

# **IBM Capstone Project**

## **Optimal Location for EV Service in the Washington State.**

### **Introduction**

Due to the growing population of electric and hybrid vehicles in the US, the new market emerging in the field of auto service. Followed by the Tesla Motors, world top carmakers offering more electric vehicles in their model line which constantly takes a significant portion of the car market in the US.

The growing number of electric vehicles collaterally boosts the EV charging market, as more consumers decide to purchase electric cars as higher demand for charging stations. On the other hand, the wider access to charging stations at specific locations stimulates consumers to choose an electric vehicle.

It is obvious that any vehicle with electric drivetrain requires maintenance and replacement services distinct from traditional gasoline vehicle, thus, a significant number of EV on the roads creates a market for “non-traditional” auto service.

Based on market opportunity analysis, potential auto service business planning to step into the EV market and provide maintenance and replacement services in the state of Washington, however choosing the most efficient deployment locations for EV service facilities that would maximize profits requires location-based data analysis and the estimated market growth. Following data analysis will help to visualize the potential EV service market as well as clustering potential customers into groups and define the most efficient deployment locations that would satisfy the EV owner’s needs.

### **Data**

Following data required to perform the analysis:

1. List of zip codes that covers the state of Washington (WA) including geolocation and county.
2. The geographical location of currently registered EV vehicles in WA will be obtained directly from (data.wa.gov), official state government site.
3. The geographical location of EV charging stations in WA will be obtained from the National Renewable Energy Laboratory (NREL) through an API.

## Methodology

The process will take 3 stages:

1. Cleaning and data preparation.
2. Transformation of the EV data and merging with EV charging station data, population, and population density data.
3. Applying K-clustering.
4. Visualizing data with folium.

After data was cleaned and prepared for analysis, we created a list of 586 zip codes located in the state of Washington. The data frame accompanied by associated city, total population, population density, and geo-coordinates (latitude and longitude).

	Zip	City	State	Latitude	Longitude	Population	Density
0	98001	Auburn	WA	47.303722	-122.26608	31,911	1,716.68
1	98002	Auburn	WA	47.304221	-122.21602	31,647	4,423.38
2	98003	Federal Way	WA	47.311072	-122.31188	44,151	3,800.35
3	98004	Bellevue	WA	47.618371	-122.20308	27,946	3,976.84
4	98005	Bellevue	WA	47.611021	-122.16858	17,714	2,361.29
5	98006	Bellevue	WA	47.562975	-122.15260	36,364	3,401.89
6	98007	Bellevue	WA	47.610935	-122.14104	24,889	5,683.90
7	98008	Bellevue	WA	47.609222	-122.11550	24,411	4,436.60
9	98010	Black Diamond	WA	47.317802	-122.01479	5,025	333.78
10	98011	Bothell	WA	47.751471	-122.20257	29,212	3,568.63
11	98012	Bothell	WA	47.843110	-122.20457	51,136	3,337.63
13	98014	Carnation	WA	47.648232	-121.91265	6,765	149.31
15	98019	Duvall	WA	47.735300	-121.96222	10,725	140.51
16	98020	Edmonds	WA	47.803668	-122.37096	18,304	3,538.83
17	98021	Bothell	WA	47.790653	-122.22021	26,722	2,633.94
18	98022	Enumclaw	WA	47.193729	-121.91915	20,987	51.70
19	98023	Federal Way	WA	47.309021	-122.36178	47,510	4,603.85
20	98024	Fall City	WA	47.565642	-121.88638	5,650	236.23
22	98026	Edmonds	WA	47.821568	-122.33651	35,921	3,851.87
23	98027	Issaquah	WA	47.522828	-122.02921	26,141	468.56

In the next step, we are visualizing the data by applying coordinates on the map of the Washington state.

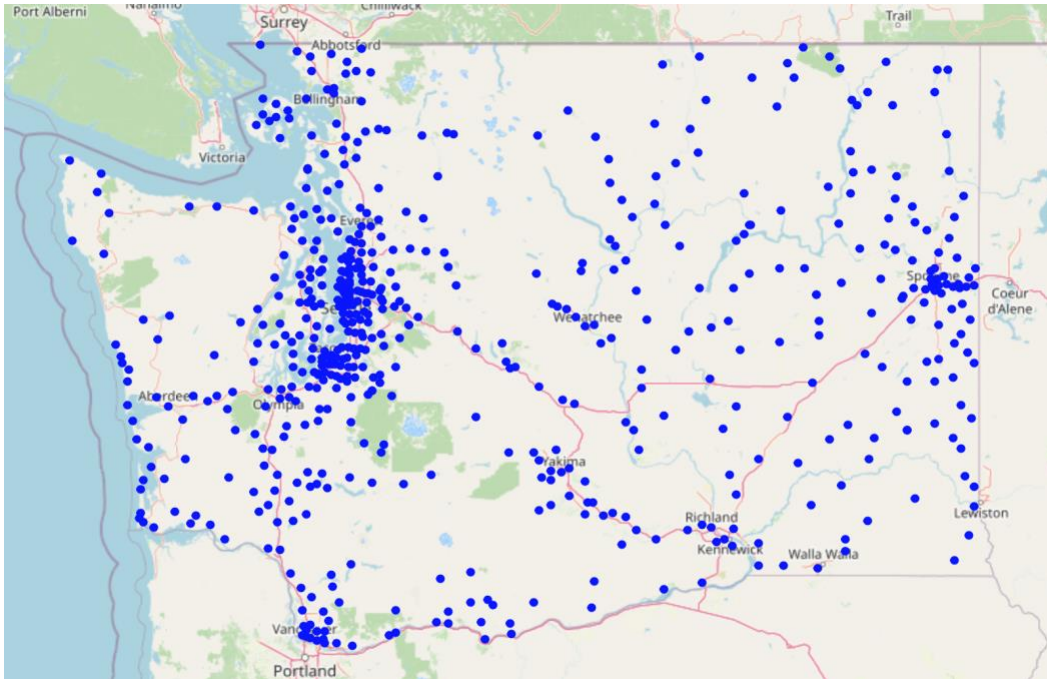


Figure 2. Visualized centers of WA zip codes

At this stage, we use API to including the data from the US Department of Energy that contain location data for each EV charging station in the US and Canada. After cleaning the data we have located every publicly available EV charging station in WA with level 2 and fast charging. In general, the API provides data for all EV charging levels (1, 2, Fast Charging) however, we filtered data for only level 2 and Fast Charging.

Figure 3. EV charging station location data

	city	zip	street_address	station_name	ev_network	facility_type	latitude	longitude
2	Bellevue	98004	450 110th Ave NE	BELLEVUE	ChargePoint Network	None	47.614745	-122.193162
5	Issaquah	98027	1755 Highlands Dr NE	KING COUNTY DOT	ChargePoint Network	None	47.545226	-122.019191
6	Bothell	98011	18500 Campus Way NE	UWB CASCADIA CC	ChargePoint Network	None	47.760178	-122.190581
7	Redmond	98052	15670 NE 85th St	CITY OF REDMOND	ChargePoint Network	None	47.679224	-122.129950
8	Redmond	98052	18080 NE 76th St	CITY OF REDMOND	ChargePoint Network	None	47.672359	-122.099034
9	Woodinville	98072	14580 NE 145th St	WILLOWS LODGE	ChargePoint Network	None	47.733788	-122.146893
25	Bellevue	98004	601 108th Ave NE	KEY CENTER	ChargePoint Network	None	47.615846	-122.196881
26	Bellevue	98004	10900 NE 4th St	KRC SKYLINE	ChargePoint Network	None	47.614105	-122.194486
29	SeaTac	98188	4800 S 188th St	CITY OF SEATAC	ChargePoint Network	None	47.434021	-122.273183
30	Tacoma	98409	3628 S 35th St	TPU	ChargePoint Network	None	47.227983	-122.485100
31	Tacoma	98421	326 E D St	URBAN WATERS	ChargePoint Network	None	47.259300	-122.434240
33	Bellevue	98006	14509 SE Newport Way	BELLEVUE	ChargePoint Network	None	47.568851	-122.145621
34	Bellevue	98007	15395 SE 30th Pl	EASTGATE OFFICE	ChargePoint Network	None	47.582366	-122.135279
35	Kirkland	98033	123 5th Ave	KIRKLAND	ChargePoint Network	None	47.678476	-122.206806
36	Kirkland	98033	308 Kirkland Ave	KIRKLAND	ChargePoint Network	None	47.675670	-122.202069
37	Sammamish	98075	801 228th Ave SE	SAMMAMISH	ChargePoint Network	None	47.601447	-122.037974
38	Kent	98032	19802 62nd Ave S	IBEW LOCAL 46	ChargePoint Network	None	47.424222	-122.256619
39	Renton	98055	400 S 43rd St	VALLEY MED CTR	ChargePoint Network	None	47.441294	-122.214247
40	Renton	98055	4033 Talbot Rd S	VALLEY MED CTR	ChargePoint Network	None	47.444230	-122.214529
42	Tacoma	98402	110 S 10th St	PW PARKING	ChargePoint Network	None	47.253809	-122.437429
43	Tacoma	98402	1801 Dock St	PW PARKING	ChargePoint Network	None	47.245933	-122.433980
51	Oak Harbor	98277	1270 SE Dock St	OAK HARBOR	ChargePoint Network	None	48.288066	-122.648224
53	Seattle	98104	201 S Jackson St	KING COUNTY DOT	ChargePoint Network	None	47.598780	-122.330837
54	Mount Vernon	98273	1800 Continental Pl	SKAGIT COUNTY	ChargePoint Network	None	48.437569	-122.325494
55	Edmonds	98026	21601 76th Ave. West	SWEDISH EDMONDS	ChargePoint Network	None	47.804365	-122.334163
56	Seattle	98101	1730 Minor Ave	MET PARK WEST	ChargePoint Network	None	47.616838	-122.329508
57	Seattle	98101	1100 Olive Way	MET PARK WEST	ChargePoint Network	None	47.616464	-122.330505
61	Olympia	98501	601 4th Ave E	OLY CITY HALL	ChargePoint Network	None	47.044892	-122.895304
62	Seattle	98121	2121 6th Ave	VIA6	ChargePoint Network	None	47.613883	-122.339405
63	Seattle	98104	800 5th Ave	800 FIFTH AVE	ChargePoint Network	None	47.605599	-122.330626
70	Bellevue	98004	11101 NE 12th St	PARKMETRO1	ChargePoint Network	None	47.620793	-122.192469
71	Renton	98055	4109-4251 Talbot Rd S	VALLEY MED CTR	ChargePoint Network	None	47.443123	-122.212538

In addition to zip code coordinates, demographical data and charging station data, we are including EV populational data in the WA. The data is available as a dataset of 39491 rows where each row represents one specific EV. The data was cleared and grouped by each Zip code with the number of EV and EVC along with population and population density within each zip code.

After dropping zip codes with 10 or fewer electric vehicles from dataframe, we have 285 zip codes.

	Zip	City	County	EV_count	EVC_count	Population	Density	Latitude	Longitude
<b>10759</b>	98052	Redmond	King	1440	11	58442	2907.83	47.677471	-122.121380
<b>7218</b>	98033	Kirkland	King	922	9	34338	3695.98	47.679030	-122.193400
<b>244</b>	98004	Bellevue	King	851	48	27946	3976.84	47.618371	-122.203080
<b>1481</b>	98006	Bellevue	King	832	5	36364	3401.89	47.562975	-122.152600
<b>20226</b>	98115	Seattle	King	820	5	46206	7018.28	47.683820	-122.301220
<b>9536</b>	98040	Mercer Island	King	761	14	22699	3591.24	47.569271	-122.232330
<b>14816</b>	98074	Sammamish	King	760	3	25748	2411.41	47.625364	-122.045347
<b>3416</b>	98012	Bothell	Snohomish	690	8	51136	3337.63	47.843110	-122.204570
<b>8140</b>	98034	Kirkland	King	644	9	40407	4428.14	47.718280	-122.197020
<b>15576</b>	98075	Sammamish	King	644	2	20715	2185.20	47.584879	-122.033685

Figure 2. EV, EV charging grouped by zip code

## Cluster Analysis

To identify groups (clusters) with similar parameters we applying the K-means clustering algorithm. To prepare data for clustering we replaced original parameters with a new parameter, "Number of EV per 1000 population", "Association between EVCS and Population Density", "Number of EVCS per 100 EV".

	EV_count	Number of EV per 1000 Population	Association between EVCS and Population Density	Number of EVCS per 100 EV
<b>10759</b>	1440	24.639814	3.782890	0.763889
<b>7218</b>	922	26.850719	2.435078	0.976139
<b>244</b>	851	30.451585	12.069885	5.640423
<b>1481</b>	832	22.879771	1.469771	0.600962
<b>20226</b>	820	17.746613	0.712425	0.609756

Figure 3. Modified dataframe

Consequently, the elbow method is used to identify the optimal number of clusters.

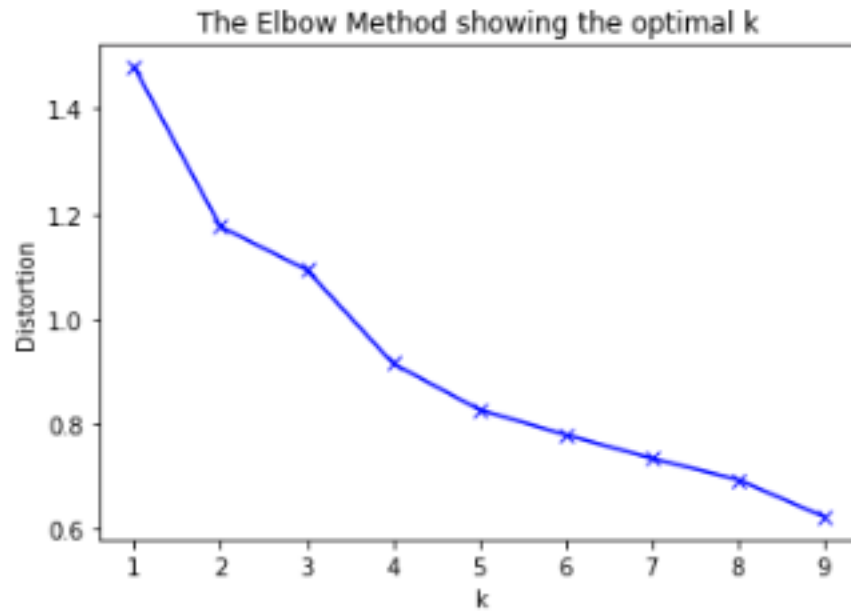


Figure 4. Clusters

The graph shows that the optimal number of clusters is 4.

The following map created based on results of K-clustering and illustrates different clusters by the color of the marker and the size of the marker is proportional to a quantity of EV in each zip code.

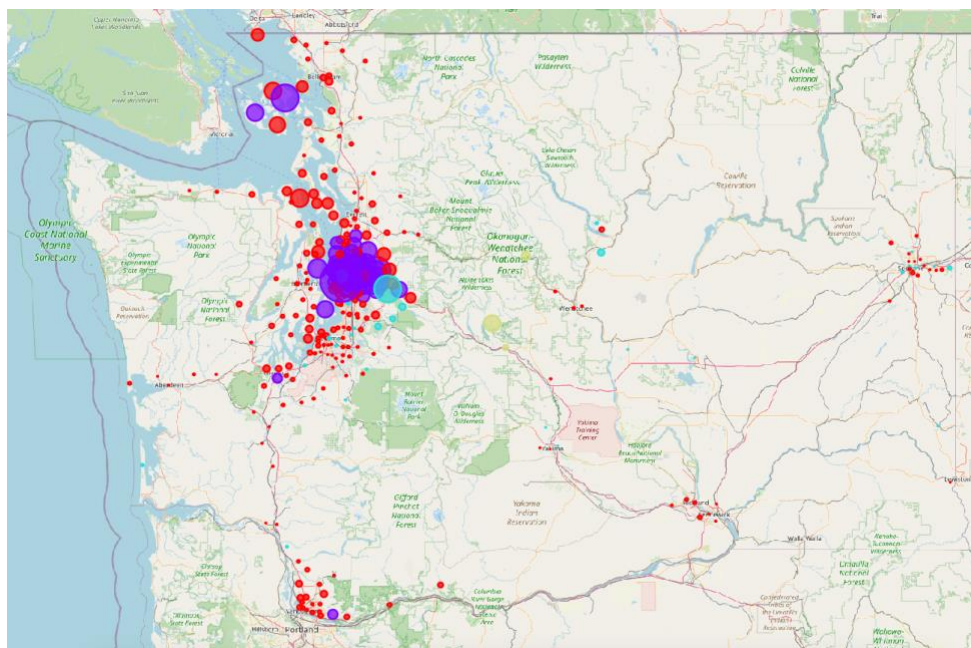


Figure 5. Washington state map with clustered zip codes.

On the scatter plot we can observe dark red circles representing the centroid of each cluster. The dark blue dots are the cluster 1, concentrating toward the upper right corner of the graph while, yellow dots are the cluster 4 which represents the majority of zip codes but have a smaller count of EV and EV per 1000 population.

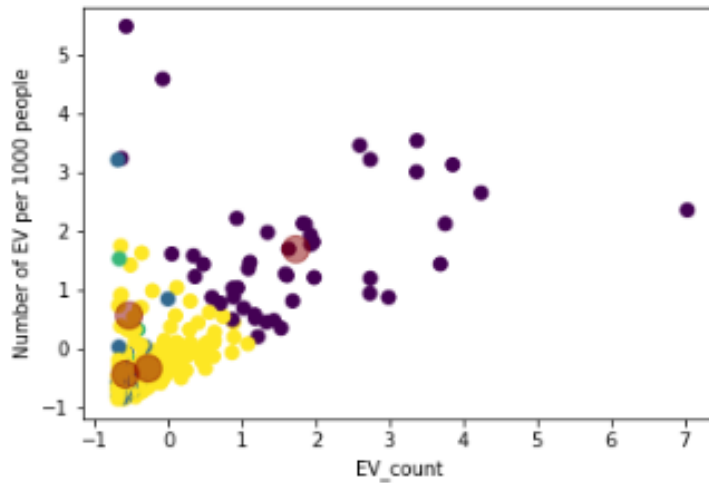


Figure 5. Washington state map with clustered zip codes.

## Results

Analysis shows that quantity and location of electric vehicles in the Washington state can be defined within 4 clusters. This clusters represents the concentration of EVs with regard to availability of charging stations, population and population density. Based on the results it is clear that cluster 1 is the most efficient option for EV service deployment. This cluster among other three, has the highest density of EVs and population on the relatively small geographic area.

Nevertheless, cluster 4 is the second by EV density but the largest, in terms of geographic size, which makes it less efficient option.

## Cluster 1



Cluster Labels	Zip	City	County	EV_count	EVC_count	Population	Density	Latitude	Longitude
10759	0 98052	Redmond	King	1440	11	58442	2907.83	47.677471	-122.121380
7218	0 98033	Kirkland	King	922	9	34338	3695.98	47.679030	-122.193400
244	0 98004	Bellevue	King	851	48	27946	3976.84	47.618371	-122.203080
1481	0 98006	Bellevue	King	832	5	36364	3401.89	47.562975	-122.152600
20226	0 98115	Seattle	King	820	5	46206	7018.28	47.683820	-122.301220
9536	0 98040	Mercer Island	King	761	14	22699	3591.24	47.569271	-122.232330
14816	0 98074	Sammamish	King	760	3	25748	2411.41	47.625364	-122.045347
3416	0 98012	Bothell	Snohomish	690	8	51136	3337.63	47.843110	-122.204570
8140	0 98034	Kirkland	King	644	9	40407	4428.14	47.718280	-122.197020
15576	0 98075	Sammamish	King	644	2	20715	2185.20	47.584879	-122.033685
16773	0 98103	Seattle	King	643	4	45911	9904.56	47.671346	-122.341660
12199	0 98053	Redmond	King	618	1	18784	662.22	47.640972	-122.033180
21347	0 98117	Seattle	King	503	3	31365	7952.92	47.685919	-122.378380
6354	0 98029	Issaquah	King	501	8	24348	2719.33	47.572401	-122.020650
2588	0 98008	Bellevue	King	495	6	24411	4436.60	47.609222	-122.115500
19251	0 98110	Bainbridge Island	Kitsap	494	4	23025	833.90	47.655260	-122.535080
19745	0 98112	Seattle	King	481	1	21077	6666.99	47.629653	-122.297520
18776	0 98109	Seattle	King	475	34	20715	10361.07	47.630648	-122.346750
13498	0 98059	Renton	King	449	1	34463	1725.23	47.493031	-122.141690
14377	0 98072	Woodinville	Snohomish	439	6	22312	1230.60	47.758786	-122.102050
4608	0 98021	Bothell	Snohomish	435	4	26722	2633.94	47.790653	-122.220210
5624	0 98027	Issaquah	King	431	9	26141	468.56	47.522828	-122.029210
17725	0 98105	Seattle	King	420	9	43924	10642.66	47.663770	-122.301180
33739	0 98501	Olympia	Thurston	402	14	38133	1107.18	47.014718	-122.881900
1095	0 98005	Bellevue	King	386	12	17714	2361.29	47.611021	-122.168580
23038	0 98125	Seattle	King	383	8	37081	6879.17	47.716648	-122.303080
21850	0 98118	Seattle	King	362	1	42731	6840.85	47.543348	-122.274960
24700	0 98155	Seattle	King	355	2	32778	4330.39	47.753019	-122.303730
22684	0 98122	Seattle	King	354	7	31454	13593.64	47.611570	-122.304060
25322	0 98177	Seattle	King	342	1	19030	3340.87	47.740886	-122.369780
25953	0 98199	Seattle	King	338	1	19686	4714.27	47.647670	-122.397580
24193	0 98144	Seattle	King	326	3	26881	7894.95	47.585770	-122.300810
18302	0 98107	Seattle	King	311	4	21147	9602.07	47.667470	-122.374680
17416	0 98104	Seattle	King	309	22	13095	16898.51	47.602520	-122.328550
21046	0 98116	Seattle	King	301	5	22241	7522.84	47.574870	-122.393920
6055	0 98028	Kenmore	King	299	2	20419	3605.57	47.752870	-122.247360
35666	0 98607	Camas	Clark	298	1	27899	593.94	45.609160	-122.405470
22212	0 98119	Seattle	King	268	2	21039	8637.64	47.638770	-122.366940
4361	0 98020	Edmonds	Snohomish	247	8	18304	3538.83	47.803668	-122.370960
13947	0 98065	Snoqualmie	King	225	2	12699	171.39	47.530639	-121.830530
22480	0 98121	Seattle	King	204	15	12628	28659.33	47.614870	-122.345780
14177	0 98070	Vashon	King	200	1	10624	287.72	47.416198	-122.468210
28300	0 98250	Friday Harbor	San Juan	146	1	7664	123.32	48.551130	-123.075630
9413	0 98039	Medina	King	123	1	2971	2058.62	47.626571	-122.232800
23970	0 98134	Seattle	King	31	9	644	190.87	47.578670	-122.334410
29607	0 98279	Olga	San Juan	19	2	608	43.35	48.632050	-122.813720



## Cluster 2

	Cluster Labels	Zip	City	County	EV_count	EVC_count	Population	Density	Latitude	Longitude
16397	1	98101	Seattle	King	136	39	10238	19718.35	47.610670	-122.334380
13171	1	98057	Renton	King	77	19	10613	1741.84	47.432251	-121.803388
25804	1	98188	Seattle	King	64	15	23111	3061.54	47.450321	-122.274720
114	1	98002	Auburn	King	46	9	31647	4423.38	47.304221	-122.216020
39059	1	99224	Spokane	Spokane	41	10	18289	156.22	47.632573	-117.493260
38388	1	99019	Liberty Lake	Spokane	36	6	9502	434.61	47.656171	-117.086280
38593	1	99201	Spokane	Spokane	32	15	13342	4445.30	47.663945	-117.431850
3083	1	98010	Black Diamond	King	32	6	5025	333.78	47.317802	-122.014790
38549	1	99163	Pullman	Whitman	30	5	31404	151.71	46.732705	-117.186480
37967	1	98837	Moses Lake	Grant	27	5	39722	82.26	47.133606	-119.284550
38625	1	99202	Spokane	Spokane	26	6	21580	3513.91	47.656692	-117.378990
32694	1	98402	Tacoma	Pierce	20	8	6356	6748.42	47.247671	-122.439710
30657	1	98327	Dupont	Pierce	20	3	8267	1203.66	47.088719	-122.643260
38052	1	98901	Yakima	Yakima	20	3	30169	258.64	46.616199	-120.464810
38928	1	99216	Spokane	Spokane	19	4	24362	1824.44	47.665819	-117.216990
10741	1	98051	Ravensdale	King	18	3	3270	64.00	47.359414	-121.886570
33299	1	98424	Tacoma	Pierce	17	3	10140	1607.53	47.242186	-122.359160
33173	1	98418	Tacoma	Pierce	16	7	10069	5981.88	47.066193	-122.113223
30677	1	98328	Eatonville	Pierce	15	3	10433	49.23	46.884733	-122.292370
37999	1	98843	Orondo	Douglas	13	5	1817	27.72	47.745842	-120.093260
38243	1	98942	Selah	Yakima	13	3	16973	90.10	46.726395	-120.569970
33324	1	98443	Tacoma	Pierce	12	3	5371	1057.51	47.202874	-122.376780
35986	1	98625	Kalama	Cowlitz	12	2	6133	76.17	46.015873	-122.797180
38970	1	99218	Spokane	Spokane	12	2	15531	2123.94	47.751674	-117.412400
10720	1	98047	Pacific	King	11	3	6339	2615.53	47.266190	-122.244630
36134	1	98640	Ocean Park	Pacific	11	2	4380	216.01	46.501781	-124.048010
38018	1	98848	Quincy	Grant	11	2	11518	25.59	47.182270	-119.858680
10731	1	98050	Preston	King	10	3	322	97.34	47.536015	-121.931195
37951	1	98831	Manson	Chelan	10	2	3708	78.99	47.915227	-120.129340

## Cluster 3

	Cluster Labels	Zip	City	County	EV_count	EVC_count	Population	Density	Latitude	Longitude
37882	2	98826	Leavenworth	Chelan	61	4	6504	6.40	47.728186	-120.73874
38134	2	98922	Cle Elum	Kittitas	32	4	5468	12.23	47.193770	-120.91733
38227	2	98940	Ronald	Kittitas	14	3	760	7.09	47.333940	-121.02979

## Cluster 4

	Cluster Labels	Zip	City	County	EV_count	EVC_count	Population	Density	Latitude	Longitude
23633	3	98133	Seattle	King	337	6	44555	6278.74	47.733852	-122.344610
5322	3	98026	Edmonds	Snohomish	302	4	35921	3851.87	47.821568	-122.336510
3115	3	98011	Bothell	King	301	8	29212	3568.63	47.751471	-122.202570
27040	3	98225	Bellingham	Whatcom	297	7	46172	3678.02	48.747578	-122.485080
2313	3	98007	Bellevue	King	275	10	24889	5683.90	47.610935	-122.141040
30114	3	98296	Snohomish	Snohomish	253	1	27956	820.32	47.846083	-122.110680
9161	3	98038	Maple Valley	King	252	1	31171	468.81	47.381989	-122.035530
12920	3	98056	Renton	King	251	3	32489	4322.67	47.510739	-122.183720
13248	3	98058	Renton	King	250	19	41938	2215.02	47.448322	-122.145840
16533	3	98102	Seattle	King	240	6	20756	15829.22	47.632870	-122.322530
27558	3	98229	Bellingham	Whatcom	237	1	30321	617.02	48.725417	-122.435478
8784	3	98036	Lynnwood	Snohomish	236	6	36000	3718.32	47.808816	-122.283940
26552	3	98208	Everett	Snohomish	230	2	51802	3200.62	47.893451	-122.197970
34141	3	98502	Olympia	Thurston	228	7	30491	560.83	47.071484	-122.977020
27337	3	98226	Bellingham	Whatcom	221	6	41235	384.54	48.759079	-122.435970
23421	3	98126	Seattle	King	212	1	20698	6731.53	47.546870	-122.374800
29801	3	98290	Snohomish	Snohomish	211	3	32714	276.26	47.930902	-122.039760
30900	3	98335	Gig Harbor	Pierce	192	5	24925	1117.29	47.301252	-122.605620
24001	3	98136	Seattle	King	192	1	14770	6424.91	47.538887	-122.388030
29336	3	98275	Mukilteo	Snohomish	190	3	20256	2653.82	47.916148	-122.302930
28509	3	98258	Lake Stevens	Snohomish	189	1	30524	1058.33	48.028355	-122.063270
10297	3	98042	Kent	King	182	5	43673	1537.33	47.363382	-122.114510
16220	3	98092	Auburn	King	177	2	39816	892.09	47.297285	-122.163280
31802	3	98370	Poulsbo	Kitsap	172	5	29528	522.07	47.743302	-122.630410
37413	3	98685	Vancouver	Clark	169	2	26217	2695.71	45.709555	-122.684730
36988	3	98682	Vancouver	Clark	169	1	52893	1754.05	45.673090	-122.513190
5086	3	98023	Federal Way	King	167	2	47510	4603.85	47.309021	-122.361780
18613	3	98108	Seattle	King	163	2	22374	2989.39	47.546188	-122.315140
4203	3	98019	Duvall	King	158	8	10725	140.51	47.735300	-121.962220
37157	3	98683	Vancouver	Clark	158	4	30832	4246.36	45.604075	-122.510350

207 rows × 10 columns

## **Discussion**

Based on the performed analysis, we are able to identify the estimate location within the largest cluster of electric vehicles in the Washington state where EV service deployment would be the most efficient. However, an additional analysis would help to predict the potential customer growth. For instance, EV data analysis relatively to all other type of vehicles registered in Washington state for the past several years will help to reveal EV market dynamic in specific cluster. Therefore, this insight will help us to take more competent approach in the case of EV service facility deployment.

## **Conclusion**

The data analysis was performed to identify the most optimal location for electric vehicle service in the Washington state. During the analysis we explored and analyzed some important statistical figures of each zip code in Washington state where any electrical vehicle registered as of May 2020. In addition, clustering analysis helped us to identify and highlight the groups of optimal zip codes. Eventually, cluster 3 which mostly situated within King County of Washington state chosen as the most optimal option for EV service that need more detailed analysis.