EVS32 Abstract

How a Mid-Western U.S. taxi company has modernized, gone green and stayed relevant as TNCs proliferate

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ABSTRACT: Columbus Yellow Cab (CYC) has operated a thriving traditional taxi company in Central Ohio, USA for 90 years. Each year they drive 5.4 million miles and provide over a million rides. While transportation network companies (TNCs) and shared mobility platforms are forming and expanding at alarming rates, CYC has taken well calculated risks to advance their services. Merging the traditional taxi fleet ownership model with the flexibility of the TNC platform they have gone green, embarked on new partnerships, moved from a central to distributed service model, and evaluated and introduced advanced technologies. The result is a hybrid model that benefits riders, drivers and their business. Our paper addresses CYC's approach and lessons learned for the eco-system, vehicles and charging infrastructure.

BACKGROUND

For 90 years, Columbus Yellow Cab (CYC) has operated as a traditional taxi service company in Central Ohio, providing transportation services to a million riders per year throughout the region. CYC's consistent ability to thrive is a result of its culture of continued improvement and innovation.

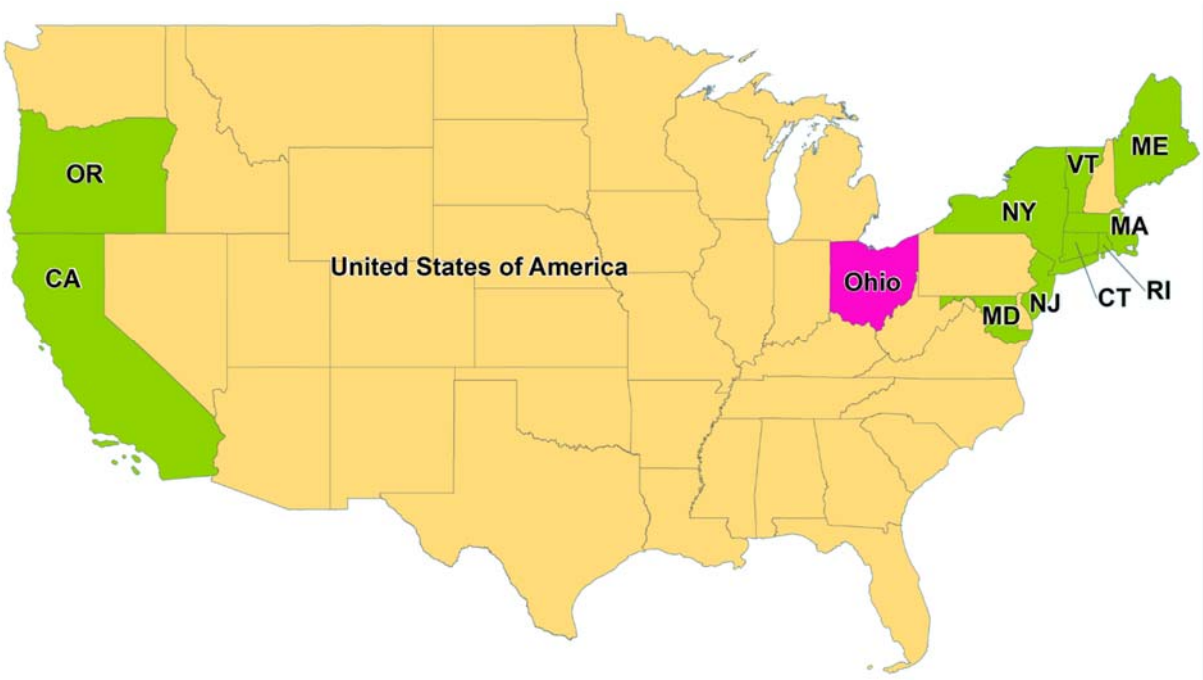
In 2011, CYC was the first in the central Ohio market to develop a free mobile ride hailing app, allowing riders to hail cabs on any mobile platform (i.e. Android, IOS, etc.).

In 2015, CYC purchased a Tesla Model S for their fleet and ran it 65,000 miles in one year, which equates to 178 miles per day. At the time there was not sufficient charging available around Columbus, resulting in 50% of the miles being stem miles (not delivering a fare), so the Tesla was removed from their fleet.

Columbus is in the mid-western United States (

Exhibit 1). Zero emission vehicle (ZEV) states, depicted in green in **Exhibit 1**, are 10 states within the United States that require vehicle manufactures to sell electric cars and trucks. The ZEV program is considered the driving force behind the increasing number of electric vehicles available for sale in the United States[1]. Ohio is a non-ZEV state with no state or local government rebate incentives, except through the Smart Columbus program.

Exhibit 1: 10 ZEV States and Ohio



In 2016 the City of Columbus, Ohio won a grant from Paul G. Allen Philanthropies. Ten million dollars in grant funds were used to leverage many millions more in investment in decarbonizing the grid, fleet and consumer EV adoption and charging infrastructure. The 3-year program, that began in April of 2017, has goals of increasing renewable energy sources in the region by almost 1 GW and deploying 925 public, workplace, fleet, and residential chargers. Smart Columbus, as the program is called, covers a seven-county area (**Exhibit 2**) and has generated excitement, urgency and awareness around conversion to EVs.

Exhibit 2: Map of Ohio and Seven-County Smart Columbus Region (Study Area)

Through their partnership with Smart Columbus, CYC benefitted from EV and charging guidance and connections. Smart Columbus benefitted from CYC's outreach efforts and willingness to innovate.

HYBRID MODEL

Columbus Yellow Cab seized this opportunity to comprehensively evaluate their company operations and determined that a hybrid-model that paired traditional taxi fleet ownership with the flexibility of a TNC platform was how they wanted to evolve their business. This approach benefited their drivers, passengers and

business. Continuing to own and maintain a vehicle fleet provided CYC a greater level of control. They continue to require background checks, provide driver safety training and collect significant amounts of data on vehicle trips and driver behavior through video feeds, GPS, telematics, and in-vehicle sensors. Rich data sets enabled CYC to provide driver coaching and often protected drivers from false accusations. They also inform strategic planning and decision making. Fleet ownership also allows CYC to provide the capitalization and maintenance support which in many cases is preferred by drivers.

As CYC combines fleet ownership with the flexibility of a TNC open-platform model, they are decentralizing access to vehicles, providing for keyless entry, streamlining operations and supporting a more diverse workforce. This hybrid model is necessary to ensure CYC maintains their strong position and viability as a company as TNCs continue to gain momentum in the U.S.

The remaining sections address the plan to phase in this new eco-system, CYC's sustainable plan to do so by converting their fleet to EVs and how they will invest in or develop agreements to utilize existing charging infrastructure.

ECO-SYSTEM

With CYC being a well-established taxi business, providing a million rides per year, they can leverage profits from their current customer base and self-invest based on their strategy of being technologically advanced, sustainable and profitable. This allows them to evaluate building and operating non-commercially available items.

Unified, Neutral Platform for All Users: In 2018, CYC launched an app-based vehicle reservation and payment platform, allowing traditional taxi drivers to reserve and lease vehicles from Yellow Cab's fleet. The mobile platform offers drivers information on all available cabs including electric vehicle state of charge; mobile reservation of vehicles for service; automated, keyless vehicle entry for drivers, and an in-app "cashiering" system enabling drivers to remotely review and complete administrative reporting and payments.

CYC is working to expand this platform to allow access for multiple use cases beyond traditional taxi service, whereby CYC fleet vehicles can be reserved and utilized by: drivers working for ride share companies (Uber, Lyft, etc.), drivers working for on-demand delivery services (Amazon, etc.), drivers utilizing Yellow Cab vehicles in a car-sharing service capacity for personal or domestic purposes.

Data Analytics Platform – CYC currently uses data aggregator and analytics software DOMO. DOMO aggregates and offers analytical reports on all available CYC data, from on-board vehicle monitoring data, to dispatching systems, to the app-based platforms used for riders and drivers. DOMO's capabilities include every data point of connection from the beginning of each initiated trip to the destination. This includes:

- Time of initiated trip call or smart phone order
- GPS of pick up and drop off locations including route taken
- Time of on/off boarding
- Driver and Rider information.
- Time stamps of every trip loaded vehicle and empty vehicle time.
- Wait time for pick up, average wait time in every geographical area.
- Distance/Time between Riders.
- Fares collected by location, distance, time, type of fare i.e. Student, Senior or ADA and method of payment.

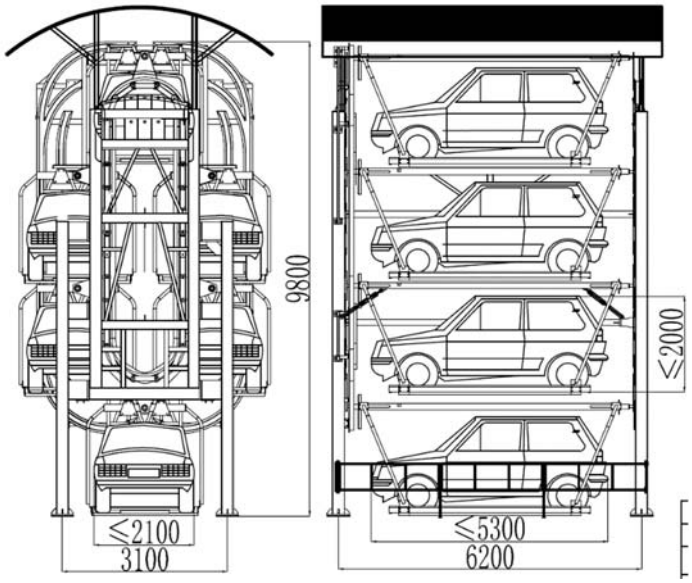
DOMO is an actionable solution to identify Key Performance Indicators (KPI) in real time.

Decentralized Vehicle Network: CYC is creating a decentralized vehicle network, with parking and cab/vehicle access points distributed throughout the region. This decentralized network will provide increased access to vehicle mobility services, putting vehicles where drivers and users need them and eliminating stem miles,

time, and cost of commutes to and from CYC's current central fleet headquarters. To minimize the footprint of its decentralized network, CYC is working to identify a location in the Short North area of Columbus to deploy a vertical, carousel-style parking solution (see **Exhibit 3**).

CYC's decentralized system will provide lower per mile operational costs, lower fleet total cost of ownership, and multiple new revenue streams to supplement the core business by opening CYC fleet vehicle use up to various users on a unified, neutral platform. This ecosystem will offer Central Ohio residents increased clean, electric transportation services, connecting communities to economic opportunities without requiring individual vehicle ownership.

Exhibit 3: 6-Vehicle Parking Carousel



Partnerships and Funding Support:
Columbus Yellow Cab is pursuing partnerships and funding support with several entities to assist in moving to this hybrid model and converting their fleet to electric vehicles. These efforts are summarized in **Exhibit 4** below:

Exhibit 4: CYC Partners

Partner	Partnership	Funding Support from Others
Smart Columbus	Battery Electric Vehicle (BEV) incentive program.	$3,000 per BEV incentive received for 10 vehicles in 2018 and up to 20 vehicles in 2019.
City of Columbus	Columbus is advising CYC how to gain access to right of way and parking spaces where they can install EV charging infrastructure and/or locate the decentralized hubs they are migrating to.	
American Electric Power, an electric utility headquartered in Columbus, Ohio, with 5-million customers in 11 states in the United States.	AEP is funding 80% of costs up to a maximum of $100,000 for up to 2 DC Fast Charger per site. AEP is funding 75 DC Fast Charing sites within their coverage area.	AEP reimbursing for $100,000 of the $125,000 cost for two 50 kW DC Fast Chargers that can operate as four 25 kW chargers as needed.
Greenlots	Greenlots is working with CYC to deploy, operate and maintain charging infrastructure at key locations in the region, starting with their headquarters.	Exploring various business models for charging with CYC. CYC as site host may own equipment and Greenlots advise, operate and maintain it.
GreenSpot	GreenSpot is interested in partnering with CYC to have them operate and maintain car sharing vehicles in conjunction with	-

	GreenSpot's EV charging deployments.	
DC Solar	-	Used 8 of their solar charging units and working to connect them to the grid at the CYC headquarters.
National Renewable Energy Lab (NREL)	CYC provided data to NREL. NREL has analyzed it to help the City of Columbus and CYC decide where to deploy charging infrastructure.	-
Ohio EPA Volkswagen Settlement funds	Ohio has $11M available for charging infrastructure	The Ohio EPA is expected to put out an RFP in the 2nd half of 2019 for proposals for them to fund charging infrastructure using Volkswagen Settlements funds. CYC is coordinating with Ohio EPA to position to apply for these funds.
Zofnass Program for Sustainable Infrastructure at Harvard University	A case study of the CYC fleet conversion was prepared using the Envision™ rating system. This will be used to educate others on the business case for investing in sustainable infrastructure.	-
Electrify America	-	CYC is pursuing funds for the installation of DC fast chargers for shared use by CYC fleet vehicles and the public.

CYC has worked hard to research and develop relationships with OEMs, vendors, private companies, government officials and non-profit representatives in the electric vehicle eco-system. The time investment has been significant and led to many successes and lessons learned.

FLEET ELECTRIFICATION

CYC has been operating a successful taxi fleet in central Ohio since 1928. CYC currently has robust fleet capabilities and maintenance resources including:

- CYC fleet of 175 taxi vehicles, including 15 ADA handicap accessible vehicles, 70 efficient hybrid vehicles, and 10 dedicated electric vehicles, 20,000 sq/ft maintenance facilities with washing bay, body shop, full time mechanics and IT dept.
- CYC existing 6,000 sq/ft office drives its cloud-based app platform, call center, interactive voice response and flexible real-time ride-hailing solutions 24/7/365.
- CYC robust analytics, including vehicle data logging, telematics, and rider info to refine and revise services in real time integrates with an aggregator DOMO.

CYC is committed to electrifying its fleet, eliminating all new conventional fuel vehicle purchases and buying only hybrid and battery electric vehicles moving forward. However, these electric vehicles need to meet operational needs, including range, cost, and storage capacity for customer and luggage.

> The Crown Victoria used to be reliable for police, taxi and fleet passenger vehicles. No similar single EV has emerged yet to provide an inclusive solution for taxi/TNC drivers.

An intense discovery phase was undertaken to determine which battery electric vehicle would be most appropriate. Four BEVs were seriously considered. The Nissan Leaf was not purchased due to concern over customer and luggage space. The BYD E6 was eliminated because they would be difficult to service and was more expensive than comparable models. At the time the Tesla Model 3 did not have a CHAdeMO converter and TNC vehicles were not permitted to use Tesla's fast charging network for work.

CYC leased 10 Chevy Bolt EVs (see **Exhibit 5**) and deployed those in July and August of 2018. The lease was set up to take advantage of the $7,500 U.S. tax incentive for EVs. After successfully purchasing, implementing, and providing data on their first 10 electric vehicles, CYC applied for and received $3,000/vehicle in incentive funds for each of the 10 Chevy Bolt EVs from the City of Columbus, Smart Columbus Transportation Service Provider Rebate program.

In January, CYC applied for an additional twenty (20) additional $3,000 BEV incentives through the City of Columbus to expand electric vehicle adoption in its fleet. The city received 33 applications for 30 spots, so CYC is expected to be awarded a minimum of 17 of these incentives. To receive the incentives CYC should purchase the BEVs by April 15, 2019.

Exhibit 5: CYC 10 Chevy Bolt EVs

Once fully deployed, Columbus Yellow Cab will have 15% of its fleet fully electrified (27 of 175 fleet vehicles). This fleet conversion will result in significant GHG reduction in the Columbus, Ohio area, with potential to scale significantly with additional fleet acquisitions and a wider, higher mileage vehicle use once all EVs are available on CYC's unified, neutral driver platform. The initial 10 vehicles are currently running at a rate of 30,000 miles per year. Once DC Fast Charging is readily available, this is expected to increase to 50,000 miles per year.

According to the US Department of Energy (DOE) Vehicle Technologies Office (VTO), improving the batteries for electric drive vehicles, including plug-in hybrid electric (PHEV) and full battery electric vehicles (BEV), is key to improving vehicles' economic, social, and environmental sustainability. In fact, transitioning to a light-duty fleet of PHEVs and BEVs could reduce U.S. foreign oil dependence by 30-60% and greenhouse gas (GHG) emissions by 30-45%, depending on the exact mix of technologies [2].

By electrifying its fleet, CYC will eliminate tailpipe emissions from its vehicles. **Exhibit 6** illustrates the impact of the current and planned near-term and full conversion to electric. A Chevy Bolt has a range of 238 miles with a 60 kWh battery. With each vehicle driving 50,000 miles per year, that is equal to about 137 miles per day – so each vehicle would need about 34.5 kWh of electricity to charge per day.

Exhibit 6: Greenhouse Gas Savings [3] by Scenario

Scenario		Vehicles Converted	Electric VMT	Metric tons CO_2 saved/year	Equivalent tanker trucks of gasoline saved
A	Current	10	500,000	115	1.5
B	Near-Term	27	1,350,000	311	4.1
C	Full Conversion and 10% of energy coming from solar	175	8,750,000	2175	28.9

VEHICLE CHARGING

Introduction of the Tesla Model S to CYC's fleet in 2016 was challenging due to lack of charging. Whereas gas stations are easy to find in the Columbus region, there were minimal public DC Fast charger location at the time and level 2 chargers were sparsely located. As of December of 2018, the region has the second most extensive rapid public charging infrastructure in the mid-western United States. Funding from AEP, mentioned in **Exhibit 4**, is supporting construction of an additional 75 DC Fast chargers throughout their coverage area. The majority of these are expected to be in the seven-county Smart Columbus program area depicted in **Exhibit 2**.

According to PlugShare and the U.S. Department of Energy's Alternative Fuel Data Center Station Locator tool, (**Exhibit *7***) as of March 2019, there are 24 public DC Fast Charging locations (orange indicator on map), with 69 plugs within a 20-mile radius of the downtown 43215 zip code (and 114 public Level II locations with 251 outlets; green on map).

Exhibit 7:CYC Dwell Time Heat Map with DCFC Locations

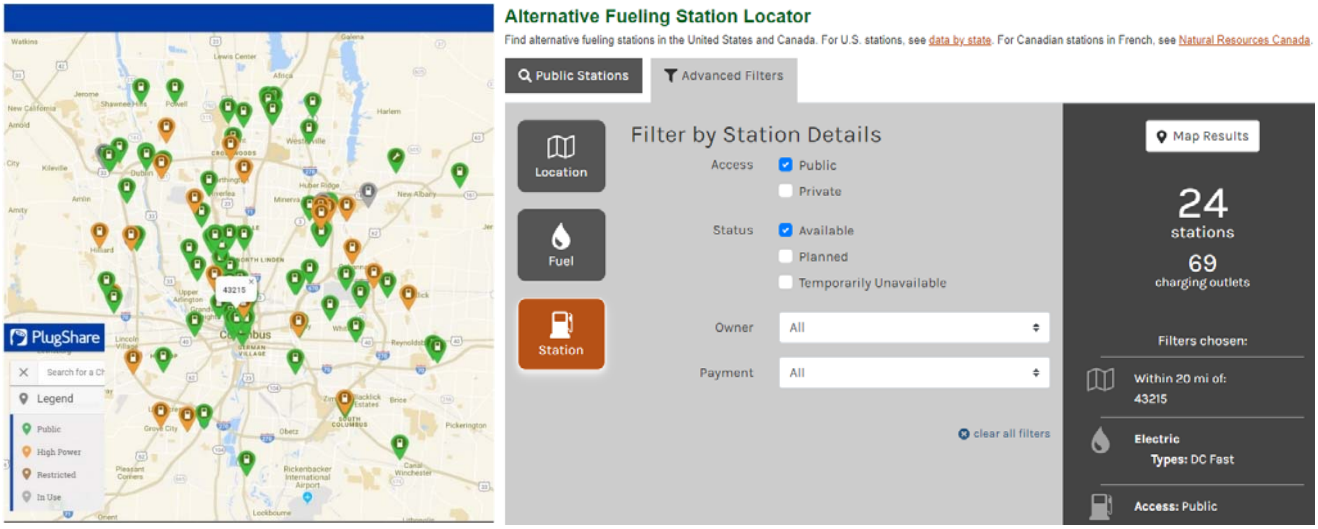
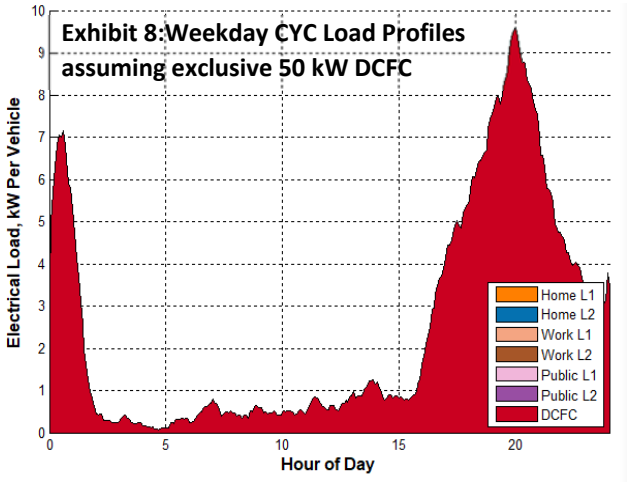


Exhibit 10 details a heat map of CYC annual service based on real GPS Telematics data analyzed by experts at the US Dept. of Energy's National Renewable Energy Laboratory. *Analysis of Fast Charging Station Network for*

Electrified Ride-Hailing Services authored by a team at the National Renewable Energy Laboratory (NREL) in April of 2018, "recommended 12 sites for DCFC installations to support a hypothetical PEV ride-hailing service in Columbus, Ohio." In a separate effort, NREL utilized 13 months of data from April 2017 to April 2018 to study CYC trip patterns and the need for 50 kW DCFC – assuming this was the primary means of charging for a fully BEV CYC fleet. **Exhibit 8** depicts the anticipated load profile needed to support a fully BEV CYC fleet. The NREL work helped quantify the number of charging events needed to support a fully BEV CYC fleet and depict where ICE vehicles are currently dwelling (see **Exhibit *7***).

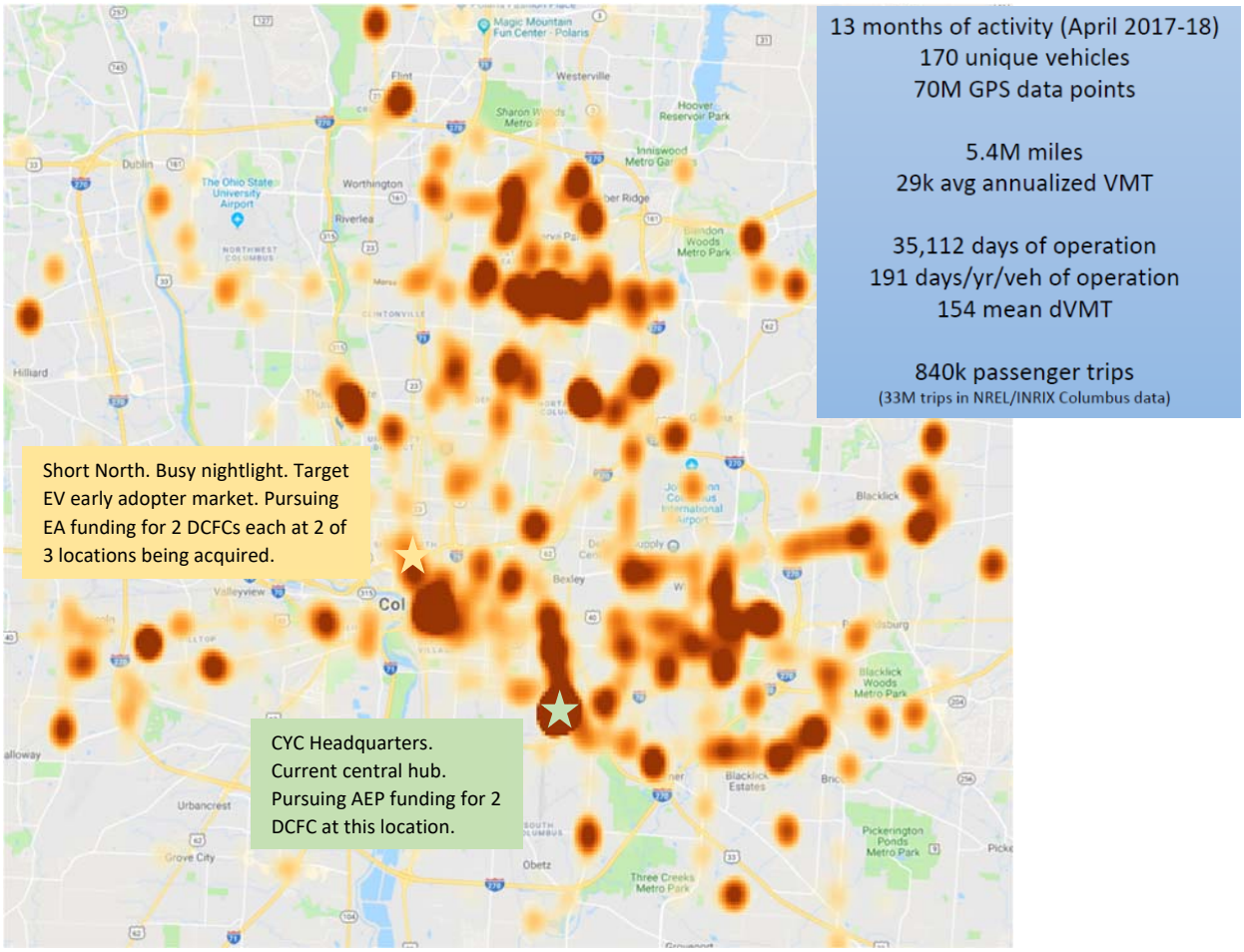
During the summer of 2018 CYC deployed eight (8) dual-port, solar powered, level II DC Solar EV chargers (**Exhibit 9**) at its current headquarters. This was not sufficient to power the vehicles for two 10-hour shifts, as desired. By working to connect solar to the grid at their headquarters CYC plans to ensure even more renewables are used and Greenhouse Gas emissions from their vehicles continues to decrease over time.

Exhibit 9: DC Solar EV Charging Unit



This will improve the air quality and quality of life of Columbus residents in perpetuity.

Exhibit 10: Heat map of CYC Annual Service [4]



The CYC team sees a few trends impacting the number of charging events needed and the dwell locations in the future. These include:

- CYC will allow other ride-hail drivers to utilize their BEVs in the future increasing the need for charging
- CYC is moving to a decentralized system so trips to/from their headquarters will be reduced in the future in place of activity around future hub locations
- Ride-hailing is gaining popularity with all groups, especially higher income segments, which will affect how the heat map evolves
- CYC will work with drivers to message and manage a charging strategy that balances minimizing demand charges and maximizing their collective trip efficiency

LESSONS LEARNED/CONCLUSIONS

Exhibit 11: Lessons Learned

Theme	Lesson	Example

First to Market	Being first to the market has long term opportunities, but numerous short-term challenges	+ "Running the train while building the tracks" analogy for the whole process + Adds time & cost to every step
Commercialization	CYC is pioneering a niche application and requires specialized technology, development and integration	+ Required technologies are not fully commercially available + Even if all tech is available its likely not easily integrated seamlessly off-the-shelf
Start-up Risks	Start-ups/New Products not always reliable or longstanding in market	+ Charging station was not as promised + Company went out of business
Investments Required	Core customer base and core business allowed CYC to invest in their future. Name recognition, visibility, current revenue streams	+ CYC has operated since 1928 and has a successful business /operational platform to build from and revenue to invest + Offers advantages over start-ups
Development Needed	Leading edge companies like CYC inevitably bear development burden	+ Created app-based platform for riders + Created app-based platform for drivers + Testing EVs, Stations, Analytics, etc.
Market Specific	Each taxi market is different. Drive and duty cycle of each vehicle must be understood to get solutions right	+ Individual taxi fleet/vehicle/driver specifics govern project needs including type of vehicle, charging, locations, etc.
Vehicle Technology	No single EV has emerged yet as single solution for taxi/TNC drivers.	+ EVs need to be lower MSRP + Greater Range (300+ Miles/charge)
Charging Stations	Faster Charging Stations Needed for full scale implementation success	+ Charging stations need to be less expensive and more widely available + Ideally charge battery in <15 minutes
Planning Required	EVs require more comprehensive and collaborative planning than gas	+ EVs need a whole charging network; proactive planning/partnership required
Partnership	Partnership necessary for success	+ Must partner with technology providers, property/charging station owners, regional planners, etc.
Patience	Patience necessary for success	+ Expect delays for products to commercialize, all systems to be able to integrate seamless
Scale & Replication	Opportunities to Scale & Replicate	+ If CYC has success across all project areas, others can replicate effectively + Data, technology, processes, best practices, solutions, etc. can be shared

References

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Authors

Katherine Zehnder, PE, PTOE, AICP has twenty years of experience with HNTB on large infrastructure and technology projects. She led a team the City of Columbus hired to prepare the technical application that won Smart City's Grants from USDOT and Paul G. Allen Family Foundation. Katie moved to Ohio to join HNTB after graduating with honors in civil engineering from Union College, Schenectady, NY in 1998. She has an MBA in Management Information Systems from Case Western Reserve University in Cleveland, Ohio.

Andrew Conley oversees the day-to-day management of the Ohio Green Fleets program for Clean Fuels Ohio, working to help fleets reduce harmful vehicle emissions and petroleum dependence, helping fleets secure project funding, and designating fleets who are leaders in deploying green technologies and practices. Since he joined the Clean Fuels Ohio staff, he has worked to develop both the public policy and Ohio Green Fleets programs for Clean Fuels Ohio. Conley holds dual Bachelor's degrees in History and Comparative Religious Studies from Wright State University.

Morgan Kauffman is a third-generation leader of the family business. Columbus Yellow Cab was established by Morgan's grandfather in 1928. Over the years, the business has evolved, and Morgan brings exciting new perspective on the logistics and meaning of taxi and livery service. As a native of Columbus, Morgan feel great responsibility for a legacy of public service the company has provided for many years. From providing transportation for at-risk members of the community to participating in the Taxis on Patrol program that helps police with a second set of eyes in our neighborhoods, Yellow Cab of Columbus continues to provide service under his leadership as a locally-owned and operated business with commitment to the Central Ohio community.

Norman L. (Bud) Braughton, PE serves as Program Manager for the $10m Paul G. Allen Family Foundation's Smart City grant to the City of Columbus. For the past 16 years he's overseen the planning, design, and construction of major downtown projects including over $100 million in projects in preparation for the 2012 City Bicentennial celebration. Prior to working at the city, he spent twenty-seven years with Conrail and CSX railroads improving and modernizing railroad signal systems and training employees in order to provide for better safety and reliability. He has an electrical engineering degree and MBA from Franklin University, Columbus, Ohio.