ASSESSING THE POTENTIAL FOR PUBLIC ELECTRIC VEHICLE CHARGING INFRASTRUCTURE IN CHICAGO TO OFFSET LACK OF RESIDENTIAL CHARGING

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ABSTRACT

Much has been discussed about whether a sufficient level of charging infrastructure is in place to support the increasing sales of plug-in electric vehicles. The lack of publicly accessible charging stations for electric vehicles may particularly discourage people from purchasing electric vehicles if they are unable to charge an electric vehicle at home. This study focuses on the greater Chicago metropolitan area to model scenarios of potential demand for and supply of publicly accessible charging stations, especially near homes, to assess to what extent the current public charging infrastructure can offset lack of home charging availability and where additional public charging may be needed. We find that the daily aggregate potential demand for public charging is in excess of the supply, distributed lognormally across the census tracts of the study area. Given certain assumptions including a 5% plug-in vehicle adoption rate, we also find that the magnitude of daily potential excess demand for public charging per census tract is not very large (median of 138 electrified miles). For public charging, supply exceeded potential demand in less than 5% of the census tracts. Sensitivity analysis shows that potential demand is heavily dependent on plug-in vehicle adoption rates and that supply is heavily dependent on the operating capacity reached by public charging stations. DC fast chargers contribute significantly to supply, but only if they are often in use.

INTRODUCTION

Since the advent of plug-in electric vehicles (PEVs) in the US market, their sales have been increasing steadily [1]. Several studies predict widely varying future levels of plug-in vehicle adoption [1,2,3]. However, studies also suggest that the sales of electric vehicles may be limited by the charging infrastructure available [4,5,6]. As many as 82% of electric vehicle charging events were recorded at home according to one report, while 18% were charged at non-home locations [7]. In the US, only about 80% of households and less than 60% of vehicles have access to home parking (with or without charging) [5]. Vehicles parked on the street and generally away from home parking, i.e. not in garages or driveways, were highly likely to not have access to home charging [4]. Renters also may not be able to easily install electric vehicle charging infrastructure at home, even if they do have parking. People in rented homes may face hurdles such as getting the landlord's consent, high cost of infrastructure installation, and the necessity of installing separate electric meters for billing [5]. Thus, there is a sizable portion of the market that cannot charge at home and hence will be discouraged to purchase a PEV.

Publicly accessible charging stations in residential areas are one way to overcome this barrier to PEV adoption. Measures to increase market acceptance of electric vehicles have entailed installing charging stations in various cities across the US [7]. Studies have addressed the level of residential charging availability on a national level [1,5,6] and for some specific geographical regions targeted by surveys, including California [4]. This paper contributes an analysis of lack of residential charging as a potential barrier to PEV adoption in the Chicago metropolitan area, as well as an assessment of the capacity of public charging to offset the lack of residential charging. We use GIS-based analysis methods on publicly available geolocated data, and our method can be easily replicated for other geographical regions if similar data is available.

We use data on driving behavior and publicly accessible charging stations in the greater Chicago metropolitan area to address the following research questions. (1) What is the potential demand for public PEV charging capacity to offset lack of home charging capability? (2) To what extent does current public charging infrastructure support that potential demand? And (3) where is the potential excess demand for public vehicle charging for this purpose?

METHODS

We address the research questions by using travel behavior data to model potential demand for public charging stations to offset lack of home charging. The potential demand is estimated in terms of electric vehicle miles travelled (eVMT) using geospatial operations to differentiate generated demand potential by proximity ("near" and "far") to charging stations. We calculate the capacity of public charging in the study area in eVMT based on publicly accessible charging station locations and the range and charging times of popular PEV models. The supply and demand projections for the entire study area are compared to gauge the gaps between them.

The scenarios we develop to examine the interaction of potential demand and supply of public charging depend on whether rented homes can use home-based charging. Most of our analysis assumes that rented homes are not able to charge PEVs at home, although two more scenarios are also addressed. We also perform sensitivity analysis on charging station operating capacity and PEV adoption levels.

We then calculate the extent to which potential demand for public charging is met by the available supply, first on an aggregate level and then the distribution on a census tracts-level in the study area.

In this paper, the definitions of the terms “demand”, “supply”, and “capacity” may differ from their usage in the literature on consumer demand. We refer to “demand” as the need for public charging for certain households to adopt a PEV, derived from household travel behavior and characteristics (e.g. lack of parking or charging availability). Demand as used in this paper is not based on modeling consumer choices and is approximately an upper bound on them, so we will usually refer to it as “potential demand”. We use “capacity” to refer to the theoretically available amount of public charging (in kWh or converted to eVMT) if the infrastructure was used at full power during all hours of operation. We use “supply” to refer to the availability of public charging (in kWh or converted to eVMT), given certain assumptions about publicly accessible charging stations, including likely usage levels.

Data

We selected data sets for this study with low levels of geographic aggregation, i.e. to the census tract level.

Travel Behavior Data

The Chicago Metropolitan Agency for Planning (CMAP) conducted a travel behavior survey known as the Travel Tracker Survey to build the Chicago Regional Travel Household Inventory (CRTHI), of the residents of the greater Chicago metropolitan area [8]. The survey contains detailed travel data for households from 8 counties in Illinois and 3 counties in Indiana, recorded between January 2007 and March 2008 [9]. All members of the chosen households recorded their travel activity over a randomly assigned period of 24 or 48 hours [9]. The survey data was weighted at the household level to match the region’s demographic and travel-related information in the 2005-2007 American Community Survey [10].

Census Tracts and Road Network Shapefiles

Since the CRTHI survey was conducted in 2007-2008, its data was geocoded to census tract centroids according to US Census 2000. For this reason, we used the GIS layers of the same tract data from Census 2000 for the 8 Illinois counties in this study [11].

Shapefiles of the road networks for each of the eight Illinois counties were taken from the US Census 2010 and merged into one road network file for the entire study area [11].

Electric Vehicle Charging Stations

The Alternative Fuels Data Center (AFDC), a part of the US Department of Energy, maintains information on electric vehicle charging stations [12]. Information includes the number and type of charging outlets at each station, hours and type of access, and location of the station. For this study, we used geospatial analysis through the ArcMap software to only choose charging stations that were publicly accessible and fell inside the study's geographic scope [13]. Note that at the time of data retrieval, data from AFDC was updated in January 2015.

Geographic Area of Interest

This study's data was geographically limited to the eight Illinois counties used in the CRTHI survey, i.e. Cook, Du Page, Grundy, Kane, Kendall, Lake, McHenry, and Will. Census tracts and public charging stations situated in these counties were considered in the study. Similarly, we excluded travel data related to all households in CRTHI survey that were either located or had made trips to destinations outside the study area, which constituted 16.9% of the surveyed households. The latter assumption may bias our travel distance estimates downwards. The study universe was made up of the following: 8,768 households; 10,490 vehicles; 124,589 trips; 51,798 locations (households and/or other trip destinations); 1,854 census tracts (excluding two that are entirely inside Lake Michigan); and 159 publicly accessible charging stations.

Proximity Analysis

This study conducts a geospatial analysis of the proximity of charging stations to origins and destinations of trips in the CRTHI survey, which include locations of households and, by extension, vehicle parking spots. Publicly available data about the locations of charging stations was used to create distance buffers for walking distance through the Network Analyst tool in ArcMap, part of the ArcGIS software suite [13]. Instead of straight-line distances, we decided to use actual walking distances based on road network data. Thus, road network was used as an input, along with the public charging stations as "facilities", for calculating a Service Area using the Network Analyst tool in ArcMap. The impedance used for service area calculation was distance (road length) and U-turns were allowed. The resultant polygon was chosen to have a 50 feet trim, and multiple facilities were to be merged by break value, i.e. distance buffers. The resulting polygon layers were used to flag locations from the CRTHI survey data according to their proximity to public charging stations. This process yielded aggregate results for the distance from each household to the nearest charging station, but did not identify which households are closest to which charging station.

The value used for walking distance in the study is based on the literature available for walking distances to transit service in urban areas. The transportation industry usually uses distance buffers of 0.25 miles for bus service and 0.5 miles for rail transport. However, there is evidence to suggest much higher estimates than what the industry uses. One such study done in Montreal, Canada, suggested that the walking distance was 524 meters, or 0.33 miles, to bus stops and 1,259 meters, or 0.78 miles, for commuter rail stations [14]. We used a walking distance of 1 mile or 5,280 feet in our study. We assume that a household is "near" the charging station if it is within 1 mile and "far" otherwise.

Trips Made by Cars

The CRTHI survey data included trips made by any mode of transport, including public transit or car. We assumed that potential demand for electric vehicles is based on trips made by car (including automobile, light duty truck, or van). Any demand for electric vehicles that might be generated through mode shifting is out of scope for this paper.

Furthermore, note that some trips were made in vehicles that weren't part of the CRTHI survey. Such trips could not have been analyzed further and thus were excluded. To avoid double counting of trips made by multiple household members, we only considered those trips where the respondent was the driver and not the passenger, reducing the number of unique car trips to 57,750 which belonged to 7,164 households and 10,490 vehicles.

Vehicle Parking and Home Ownership Attributes

Much of the study's analysis was based on two attributes: parking location of the vehicles and the home ownership status of the household.

The CRTHI survey reported the parking locations of vehicles mainly as: On Street, Driveway, or Garage. Vehicles without meaningful parking location data (responses of Someplace Else, Do Not Know, or Refused) were excluded from our sample. We concentrated on the 97% of vehicles for which we have parking information. Of those, 11% park on-street, 30% park in a driveway, and 59% park in a garage.

We limited our data to households with home ownership status in the CRTHI survey of Owned/Mortgaged or Rented, excluding the category of Other ownership status and refused responses.

Demand Assumptions According to Parking and Home Ownership Characteristics

According to the evidence from previous studies, we assume that most electric vehicles charging events will occur at the home of the owner (although we make no assumptions about the time of day). Therefore, we also assume that public charging stations will primarily be needed for vehicles that cannot charge at home. We do not include convenience/opportunity charging by vehicles from other destinations. We have identified three categories of vehicles on the basis of their potential for generating demand for public charging stations: (1) Vehicles that usually park on the street have a high potential demand for public charging stations because they cannot be charged at home. (2) Vehicles that park off-street but at a rented home have a medium potential demand for public charging because of the additional barriers to home charging faced by renters. (3) Vehicles that park off-street at owned homes have a low potential for using public charging since they are more likely to charge at home.

In order to project the potential demand for public charging stations from the surveyed responses, we assume that a household can replace at most one conventional vehicle it owns with an electric vehicle. Of the 10,490 vehicles given in the table, 10,149 had complete parking and home ownership information, which corresponded to 6,944 households. Many of these vehicles belonged to the same household. Therefore, one vehicle was randomly chosen in case of each household to represent the potential demand for public charging stations from that household.

The 6,944 households can be categorized as (i) those with only one type of parking, i.e. either on-street or off-street, available to all owned vehicles, and (ii) those with both types of parking sports available. The vast majority (96%) of households had only one type of parking available. One vehicle was randomly chosen for each household to be included in the sample. Therefore, in case a household had both on-street and off-street parking available, only one type of randomly selected parking was registered in the sample data for that household, based on which vehicle was chosen.

The majority (80.7%) of the households own their homes and have vehicles parked off the street in driveways or garages. Most of these households parked all vehicles only in off-street parking locations, making them prime candidates for home-based charging, but not for public charging use. On the other hand, households with only on-street parking spots, irrespective of their home ownership status, have the highest likelihood of using public charging stations. Overall we found the following numbers when we placed the selected vehicles into our defined categories: 814 vehicles (11.7% of potential PEVs and 11.4% of total vehicles) had high demand potential; 525 vehicles (7.6% of potential PEVs and 7.3% of total vehicles) had medium demand potential; and 5,605 vehicles (80.7% of potential PEVs and 78.4% of total vehicles) had low demand potential. Note that the total vehicles randomly chosen as potential PEVs were 6,944 and the total vehicles overall were 7,149.

Our focus will be on the high and medium potential demand categories (1,339 vehicles) for further analysis and modelling potential demand for public charging.

Proximity of Chosen Vehicles/Households and Public Charging Stations

We are interested in whether a parked vehicle at a household is located within a 1-mile walking distance ("near") of a charging station, or if it exceeds that distance ("far"). For vehicles parked on the street, only 25.3% were within a 1-mile walking distance of a charging station, while only 20.4% of households with rented homes and off-street parking lived within walking distance. The majority of households with medium or high potential demand for public charging stations are not located at a walking distance from a currently existing public charging station.

Supply of Electric Vehicle Charging

The study area had 159 publicly accessible charging stations for electric vehicles. Some stations also stated their opening dates which varied from 2011 to 2014. The most recent station opened among the 159 included in this study was on November 17, 2014. Note that each charging station can have more than one charger installed. These chargers can be of three types [15]:

- Level 1 – Charges using an AC connection of 120 volts. One hour of charging can give between 2 and 5 miles (average: 3 miles) of driving range.
- Level 2 – Charges using an AC connection of 240 volts. One hour of charging can give between 10 and 20 miles (average: 15 miles) of driving range.
- DC Fast Charging – Charges using a DC connection of 480 volts. One hour of charging can give between 150 and 210 miles (average: 180 miles) of driving range.

Each charging station had different business hours, which we took into account in determining the capacity. Many offered 24 hours of access, 7 days a week. Some charging stations had restrictions during weekdays or weekends. Furthermore, we made assumptions on the amount of electric vehicle miles traveled (eVMT) yielded by an hour of charging an average vehicle, based on a sales-weighted average of charging times for three popular plug-in electric vehicles: Nissan Leaf (range: 84 miles, Level 2 full charging time: 5 hours), Chevrolet Volt (range: 38 miles, Level 2 full charging time: 4 hours), and Tesla S (range: 208 miles, Level 2 full charging time: 10 hours) [16]. We calculated the eVMT yielded by one hour of charging for each of these models. The yields were averaged using calculated sales-based weighting factors for these vehicles in the period January 2014 to May 2014, i.e. 45.5%, 30.0%, and 24.5% for the Leaf, Volt, and Tesla S, respectively [16]. This gave weighted average yields of 3.6 eVMT per hour for Level 1 charging, 15.6 eVMT per hour for Level 2 charging, and 187.1 eVMT per hour for DC Fast charging.

The chosen vehicle models were three of the four highest-selling PEV models in the US during the reference time period. Although the plug-in model of Toyota Prius was among the top three sellers, we exclude it from our model since it has a much smaller electric range on a fully charged battery [16]. Note that doing so results in more optimistic estimates about the supply of public charging available.

Using assumptions about the business hours available for charging, and the average eVMT yielded per hour of charging, we estimated the potential charging capacity per day offered by each type of charger in the study area, i.e. 29 Level 1 chargers with 2,533 eVMT of charging capacity; 313 Level 2 chargers with 114,061 eVMT of charging capacity; and 24 DC Fast chargers with 107,789 eVMT of charging capacity.

RESULTS AND DISCUSSION

We present results for the potential demand for public electric vehicle charging in the greater Chicago metropolitan area to offset lack of residential charging as a barrier to PEV adoption. We also present findings on the current capacity of public charging and the extent to which it could handle the potential demand.

Potential Electric Vehicle Miles Traveled

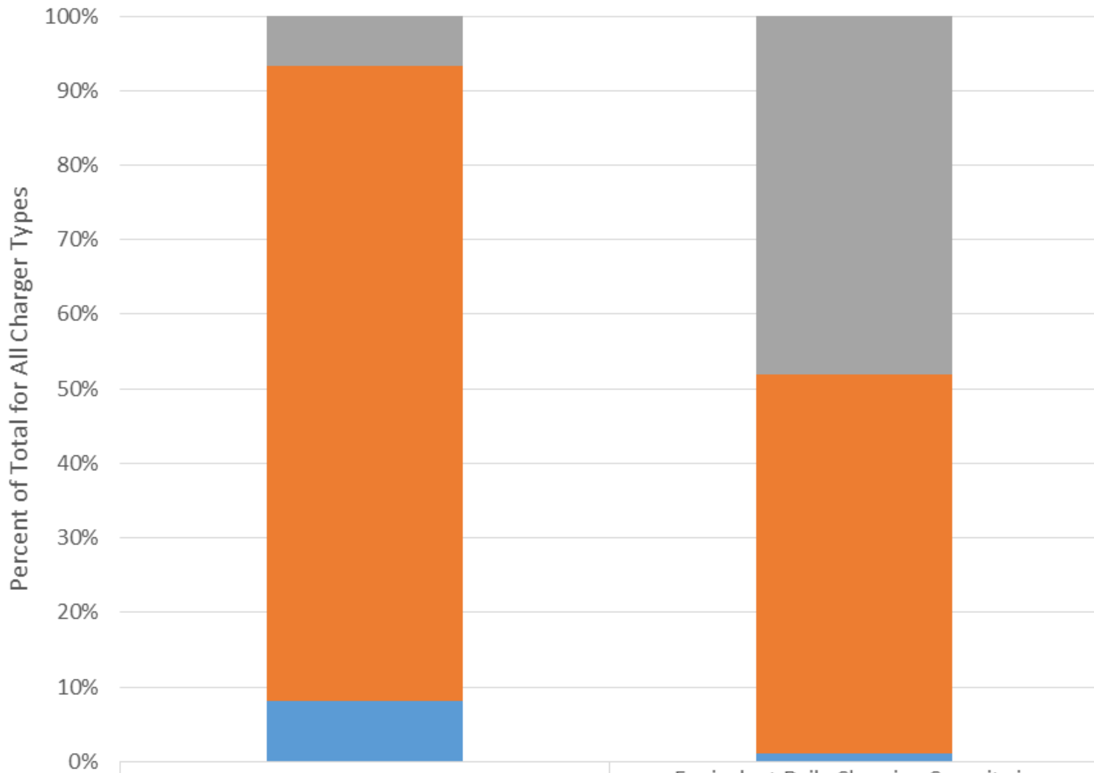
The CRTHI survey includes straight-line approximations of distances travelled in each trip, which can be used to calculate the daily (straight-line approximation) distance travelled by a vehicle in the survey. Considering the case that a household can replace its conventional vehicle with an electric one, these daily distances serve as a proxy for the (optimistic) potential daily driving distances powered by electricity. The survey also provides the weighting factor for each household, which can be used to project a statistic for the entire population of households in the area of interest.

Using these concepts, we projected the eVMT for the population of households in the study area that have high or medium potential public charging station use. Vehicles with medium demand potential (off-street parking at a rented home) were projected to have daily driving distances totaling 5,881,446 eVMT far (more than 1 mile) from charging and 567,601 eVMT near (within 1 mile of) charging stations. Vehicles with high demand potential (on-street parking, either owned or rented home), were projected to have daily distances of 2,669,051 eVMT far from charging and 1,351,844 eVMT near charging stations.

An additional possible assumption could be that vehicles parked far from a public charging station at home may make trips to a workplace which is near charging station. Thus, an electric vehicle can possibly be charged near a workplace instead of near home. Of the 1,026 vehicles in the sample that were flagged as being far from a charging station, only 127 were used to travel to work-related destinations that were near charging stations. Considering vehicle charging at workplaces is an optimistic assumption since households may not consider public charging near a workplace to be sufficient to overcome the barrier of having no charging at home. This changes the total daily demand potential near charging stations to 1,602,670 eVMT (high demand potential) and 731,375 eVMT (medium demand potential), and far from charging stations to 2,669,051 eVMT (high demand potential) and 5,881,446 eVMT (medium demand potential).

Capacity of Charging Stations

Figure 1 shows our results for the capacity of public electric vehicle charging in the study area if all charging stations operate at full power during all hours of operation. Interestingly, DC Fast chargers are the lowest in number and in daily charging hours available, but make up almost half of the total potential charging capacity. Full operating capacity, i.e. 24 hours a day or during all hours of operation, is unlikely as there will be instances of idle time in a day when no electric vehicle is being charged. Taking this into consideration, we calculate potential supply in our subsequent analysis by assuming that 50% operating capacity is achieved.



	Daily Charging Hours Available	Equivalent Daily Charging Capacity in eVMT
DC Fast	576	107,789
Level 2	7,314	114,061
Level 1	696	2,533

Figure 1: Estimated Charging Potential for Public Charging Stations

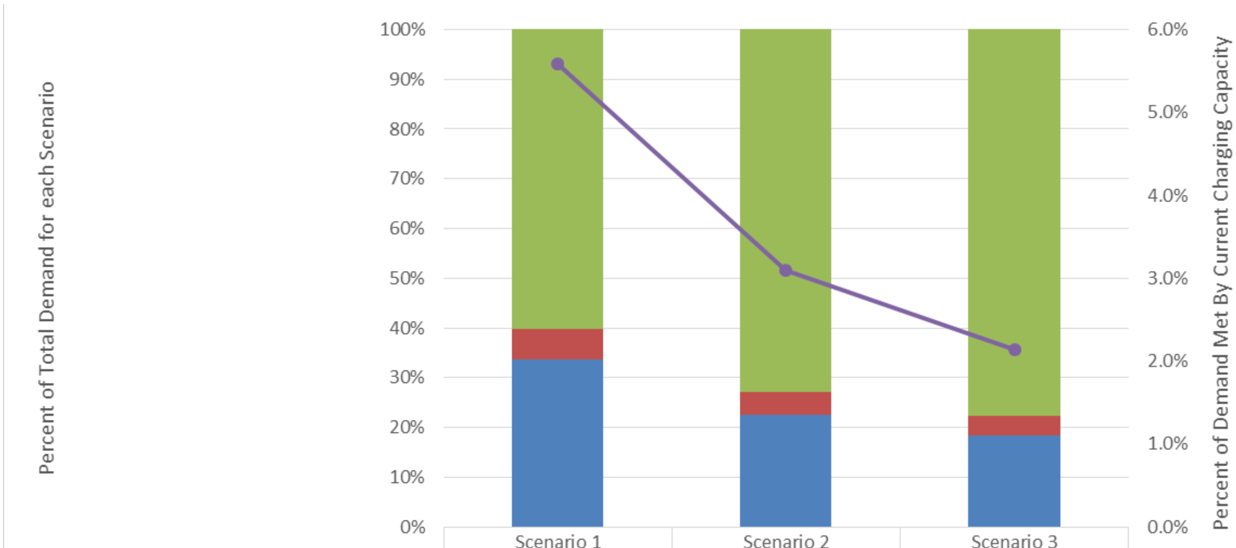
Interaction of Supply and Potential Demand

Till now, we have established the potential demand and installed capacity of publicly accessible charging in terms of eVMT, assuming that 100% of households who could adopt a plug in vehicle do so. We will perform sensitivity analysis on the vehicle adoption rate later in the section. For now, we are considering the entire potential demand.

We now investigate whether the current public charging infrastructure in the study area is sufficient to meet potential demand to offset lack of residential charging. We analyze (1) whether the aggregate supply of public charging is enough to meet aggregate potential demand, (2) whether the supply of public charging can meet the potential demand generated by vehicles parked near (within walking distance of) charging stations, and (3) which census tracts in the study have excess potential demand or supply of public charging.

We define three scenarios for vehicles at rented homes based on whether rented homes can offer home charging or not, since renters face additional barriers to making residential charging available. In Rental Scenario 1, vehicles can be charged at rented homes. In Rental Scenario 2, 50% of rented homes can charge a vehicles. In Rental Scenario 3, rented homes do not have vehicle charging. Since Rental Scenario 3 is closest to the current situation, we will present results primarily for Rental Scenario 3.

Based on these scenarios, the potential demand for public charging would vary and we can see this in Figure 2 below. Note that even in the case of least potential demand, Rental Scenario 1, the total installed capacity of charging stations can only cater to 5.6% of the total potential demand. The portion of demand potential for charging at homes and workplaces that is generated near (within 1-mile walking distance of) charging stations is 39.9% of the total demand potential, but those charging stations are often not large enough to support the level of demand potential near it.



	Scenario 1	Scenario 2	Scenario 3
Demand Not Near Charging Stations	2,418,225	5,277,061	8,135,897
Demand Near Workplace	250,826	332,713	414,600
Demand Near Home	1,351,844	1,635,644	1,919,445
Installed Public Charging Capacity as % of Total Demand (Righthand Axis)	5.6%	3.1%	2.1%

Figure 2: Potential Demand and Supply Available (in eVMT) in Different Rental Scenarios

Assumptions for PEV Adoption Levels

The above results assume that all households with the potential to buy an electric vehicle will do so. In the near term, only a fraction of them would replace their current conventional vehicles with an electric one. In 2013, 0.15% of registered automobiles in the US were plug-in electric vehicles [17,18]. We use this adoption level as our lower bound for sensitivity analysis. Other levels considered are 0.32%, the electric vehicle market share in Chicago for March 2013 to March 2014 [19]; 3.33%, based on March 2013 to March 2014 sales levels in the San Francisco-Oakland-San Jose metropolitan area, the highest for any US metropolitan area [19]; and 5% and 10% as more optimistic cases. We use these percentages of PEV adoption as an approximation of potential demand in terms of eVMT. Thus, by assuming that, 0.15%, 5%, or 10% of the vehicles will be replaced by an electric vehicle, we are also optimistically assuming that 0.15%, 5%, or 10% of the daily distances travelled by cars in the study area will be electrified. We then gauge whether the estimated potential demand of public charging near and/or far from the charging stations can be met by the currently available supply.

The estimation of daily distances travelled by car is based on the CRTHI survey, which has data as recent as March 2008. Since the average daily VMT in the eight Illinois counties of our study area has changed little between 2007 and 2014 (decreased by 2.38%), we decided to use the estimates derived from the CRTHI survey [20,21].

Comparing Public Charging Supply and Potential Demand Projections

Table 1 shows the cases of aggregate daily surplus and deficit of supply, i.e. supply minus potential demand, of public charging available, assuming varying operating capacities of charging stations and PEV adoption rates. The table takes into account only the potential demand generated from vehicles located near (<1 mile) charging stations in part (a) while considering the total potential demand, both from near and far, in part (b).

Table 1. Surplus/Deficit of Daily Public Charging eVMT Available based on Projected Potential Demand and Supply in eVMT (including 3 Rental Scenarios).

(a) Only Considering Demand Near Charging Stations

PEV Adoption Rate		Supply of Public Charging in eVMT when Stations Operate at X% Capacity				
		60%	**50%**	**40%**	**30%**	**20%**
Scenario 1	**10%**	-25,637	-48,076	-70,514	-92,952	-115,390
Scenario 1	**5%**	54,496	32,058	9,620	-12,819	-35,257
Scenario 1	**3.33%**	81,261	58,822	36,384	13,946	-8,492
Scenario 1	**0.32%**	129,501	107,063	84,624	62,186	39,748
Scenario 1	**0.15%**	132,225	109,787	87,349	64,911	42,472
Scenario 2	**10%**	-62,206	-84,644	-107,083	-129,521	-151,959
Scenario 2	**5%**	36,212	13,773	-8,665	-31,103	-53,541
Scenario 2	**3.33%**	69,083	46,645	24,207	1,768	-20,670
Scenario 2	**0.32%**	128,331	105,892	83,454	61,016	38,578
Scenario 2	**0.15%**	131,677	109,239	86,800	64,362	41,924
Scenario 3	**10%**	-98,775	-121,213	-143,651	-166,090	-188,528
Scenario 3	**5%**	17,927	-4,511	-26,949	-49,387	-71,826
Scenario 3	**3.33%**	56,906	34,468	12,029	-10,409	-32,847
Scenario 3	**0.32%**	127,161	104,722	82,284	59,846	37,408
Scenario 3	**0.15%**	131,128	108,690	86,252	63,814	41,375

(b) Considering Overall Demand (Near and Far from) Charging Stations

PEV Adoption Rate		Supply of Public Charging in eVMT when Stations Operate at X% Capacity				
		60%	**50%**	**40%**	**30%**	**20%**
Scenario 1	**10%**	-267,460	-289,898	-312,336	-334,775	-357,213
Scenario 1	**5%**	-66,415	-88,853	-111,292	-133,730	-156,168
Scenario 1	**3.33%**	734	-21,705	-44,143	-66,581	-89,019
Scenario 1	**0.32%**	121,763	99,324	76,886	54,448	32,010
Scenario 1	**0.15%**	128,598	106,160	83,722	61,283	38,845
Scenario 2	**10%**	-589,912	-612,351	-634,789	-657,227	-679,665
Scenario 2	**5%**	-227,641	-250,080	-272,518	-294,956	-317,394
Scenario 2	**3.33%**	-106,643	-129,081	-151,519	-173,958	-196,396
Scenario 2	**0.32%**	111,444	89,006	66,568	44,129	21,691
Scenario 2	**0.15%**	123,761	101,323	78,885	56,447	34,008
Scenario 3	**10%**	-912,365	-934,803	-957,241	-979,679	-1,002,118
Scenario 3	**5%**	-388,868	-411,306	-433,744	-456,182	-478,621
Scenario 3	**3.33%**	-214,020	-236,458	-258,896	-281,334	-303,773
Scenario 3	**0.32%**	101,126	78,687	56,249	33,811	11,373
Scenario 3	**0.15%**	118,925	96,486	74,048	51,610	29,172

In case of Table 1 (a), the current infrastructure will fall short of meeting potential demand if 10% of market adoption is realized, even if charging stations operate at 60% capacity (in use 60% of the time). The same will be true in case 5% PEV adoption is realized, given that operating capacity is less than 30%, 40%, or 50% for Rental Scenarios 1, 2, and 3 respectively. This indicates that existing charging station locations may need the ability to charge more vehicles simultaneously. In case of Table 1 (b), however, supply shortfall projections are more likely. In almost all cases, if 3.33% of the vehicles are switched to PEVs, charging stations will fall short of meeting the potential demand, even if they operate at 60% capacity. This shortfall is more pronounced in Rental Scenario 3 due to higher potential demand projections. This indicates an overall lack of charging capacity in the region, disregarding location.

The rest of the analysis assumes a 5% market adoption rate and 50% operating capacity for charging stations (i.e. each station in use during half of the operating hours). Given these assumptions, the charging stations are estimated to meet 55.8% of total projected potential demand in Rental Scenario 1, 31% in Rental Scenario 2, and 21.4% in Rental Scenario 3.

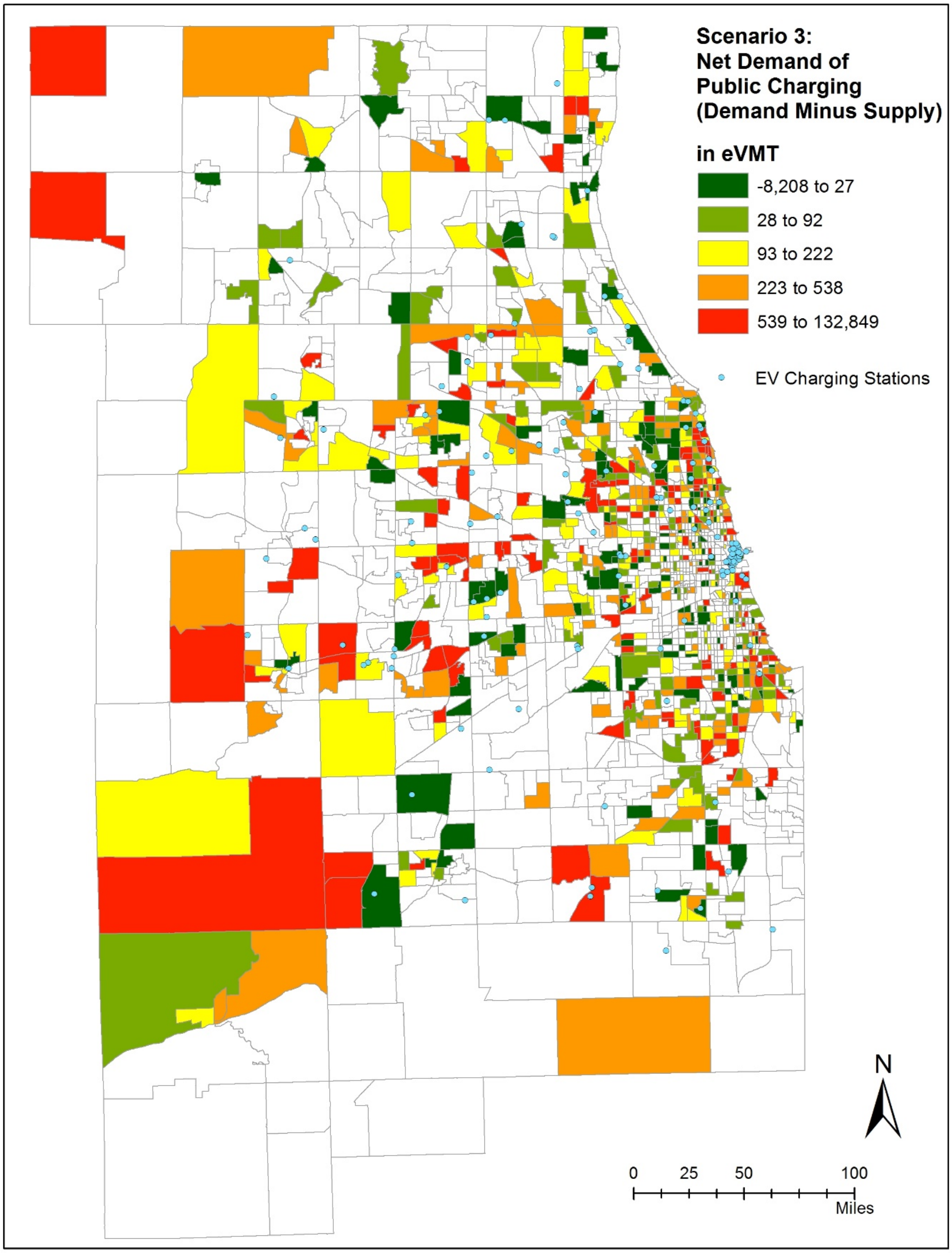


Figure 3. Potential Net Demand of Public Charging in each Census Tract for Scenario 3, at 50% operating capacity and 5% market adoption.

The aggregate estimates of potential demand and supply of charging can be represented geographically. Figure 3 refers to Rental Scenario 3 and shows the census tract-level breakdown of daily potential net demand (i.e. potential demand minus supply) of public charging. In the geographic study area, there were 764 census tracts which generated potential demand for public charging in Rented Scenario 3. Bins of data were created using the "Quantile" option in ArcMap, indicating that all bins have similar number of observations. Census tracts without any color indicate the absence of potential demand. Some of these tracts host EV charging stations. Only 33 census tracts had more public charging supply in eVMT than the locally generated potential demand. This low incidence of excess supply is more apparent in Figure 4, which shows a right-ward skew in the distribution of potential net demand. Figure 4 was made excluding outliers, i.e. data points with values that were less/more than first/third quartile by a magnitude of 1.5 times the interquartile range.

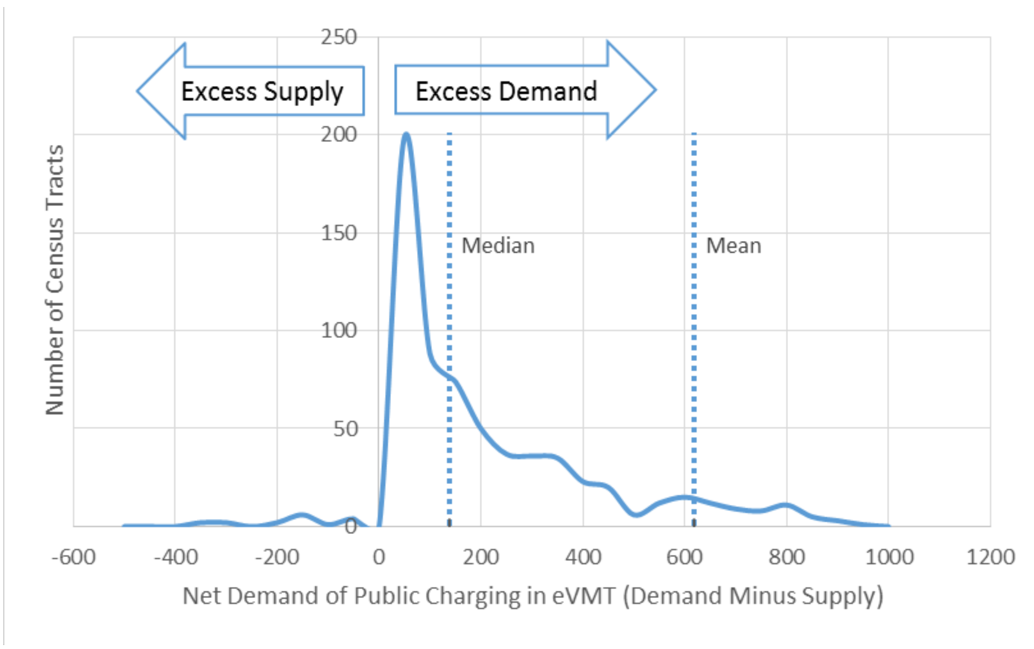


Figure 4. Scenario 3: Distribution of Daily Potential Net Demand of Public Charging and Census Tracts, at 5% market adoption and 50% operating capacity.

Despite the high number of census tracts with potential excess demand for public charging, magnitude of the potential excess demand is not large when assuming 5% PEV adoption. The median potential net demand per day in eVMT for the census tracts is 138 eVMT, while the mean is 618 eVMT. Figure 5 shows the total potential demand and total supply along with the apparent supply shortfall in distribution and the different means. Of 764 census tracts considered in Rented Scenario 3, 710 had no charging stations.

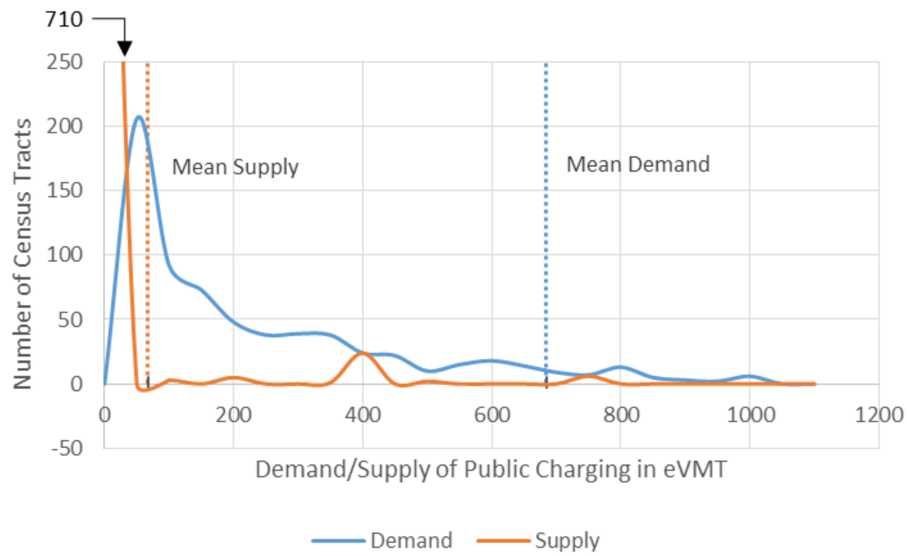


Figure 5. Scenario 3: Distribution of Potential Demand and Supply of Public Charging, at 5% market adoption and 50% operating capacity, excluding outliers.

Model Limitations and Future Work

This study has several limitations, which can be addressed in future work. To begin with, the travel survey data contained straight-line trip distances, which were used in the study as proxies for on-road distances. For future work, on-road driving distance estimates will be developed. Another limitation is the use of optimistic assumptions for the supply of charging stations. Inclusion of DC Fast chargers and charging at workplace are two such assumptions. Also, we based potential future driving distances on current driving distances without accounting for mode switching or other travel behavior changes that may take place when adopting PEVs. We also supposed uniform PEV adoption and usage behavior among all customer types. We assumed a charging station will be used if it is within a 1 mile walking distance, leaving sensitivity analysis on that parameter for future work. Finally, we used the optimistic assumption that all miles driven by a PEV could potentially be electrified. We examined potential charging locations but did not examine time of day for charging or length of time spent charging.

CONCLUSIONS

We evaluated the potential demand and supply of publicly available charging stations in the greater Chicago metropolitan area using publicly available geolocated data on travel behavior and publicly accessible electric vehicle charging stations. For estimating potential demand, we assumed that vehicles parked on-street will have a high potential for using public charging stations, while vehicles in rented homes have a medium potential even when parked off-street. Of the 10,149 vehicles analyzed in the study, 1,104 (10.9%) did not have home parking, while an additional 630 (6.2%) vehicles had home parking but according to our assumptions may not have charging because they belong to renters. As a result, 1,734 (17.1%) vehicles may not have access to home charging. We also assumed that charging stations will be used if within a 1 mile walking distance of either a home or workplace destination.

The capacity in eVMT of public charging was significantly augmented by the presence of DC Fast chargers, which make up almost 48% of charging capacity. This is due to their high power, even though only 24 out of the 366 chargers installed in the study area are DC Fast chargers.

When considering the pessimistic case (closest to current situation) where no rented homes have home-based charging, i.e. Rental Scenario 3, a cumulative potential excess demand of over 400,000 eVMT per day is projected to offset lack of residential charging ability. There is potential excess demand for all cases with 3.33% or more of the projected daily driving distances in the study area electrified, even if public charging stations operate at 60% capacity (in use 60% of the time). When considering a disaggregation to the census tract level for the case with 50% charging station capacity 50% and 5% market adoption, the incidences of potential excess demand are numerous even though the magnitude is not large (median of 138 eVMT per day per census tract). About 75.8% of the 764 census tracts had a daily potential net demand between 0 and 538 eVMT. Only 33 census tracts had greater supply of public charging than potential demand. There is a substantial gap between total potential demand and total supply distribution, with only 54 (2.9%) census tracts in Rented Scenario 3 having a public charging station.

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