Short-range Electric Cars Used in Multi-Hour Travels: Is Vehicle Electrification in Western New York and Western Pennsylvania Progressing?

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Abstract

There are thousands of short-range electric cars being purchased every month throughout North America. However, is the charging infrastructure for use with electric cars and plug-in hybrids keeping up to demand? A short-range electric car was used to determine if current charging infrastructure (available in June 2019) in Western New York and Western Pennsylvania could be used in a convenient and time-efficient manner during a "typical" three-hour trip. Convenience is a key factor influencing the adoption of EVs. Obstacles to adopting electric vehicles (EVs) were discovered during the road trip to Erie, PA., these included slow chargers, no chargers, no redundancy of chargers (those currently out of service), lack of nearby services, varied terrain affecting kilometers (mileage), and a drivers' need for planning. Results found redundancy remains a key issue for adoption with many charging stations on the route "out of service" with no nearby options or backups. Previous research found similar problems with few level 3 ("fast") chargers installed in convenient locations such as Welcome Centers. Companies involved in the "electrification movement" in the United States were currently installing multiple level 3 chargers in Erie, PA, at a central location which bodes well for future trials. More studies on short-range electric cars need undertaking because EV adoption is likely to be "ground up" (less expensive economy cars) instead of a "top-down" (more expensive luxury cars) approach.

Keywords:
electric vehicle, charging infrastructure; EV adoption, CHAdeMO, Nissan Leaf

Introduction

Both long-range and short-range electric cars have been discussed in the news over the past few years as they slowly gain popularity. Long-range electric cars include various models from Tesla and the GM Bolt. Many types of short-range electric cars have been developed and are less expensive than their long-range counterparts. Examples of short-range cars include the Ford Focus Electric, Mitsubishi i-MiEV, Hyundai Ioniq, Nissan Leaf, Kia Soul, BMW i3, and Volkswagen eGolf. Short-range electric cars are defined as those from 100.8 kms (63 miles) to 182.4 kms (114 miles) of range. The provided range is based on information gathered from the car model year 2017.

The initial cost of short-range electric cars is becoming "more reasonable" overtime while long-range are still above the means of most middle-class car owners. Short-range cars could see an upswing in adoption as prices begin to revival gas-powered cars. The cost for a long-range Tesla in 2019 starts around $44,500 US (Model 3) and ends around $124,000 US (Model X). According to the Nissan USA website, a 2019 Nissan Leaf starts around $29,990 US (without incentives applied). Similarly, a 2019 Hyundai Ioniq is advertised at $29,815 US. For most consumers, a 33% increase in the price of a long-range electric car versus short-range is a substantial amount of money.

Short-range EV travel ranges can be examined from short, middle, and long perspectives. A short-range EV taking a "typical" short outing involves a single charge (usually completed from the home charger) or approximately

1.5 hours of travel. A mid-range trip requires at least one recharge and is from 1.5 to 5 hours. Long-range travel involves journeys over 5 hours and charging a short-range EV multiple times.

What are the issues related to the slow adoption of electric cars/vehicles? It appears cost, convenience, lack of distance (range), poor recharging options, and redundancy of currently set up chargers all contribute to poor adoption. The lack of distance for short-range cars may give possible buyers "range anxiety" leading to purchasing a non-electric or hybrid car. Another concern from potential EV purchasers is the need for chargers in convenient locations when traveling long distances. Charging an electric vehicle involves using the included manufacturer charging cable (level 1), level 2 (J-1772), or level 3 chargers. A level 1 uses a 120 V connection, level 2 (J-1772) uses a 240 V, and level 3 requires 480 V. Level 3 chargers are often called "DC Fast" or "Fast" chargers. There are two types of level 3 chargers – CHAdeMO and Combined Charging System (CCS). Mitsubishi and Nissan use CHAdeMO chargers. Ford and GM vehicles use the CCS charging system. Times for recharging depend on the car, type of connection, charger voltage, and weather. Nissan EVs can use level 2 (J-1772) or level 3 CHAdeMO chargers. A Nissan Leaf has both connection ports for level 2 and level 3 chargers located at the front of the car.

The purpose of the study is to examine if current EV charging infrastructure is convenient for short-range EVs to travel on a multi-hour (mid-range) trip within Western New York and Western Pennsylvania. The second objective of the study was to examine the redundancy and location of EV charging stations to make productive use of time spent while recharging. Third, do the above factors lead to lower EV adoption? Finally, the actual distance traveled versus the kilometers shown available by the EV was recorded to show any discrepancies in manufacturers' advertised kilometers (mileage). Possible reasons for the discrepancies are discussed to help in understanding of how EVs function "in the real world."

Literature Review

Over the past ten years, many studies and surveys have been conducted to gain an understanding of the general publics' attitude toward EVs. Egbue & Long (2012) used a large survey to find what participants acknowledge as the barriers to the adoption of EVs. Egbue & Long (2012) found battery range, cost, and infrastructure are the foremost socio-technical barriers. Cui, Zhao & Zhang (2018) had similar findings acknowledging issues such as their limited range, long recharging time, and scarce charging facilities. Although 2012 data is becoming outdated, the barriers still seem relevant in 2019. Charging infrastructure, convenience, adoption, alternatives to charging, and battery range will be analyzed to create an understanding of needs for short-range EVs on "mid-range" trips in Western New York and Western Pennsylvania.

Charging Infrastructure

The number and types of charging stations influence the utility of EVs. The Euro Working Group on Transportation met in 2016 leading to an article by Soltani-Sobha, Heaslip, Stevanovica, Bosworth & Radivojevica published in 2017. The physical location of the Soltani-Sobha et al. (2017) research included the United States. Although the variable of adding more charging stations was not examined, Soltani-Sobha et al. (2017) conclude the construction of more stations will increase the possible operation range of EVs, which will increase the utility of EVs and encourages commuters to adopt them. Other studies by Ghamami, Nie & Zockaie, 2014; Yeh, 2007; Struben and Sterman, 2008; Egbue and Long, 2012 found the amount of charging stations to influence consumer purchases. Neaimeh et al. (2017) focused on both the number of available chargers and types. They conclude fast chargers (level 3) could be the solution to perceived and actual range barriers for EVs. According to Kuby & Lim, 2005; Melaina & Bremson, 2008; Romm, 2006, insufficient refueling infrastructures pose a threat to the market share of BEVs (Battery Electric Vehicles). Without the charging infrastructure, many consumers are not willing to travel mid-range or long distances. The Neaimeh et al. (2017) study analyzed data from EVs and found that "fast" charging infrastructure can increase the Vehicle Miles Traveled) VMT in EVs. Developed and implemented infrastructure helped overcome actual range issues allowing drivers to complete more journeys beyond the range of their vehicles. "Mid-range" journeys appear to need active charging infrastructure whether in the U.K. or the United States.

From the analysis of reviews, charging time is important to consumers. Neaimeh et al. (2017) conclude there exists a relationship between fast charging and increased driving distance. Cui et al. (2018) found charging time important but tried to optimize results for various levels of chargers (level 2 or 3) within a budget. Coffman et al.

(2017) note charging times of one hour is still a deterrent to long-distance travel and it needs to be reduced to ten minutes, but they do not define what is considered long-distance. A one-hour charging time would be using a level 2 charger for a short-range EV. Typically, a level 3 charger takes less than 40 minutes when used with short-range EVs. Coffman et al. (2017) conclude EVs could be the preferred method of travel (as compared to Plug-in Hybrids) if the adequate charging infrastructure is developed. Both speed and number of chargers are needed to increase infrastructure development.

Campbell (2017) says there are around 150,000 charging points in the UK for electric vehicles, of which only about 12,000 are publicly available. The total needed in the UK by 2040 is significantly higher according to Erik Fairbairn of electric charging company PodPoint. Fairbairn (as cited in Campbell, 2017) estimates that 45 million charging points will be needed by 2040 when sales of gas and diesel cars will be banned. Thomas & Campbell (2019) note recharging on long trips as one of the biggest barriers to those who would like to move from a combustible car engine to electric. The Thomas & Campbell (2019) article took place with data from the U.K. Considering the geographical size difference between the U.K. and the United States, there will need to be enormous charging infrastructure development within the United States required to increase the utility of short-range EVs.

Convenience/ Location/ Redundancy

Hardman, Jenna, Tala, Axsenb, Beard, Dainad, Figenbaume, Jakobssonf, Jochemg, Kinnearc, Plötzh, Pontesi, Refaj, Spreif, Turrentinea & Witkamp (2018) researched in June and October of 2017 on consumer preferences with EV infrastructure. Summarized results found the location of charging a key component to purchasing an EV. Hensley, Knupfer & Krieger (2011) narrowed the location to "conveniently located" charging spots for New York consumers. Previous EV studies were conducted in countries around the world. According to Idaho National Laboratory, 2015; Ji et al., 2015; Nicholas, Tal & Turrentine, 2017; Nicholas and Tal, 2014 (as cited in Hardman et al., 2018), the locations (in order of preference) to recharge an EV include (1) at or near home, (2) at workplaces or commuter locations, (3) publicly accessible locations other than work (e.g. malls), and (4) on travel corridors where drivers stop between the trip origin and destination during long-distance travel. Hardman et al. (2018) had two other key findings: (1) public and corridor charging stations are the least used infrastructure type(s), and (2) short-range BEVs DC fast charge points are used mostly at intra-urban locations. Nicholas et al. (2017) study found the location of charging stations were affected by the type of EV. Nissan Leaf users (the participants in this study) were the most likely to get the electricity from public locations compared to Prius, Energi, and Volt EVs. Hardman et al. (2018) conclude there are five core perceptions relating to EVs and PEVs including (1) the importance of infrastructure at home, work, and public locations, (2) consumers access to charging infrastructure, (3) the cost to charge a PEV, (4) how many charge points are needed to support the introduction of PEVs, and (5) the impact of charging on power grids. Hardman et al. (2018) note one of the most severe limitations of the literature is that the number of charging stations in Europe, Asia, and North American is needed, but is currently unknown.

The number of charging stations and locations in Berlin were known prior to 2016. Hardinghaus, Blümel & Seidel (2016) chose Berlin to study and analyze how EV infrastructure was planned and developed. Hardinghaus et al. (2016) found 279 publicly available charging stations in Berlin at the start of the project. The City of Berlin planned the location of an additional 264 stations based on charging demand. The City of Berlin funded its' holistic plan for charging stations. Berlin has a small geographical size with over 3.5 million citizens compared to Western New York that covers a larger land area occupied by fewer people. Unfortunately, the holistic planning approach for Western New York and Western Pennsylvania does not seem realistic based on the Hardinghaus et al. (2016) study.

Adoption

The central focus of multiple studies has been the Adoption of EVs within large metropolitan areas. Most cities Hensley, Knupfer & Krieger (2011) researched the adoption of electric cars in Shanghai and New York City. The article research takes place in 2010 before widespread development and access to EVs took place. The belief from Hensley et al. (2011) is electric car adoption will begin in large cities which explains why they chose two metropolitan cities to conduct their research. Hensley et al. (2011) found early adopters willing to adjust both driving and parking habits to own an electric car. The type of required adjustments is not discussed in detail. The 60 to 90-kilometer range is mentioned as acceptable to people in New York City because of the short distances traveled. Another critical issue to adoption is education about the advantages of owning an electric car—many of those surveyed were unaware of maintenance savings. Hensley et al. (2011) concluded a broad plug-in infrastructure is critical for electrified vehicles if mass adoption in large cities and elsewhere is to take place.

Rezvani, Jansson & Bodin (2015) provide a wide-ranging view of barriers to consumer adoption of electric cars and PEVs. Studies they reviewed for research were created between 2007-2014 and included consumer data. They found three factors affecting EV adoption—technical factors, cost factors, and contextual factors. Technical factors include the limited range (see below) and the charging behaviors (see above). Both Coffman et al. (2017) and Rezvani et al. (2015) found high up-front costs involved in the initial purchase is a barrier to adoption. Rezvani et al. (2015) suggest a solution of policymakers assisting consumers with alleviating the upfront cost of purchasing an EV utilizing different financial incentives. Contextual factors of assisting consumers include supportive factors within a country. Many national governmental bodies have developed their assistive policies and plans for reducing CO2 emissions which includes enhancing the adoption of EVs." (Rezvani et al., 2015). Canada and Sweden are countries supporting the reduction of emissions through the adoption of EVs. Many barriers to consumer adoption of EVs continue to exist such as range, cost, and contextual factors, but these are slowly being eroded.

Coffman et al. (2017) assessed peer-reviewed literature about the adoption of electric cars/vehicles. There were over 50 studies on EVs reviewed. Many of the studies took place outside North America in geographically smaller countries such as the United Kingdom, France, and Sweden. Coffman et al. (2017) found four key factors that stood out in studies of EV adoption including the relatively high purchase price of EVs, battery costs, restricted driving range, and the potential for long charging times. Mak, Rong & Shen (2013) concluded the single most possible significant challenge for adoption is recharging. Coffman et al. (2017) reference the Carley, Krause, Lane & Graham (2013) article—Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cities. Carley et al. (2013) developed their study pre-2013 where many findings regarding price or battery cost for an EV are no longer relevant in 2019. Coffman et al. (2017) note the rapid price decline for EVs suggests there is a need for on-going studies of maintenance costs and the influence of purchase price on EV uptake.

Alternatives to charging

The Naor, Bernardes, Druehl & Shiftan (2015) tested a business model separating the battery from the car and paying for the battery usage as needed. Battery changing stations instead of charging was a solution developed to remove the inconvenience during long trips. A proposed plan for changing stations was also discussed by Mak et al., 2013. Mak et al. (2013) mention battery standardization as an option to help implement changing stations, but their study was completed before 2013 when few EVs were released. Battery standardization (in the marketplace) did not take place (as we now know in 2019) which makes it difficult to employ the battery swapping stations. Keeping spare battery inventories of different batteries is expensive. Naor et al. (2015) discussed Better Place's plan to create changing stations at gas stations in Israel; approximately 100 were planned. Better Place's solution was to look at multiple barriers and adopt a holistic approach with the implementation of various products to mitigate those issues. Better Place went bankrupt which illustrates the difficulty in developing battery charging alternatives. Israel is small geographically compared to the United States and Canada so battery changing would be more challenging due to the distances between stations. The battery changing system does not appear to be a viable solution for use with EVs.

Range

"Range anxiety" is a key issue affecting long-distance travel with short-range EVs. "Range anxiety" refers to fear, perceived or actual, EV drivers have of running out of power going from point-A to point-B. Cui, Zhao & Zhang (2018) note the reason people do not take long journeys with their EVs is because of the "range anxiety."

Travel time and energy consumption are related, unlike a gas-powered vehicle. Jing, Ramezani, An & Kim (2018) examined congestion patterns of electric vehicles with limited battery capacity. Egbue & Long (2012) found similar reasons for slow EV adoption as Jing et al. (2018) found for EV path choice. Path choice behavior of EV drivers is influenced by the lack of public charging stations, limited battery capacity, range anxiety and long battery charging times. Travel time is influenced by the chosen route of an EV. Jing et al. (2018) conclude it may take years to deploy enough electricity-recharging infrastructure to reach levels of appropriate coverage for optimal EV paths. Mebarki, Draoui, Allaou, Rahmani & Benachour (2013) found air conditioning and heating consume substantial amounts of energy thereby reducing the EVs range limit. Mebarki et al. (2013) used simulations to test the impact of air-conditioning on the lithium-ion battery. If air conditioning or heating is used with an EV, then energy is depleted even when the vehicle is not moving. In colder climates such as Ontario, Canada, and Western New York, the winter requires EVs to use heating to keep passengers warm thereby increasing energy consumption.

Coffman et al. (2017) reviewed multiple studies and found a consensus regarding the limited range directly effecting the adoption of EVs. Similarly, Egbue & Long (2012) administered a web-based survey at a technological university where 33% of the respondents identified battery range as their biggest concern with EVs. Kim, Lee & Lee (2017) examined the range of EVs and the impact on adoption across 31 countries in the world. The research took place with EV range values from 2011-2015. Kim et al. (2017) relate both the expensive price and driving range to the batteries purchased with the EV. They suggest both price and range are barriers to EVs becoming more successful in the car marketplace. Adoption of short-range EVs continues in North America demonstrating the demand for long-distance driving with them is small because of the known driving range limitation according to Kim et al., 2017.

Methodology

The journey consisted of traveling from St. Catharines, Ontario, Canada to Erie, Pennsylvania, United States and back. Research was conducted from June 22, 2019 to June 23, 2019. The electric car used for the study was a 2017 Nissan Leaf S purchased in Oakville, Ontario, Canada on March 31, 2017. New tires on the vehicle had less than 500 km (312.5 miles) on them (purchased in May 2019). The car weighs approximately 1503.18 kg (3307 lbs). The speed limit was adhered too as much as possible in both Canada and the United States. All travel was conducted with Eco mode engaged. There was no cruise control or air conditioning used anytime during the trip. No traffic congestion occurred during this trip. Ages of the participants were 48 and 45, a male and female; respectively. The two occupants weighed in at approximately 136.36 kg (300 lbs.) during the trip. Also, there were approximately 11.36 kg (25 lbs) of luggage, food, recharging cable, and tools always in the car. A Magellan Roadmate GPS was used for directions. The PlugShare app on an Android phone was used to locate charging stations along the trip route.

The side streets in St. Catharines, Ontario were used before reaching the main highway. Side street travel consisted of 1.6 km (1 mile). In Canada, only the QEW (Queen Elizabeth Way) and highway 405 were used before entering the United States. The main route going to Erie, PA was comprised of taking I-190 (South) to toll road I-90 until the exit closest to Silver Creek, New York. After exiting, the rest of the trip took place on Highway 20 (going westbound). The route home (eastbound) consisted of taking Highway 20 into New York state. I-90 was taken in New York state near Hamburg, NY until reaching I-190. Interstate 190 connects to highway 405 in Ontario, Canada. The final part of the trip took place on the QEW into St. Catharines.

The terrain was "hilly" throughout most of the travel through New York and Pennsylvania. The trip included travel through the Appalachian Region of the United States. There were two large bridges in Grand Island, New York, and one large skyway in St. Catharines, Ontario. The terrain, bridges, and skyway had a direct impact on the energy (kilometers) available in the electric car as shown in Figure 1.

All three levels of electric vehicle chargers (1 to 3) were used in this study. A level 2 charger (ChargePoint) was initially used from the home beginning in St Catharines, Ontario, Canada. In Grand Island, New York, a level 3 CHAdEmo connection was used at the Western New York Welcome Center. In Chautauqua, New York, a level 2 ChargePoint charger was used. A regular 120 V electric receptacle (level 1) was used to recharge the car while in Erie, PA for the night, A top-up at a level 2 in Erie, PA was employed before heading toward home (eastbound) toward St Catharines. The same level 2 ChargePoint charger was used in Chautauqua, New York on the route home as was the Western New York level 3 charger. An additional level 2 charger was used in New York while dinner was consumed.

Location	% battery	Plug-in Time	Charger Type	KM available	Distance (KM/Miles)	KM Difference
St Catharines	100%	N/A	2	169	0	0/0
Western NY Welcome Center	**98%**	**24 min**	**3**	**161**	**37.6 / 23.5**	**131.4**
Merritt Winery (using I-90)	**37%**	**18 min**	**1**	**67**	**93.8 / 56.3**	**67.2**
Liberty Winery	63%	20 min	1	71	4.48 / 2.8	62.52
Chautauqua. 3375 E Main St, Dunkirk, NY	**63%**	**1 hour 4 min**	**2**	**120**	**3.52 / 2.2**	67.48
Solstice Inn Erie, PA. 8040 Oliver Rd, Erie, PA	**0%**	**12 hours**	**1**	**142**	**89.8 / 54.25**	**30.2**

Travel to West Erie Plaza Dr.		16 minutes	N/A		10.4/6.5	
West Erie Plaza Dr, Erie, PA (start point)	90%	1 hour 16 min	2	191	0	0
Chautauqua. 3375 E Main St, Dunkirk, NY	75%	1 hour 18 min	2	154	83.84 / 52.4	107.16
Mitsubishi, 5160 Camp Rd, Hamburg, NY	59%	37 min	2	108	48.48 / 30.3	105.52
Western NY Welcome Center	86%	16 min	3	156	38.08 / 23.8	69.92
Home St Catharines	N/A	N/A	2		40.6 / 23.5	118.4
				Total	**450.6 / 281.63**	

Figure 1. Charging information recorded from St. Catharines, Ontario to Erie, Pennsylvania

Discussion

There are many inconveniences for EV drivers traveling on multi-hour trips at this point (2019) in time. A lack of charging infrastructure is one of many inconveniences. The inconveniences are not helping increase the adoption of electric vehicles in Western New York and Western Pennsylvania. Convenience is about taking current driving practices for gas-powered vehicles and creating processes and procedures to closely mimic them using an EV. Alternatives such as battery changing have been tested in the past with no success. Changes need to be made in how and where drivers recharge so EV users can be productive during idle time. Keeping driving practice changes to a minimum will help remove inconveniences for consumers, but these have yet to be implemented.

Returning from Erie, PA to St. Catharines, Ontario took a total of 6 hours 17 minutes which includes five minutes at the Canada/United States border. Using a gas-powered vehicle, the travel time from Erie, PA to St. Catharines, Ontario is approximately 2 hours 30 minutes including time to cross the border. A difference of 3 hours and 47 minutes (227 minutes) creates an inconvenience for "most" people. In addition, it makes it difficult to plan to arrive at a location at a specific time when multiple points of recharging are required. The increase in time using an EV during mid-distance travel presents an inconvenience that continues to thwart adoption.

It's likely the less expensive EVs (with short-range batteries) will be purchased if appropriate (speed and type) infrastructure exists to support them on medium to long-distance travels. The total cost of recharging during the trip, after the initial charging at home in St. Catharines, Ontario, was $0.00. The initial charging cost $1.71 (Canadian dollars). Consumers need to be educated about the cost savings including charging and maintenance. A larger amount and more appropriate infrastructure mean less inconvenience and lessens the need for long-range batteries to be installed in EVs. Past studies believe the construction of more charging stations will increase the operation range of EVs, which will increase the utility of EVs and encourage consumers who travel for multiple hour trips to adopt EVs. From the current findings, there are not enough recharging stations, both level 2 and level 3, to make a multi-hour trip convenient in the Western New York and Western Pennsylvania areas.

Redundancy of charging stations was a major factor affecting this trip. Two of the level 3 chargers along the route were unavailable during the trip and no backups in the general vicinity were online. The lack of level 3 chargers required our route to Erie, PA be modified from I-90 to Highway 20. The level 3 charger in Fredonia, NY was not available, it had been down for over a month. Like Fredonia, the level 3 charger at Walmart in Cheektowaga, NY was unavailable. There were no level 2 or 3 chargers or outdoor outlets at the Pennsylvania Welcome Center along highway I-90 (toll route) which added inconvenience. Near the end of traveling to Erie, PA the electric car ran out of power. There were no level 2 or level 3 chargers within 5 km (3.125 miles) when the car stopped. The Nissan Leaf was 8 km (5 miles) from the planned hotel before losing power. The car needed to get a tow from AAA for 8 km (5 miles). The current state, in October 2019, of level 3 chargers in Erie, PA is better than June, but similar issues are arising with newly installed chargers. On September 12 and 29, 2019 users reported an issue with one of the new level 3 chargers at Peach Street Walmart. There were network errors and faults with one of the level 3 chargers. There are no other level 3 chargers within 10 km (6.25 miles) of the Peach Street Walmart. As the amount of short-range electric cars continues to increase the need for redundancy and fewer network problems will be required from consumers.

The location of charging stations provided another inconvenience on the trip. The level 3 charger at the Western New York Welcome Center is excellent because it's fast and free. Amenities provide a great experience for those charging at the WNY Welcome Center including a playground for kids, restrooms, vending machines and information about the area—all free of charge. All other areas along the trip route were not EV friendly. None of the wineries visited in New York or Pennsylvania had level 2 or 3 chargers available for guests. In the Niagara Region, Canada, approximately 20% of the wineries have level 2 chargers available. As shown in Figure 1, there was one hour and four minutes charging time spent in Chautauqua, NY while traveling to Erie, PA. One hour and eighteen minutes were spent recharging in Chautauqua, NY on the way back. The Chautauqua, NY level 2 charging station has no facilities such as restrooms, restaurants, or a vending machine. It is located at a store which was closed for a month. Both researchers had to walk approximately one kilometer (.6 miles) to visit a convenience store for a soda. Before heading back to Canada, the West Erie Plaza level 2 charger was used. The West Erie Plaza was 15.2 kms (9.5 miles) from the hotel and was the closest level 2 charger available. Driving over 15 kms to recharge is not convenient for EV owners, but was needed to insure enough energy to Chautauqua, NY. There were stores and restaurants in the area of the West Erie Plaza which helped in passing the time, but if enough charging stations were available near major motels only a minor inconvenience would occur.

There were no charging stations (level 2 or 3) at either the Microtel Inn or the Solstice Inn, both located in Erie, PA. The Microtel Inn had no outlets on outer walls where a level 1 charger could be plugged-in. Solstice Inn had outside outlets and the EV was plugged-in there overnight gaining 144 km of power. Sad to say, but it not uncommon for hotels in the United States and Canada to provide neither an outdoor outlet or level 2 charger. Good news for EV owners is Sandman hotels in Canada are starting to add Level 2 chargers so patrons can plug-in at night and EVs can be fully charged in the morning. Hopefully, other hotels in Canada and the United States will follow suit!

Range is a key factor affecting the uptake of electric cars. While the short-range electric cars in 2017 were advertised as providing from 100.8 kms (63 miles) to 182.4 kms (114 miles) of range, multiple factors negate those optimal outcomes. Those factors are often not shared and detailed with customers. One, the weather is a major factor in how an electric car will charge and disperse energy; especially in the winter. The weather was a minor factor in this study because it was conducted in spring with temperatures above 20 degrees C (68 degrees F). As noted, the terrain was "hilly" during most of the trip which drained energy from the car. Electric cars lose power as they climb hills or high bridges such as the two noted—Garden City Skyway in St. Catharines, Ontario and a high bridge in Grand Island, NY. Speed is another factor affecting the amount of power consumed by the EV. The return from Erie, PA to St. Catharines, Ontario was completed via Highway 20 throughout Western Pennsylvania and most of Western New York to optimize battery life. Usage of the EV on freeways while maintaining the speed limit draws more energy than shown available on the instrumentation.

The available kilometers to travel shown in the car were different than those traveled in multiple circumstances—this is a confirmed finding in the study. As shown in the bolded Figure 1, statistics from Chautauqua, NY showed 120 kilometers available for travel according to the Nissan Leaf instrumentation. The distance to the Solstice Inn was a total of 86.8 kilometers on Highway 20 from the recharging station. There was an alteration made at eight kilometers from the hotel when the Leaf ran out of power. The cars' instrumentation began to flash and there were no kilometers left showing. The percentage of power showing available was three dashes— zero. The researchers traveled another five kilometers along Highway 20 with the flashing instrumentation before stopping. The car stopped at a garage at the bottom of a hill in Erie, PA. We called AAA to tow us to the Microtel Inn which was eight kilometers (five miles) from the garage. Microtel Inn and the Solstice Inn are across the road from each other in Erie, PA. The Nissan Leaf was recharged at the Solstice Inn overnight. The Welcome Center in Western New York traveling to Merritt Winery had similar results of kilometers as shown in the car versus actual kilometers traveled. The discrepancy between kilometers available and traveled can be accounted for due to the terrain and speed. Other factors such as cold weather (less than 0 C or 32 F), air conditioning, and tire condition can be discounted as reducing the kilometers available for travel because they were all controlled during the experiment.

Conclusion

The charging infrastructure in Western New York and Pennsylvania is not ready to handle short-range electric cars on trips more than ninety minutes of continual driving. Electric car manufacturers need to test under "real world" scenarios to produce more accurate driving ranges for short-range EVs. Accurate kilometers available to travel will help with range anxiety of many consumers. Testing in a lab environment using only movement of the tires while the car body remains in a fixed position is not producing accurate results for use by consumers. It is a recommendation of this study that all hotels along the I-90 corridor provide a level 2 charger to their guests in the future to add convenience, promote green solutions for travel, and increase tourism. All Welcome Centers in Western Pennsylvania need to provide a level 3 charger to encourage EV adoption and clean energy travel. Level 2 chargers are useful if there are services in the vicinity including malls or restaurants. If there are no service industries in the vicinity, it is recommended level 3 chargers are installed. There are so few fast chargers (level 3) in full operation in multiple spots along Interstate 90 that people driving gas-powered cars are unwilling to give up their cars due to inconvenience. Neaimeh et al. (2017) suggested fast chargers could be a solution to support EVs on trips—this study agrees with their conclusion. The study found fast chargers in multiple spots such as the Welcome Center and Chautauqua, NY would have helped the speed of travel and convenience. The new level 3 chargers in Erie, Pennsylvania at the Peach Street Walmart (available as of September 2019) will immensely help in attracting those with short-range electric vehicles. However, getting to Erie, Pennsylvania from Ontario, Canada will continue to be difficult without additional locations introducing level 2 and 3 chargers.

Future recommendations include revisiting the same path with a 2019 or newer model Nissan Leaf or comparable car to see how improvements in battery range can help in a mid to long-range trip scenario. The addition of an automated data logger would help track information related to the trip. A repeat of the trip with a newer model car could see if planned improvements are operational and offer a better experience for driving time and convenience.

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Biography

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