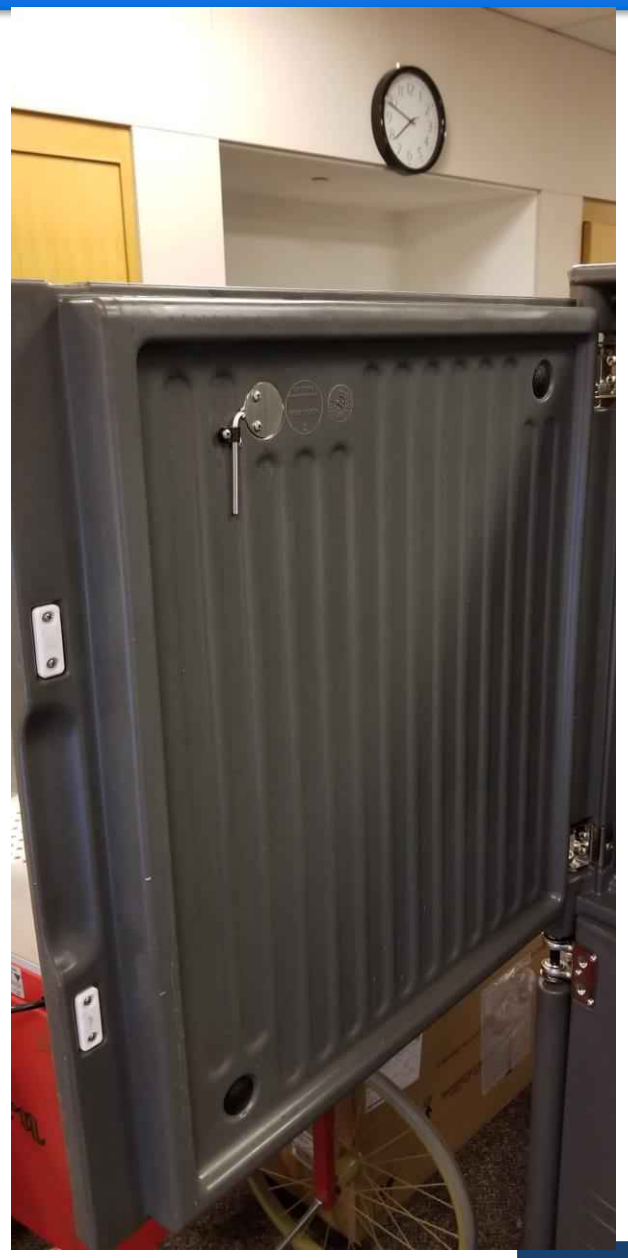
Pilot Site Challenges

- Identified all current processes for loading and unloading food into university building.
- Identified key metrics associated with current delivery of goods.
- Defined planned path for autonomous bot navigation and initial proposed metrics for improving efficiency and safety.



Pilot Site Requirements Study





Build Details Modifications

- Design a new lidar bezel that repositions the lidar so it will view lower toward the front of the BOT and views higher towards the rear of the BOT. surface paint
- Complete all electrical and electronic revisions and upgrades to B1 BOT
- Fabricate the lower drawer to open from both front and rear sides of the BOT
- Remove lower drawer limit switches and gear drive system so drawer operates manually
- Fabricate individual manual release cable mechanisms for the top bin and

Build Modifications

- Fabricate and install attachment to Refrigeration Pods
- Fabricate individual manual release cable mechanisms for the top bin and
- the lower sliding bins.
- Fabricate and cut out the existing bottom floor of top bin. fabricate and install
- a drop-in stainless-steel liner for the top bin area:
- Fabricate and install top bin door hinge limiter and shock/strut damper
- Final Assembly

Final Pilot Steps

- Run a manual navigation test for the pre-planned route using Cameras and LIDAR
- Survey and meet stake holders and customers for preplanned path deliveries (UOM management staff meeting and approval on Assembly space)
- Generate report and plan for preplanned route and stake holder's participation roles
- Run a Teleoperated road test with B1 on preplanned path
- Modify Simulation
- Run an autonomous road test with B1

Pilot Build Modifications

Pilot Build Modifications

Insulated tray compartment for food delivery

Pilot Build Modifications

Insulated Refrigeration Pods

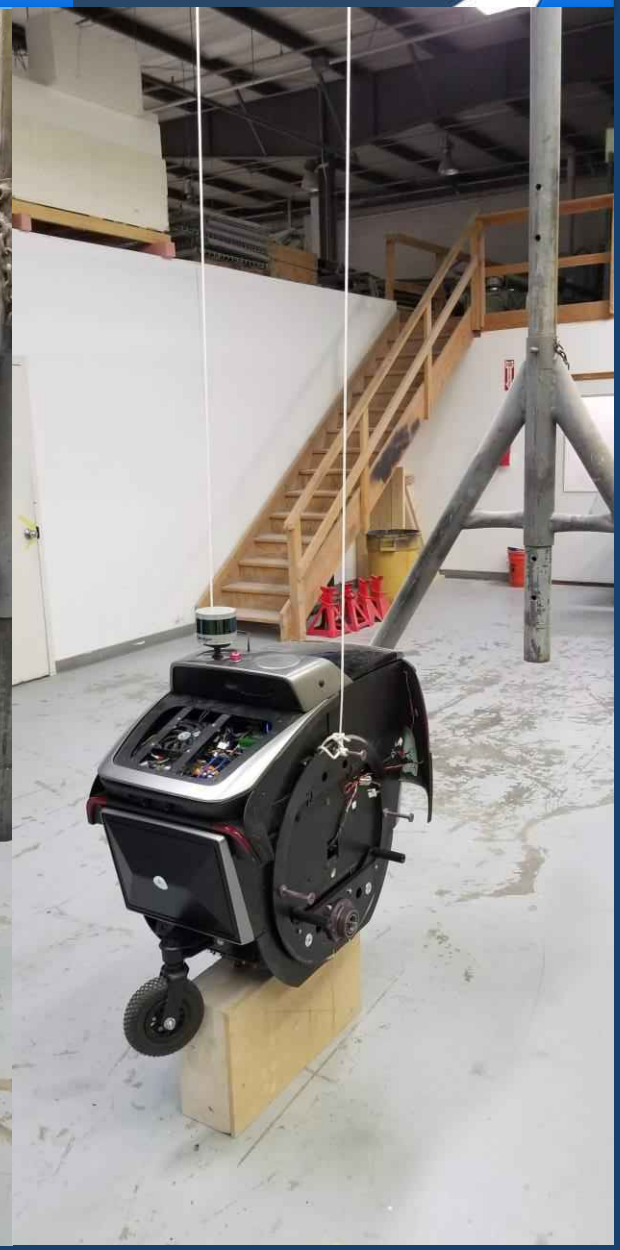
Pilot Build Modifications

New attachment mechanisms for Pods

Pilot Build Modifications

Testing Validation

Balance and mass testing for odometry

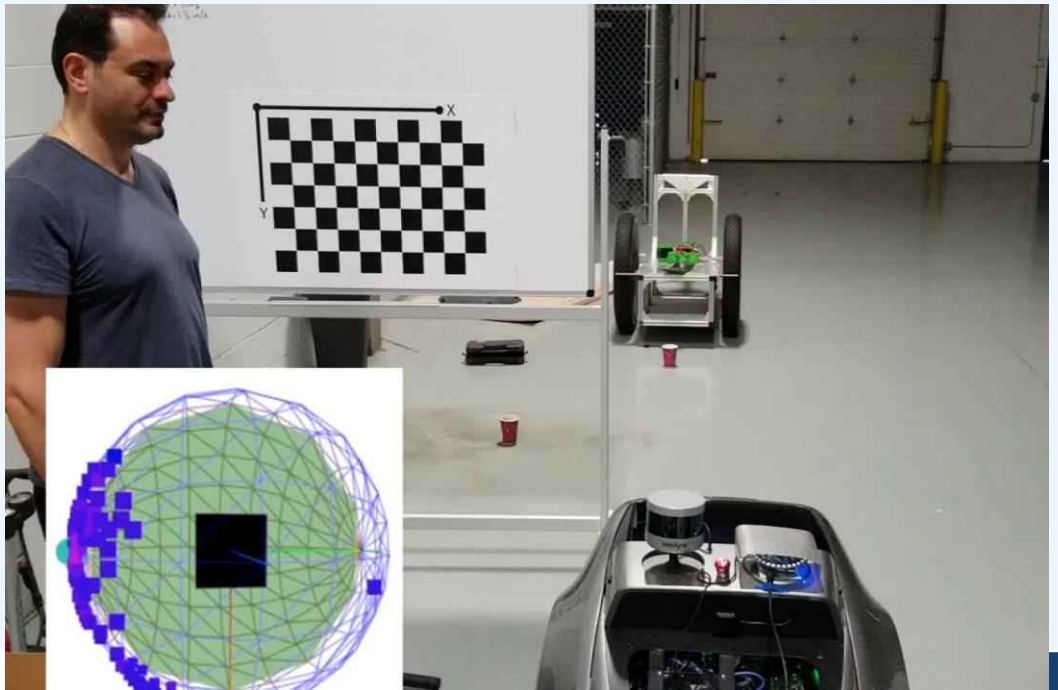


Testing Validation

Voice commands for Advanced Pedestrian Warning test

Bedestrian demonstrated Teleoperation test, and a State-of-the-art feature for Spatial Awareness with link to Voice.

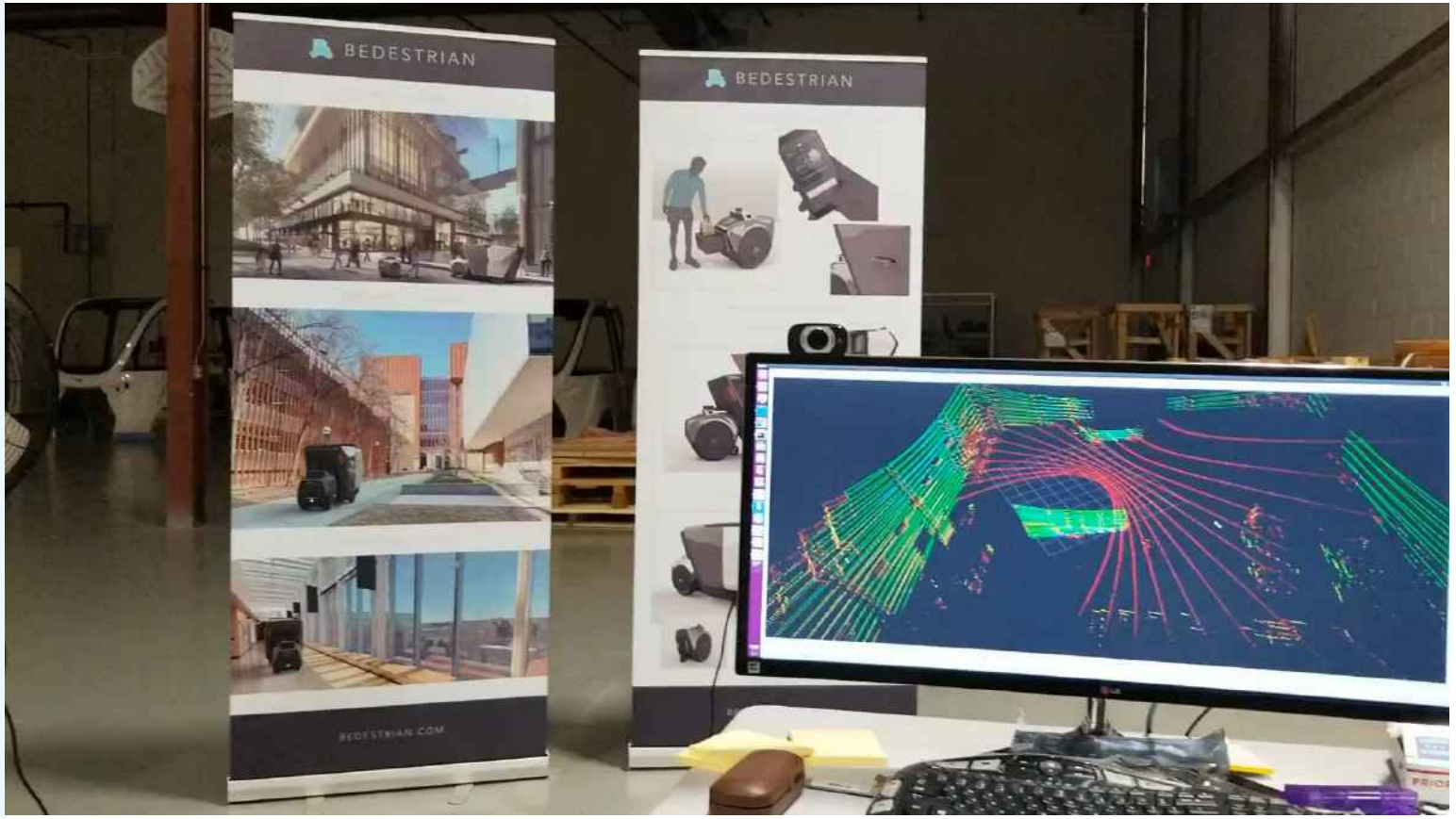
Refer for Teleoperation test of B1 and Voice Test Videos:
https://vimeo.com/337110518/b374a3b351 https://vimeo.com/346726953/0a0d771b2f



Testing Validation

Simulation testing Video

Bedestrian conducted simulation testing (similar to Amazon robotics lab approach to testing). Refer to B1 Hospital Rooms Simulation video: https://vimeo.com/341097386



Testing Validation

Videos and images documenting progress highlights:

- Preforming tight turn after wheel modifications: https://vimeo.com/353797652/8c51f2b73b
- Indoor to outdoor road navigation testing: https://vimeo.com/358826781
- Outdoor hill climb autonomous speed consitincy test: https://vimeo.com/358827290/4df00f675e

Pilot Findings

1) Both indoor food delivery and collection of excess food are high value opportunities within a University setting. The former impacts the quality of experience for staff, students and visitors while the latter enables achievement of broad university-wide sustainability goals.

2) Simulation proved to be a highly effective tools for validation of real-world path study.

3) Trailer modularity and flexibility confirmed as highly valuable component of system of vehicles. Enables eased collaboration with stakeholders existing systems.

4) Existing building infrastructures - even in new builds – are not autonomous friendly. Design and build of most commercial buildings are not built with the idea of autonomous bots navigating hallways, doorways and elevators. Most indoor autonomous activity will encounter necessary modifications which then trigger approval processes in different organizational domains - which slow progress.

5) Early stakeholder engagement is critical: initial engagement and eagerness to collaborate with mobility tech startups in MI is high; navigating stakeholder processes and receiving final approvals for advancement is delayed.

Pilot Recommendations

Value Chain Impact of Hardware Startups

Investment in startups that are building complex hardware and software is challenging for Venture Capital firms due to the initial capital cost versus a pure software endeavor. However, hardware/software startups such as Rivian, Tesla, and Apple have proved they have the biggest impact on job creation, infrastructure investments and a long value chain of suppliers. Over the long-term, companies such as ours create high value jobs in robotics, in manufacturing, in infrastructure, and have an enduring multiplying effect on the state economy. This is where the state has a valuable role to play, and where Venture capital might fall short.

Mobility Ecosystem

We recommend that State of Michigan and MDOT should increase focus and investment on autonomous simulation technology in the mobility ecosystem. It increases access and affordability to testing and therefore lowers the bar for entry of autonomous tech startups seeking to build in Michigan. Also accelerates the ability to deploy technology in the physical world.

Grant Programs

MDOT and all State programs supporting startups should invest heavily in the upfront work of matchmaking stakeholders with startups to ensure full commitment on planned pilots is understood at outset.

Pilot Recommendations

Mobility Regulations

State of Michigan via Department of Licensing And Regulatory Affairs (LARA) should adopt similar model as it has with MDOT relative to infrastructure for mobility. Just like MDOT has led the research and implementation of recommendations on transporation infrastructure necessary to make MI mobility tech friendly, there is a need for Michigan Commercial Building Construction Code to contemplate architecture designs and building that enable a seamless interaction not just for humans but autonomous robots and drones (i.e. staging/landing areas, automatic entry of doors, corridor width, etc.)

Social Impact

Significant opportunity for increasingly sustainability and eliminating waste - particularly in food delivery - exists within large institutions (universities, corporate campuses, hospitality, casinos, etc.) and autonomous tech offers opportunity to make significant impact. But requires large enterprises to be incentivized to leverage mobility tech for social impact purposes (i.e. shared objectives/metrics on sustainability, food pantry donations, etc.)

Next Steps

Bedestrian, the City of Ann Arbor and UofM Ross School of Business planned to continue to pursue deployment of this capability to gather excess food from various university buildings and increase the frequency of collection and donation of food to community organizations feeding underserved communities.

The Covid19 outbreak and its impact on the future of in-person university meal programs and cafeterias, however, has created a significant barrier to future planning regarding that specific use case.

Bedestrian, through its relationship developed with Aramark at the University of Michigan during this pilot, is exploring alternative innovations, including use cases for contactless food delivery (i.e. mobile vending) at the University and other facilities served by Aramark.

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