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Implementation of Electric Vehicle Database for Evaluation of the Government Vehicle Promotion Policy

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ABSTRACT: *This study analyzed the perception that the Korean government's electric vehicle promotion policy was insufficient by implementing electric vehicle database utilizing open big data, and compared the number of electric vehicle registrations by year and the status of electric vehicle charging stations by year to find out if the support policy worked significantly. Based on data extracted from the past and present policies, it not only analyzed the current situation of the Korean government's electric vehicle promotion policy, but also presented a rough image and roadmap for the future situation. Currently, the Korean government is implementing support policies of electric vehicle purchase in various fields, such as infrastructure expansion and subsidies, to achieve target number for electric vehicle supply. For the study, data tables such as the number of vehicles by region & by fuel, current status of electric vehicle charging stations by region, electric vehicle subsidies by region and electric vehicle subsidies were processed through formulas and database skills to produce significant data that could evaluate the government's promotion policy judgment. This study deserves high utility value in grasping the overall flow of the electric vehicle market in Korea.*

KEYWORDS - *Database, Electric Vehicle, Electric Vehicle Subsidy, Promotion Policy, Charging Station*

I. INTRODUCTION

The vision of the 4th Basic Plan on promoting the eco-friendly automobiles announced by the Ministry of Trade, Industry and Energy of Korea is to establish an eco-friendly car-centered social and industrial ecosystem in 2025 [1]. Specifically, the goal is to supply 2.83 million eco-friendly cars by 2025, of which 1.13 million are electric vehicles [2, 3, 4]. In order to achieve the target of electric vehicle supply, the government is implementing support policies in various ways, such as expanding infrastructure and providing subsidies for purchasing.

Starting from the perception that existing promotion policies has been insufficient, this study implemented database to compare the number of electric vehicle registrations and the status of electric vehicle charging stations by year and by region to determine whether the support policy worked significantly and to present the policy direction [5, 6, 7, 8, 9].

Earlier works [10,11] primarily focused on the location and optimal route of electric vehicle charging stations. These researches were getting into full swing. but did not deal with whether the government policies had a significant effect on demand for electric vehicles. This study focused on the Korean government's electric vehicle policies and changes in user demand.

II. SYSTEM ARCHITECTURE OF THE DATABASE

The database system for the Korean electric vehicle policies in Fig. 1 was created to evaluate whether government and corporate policies worked [12, 13, 14].

The entity ‘car_num’ had the number of vehicles by region / by fuel in 2021, 2020, 2019, status of electric vehicle charging stations by region in 2021, electric vehicle subsidies by region in 2021, electric vehicle subsidies by region in 2021, and electric vehicle subsidies by vehicle in 2021 [2, 3, 6]. The ‘car_num’ entity

consisted of attributes excluding the total number of vehicle registrations, electric vehicle registrations, and electric vehicles by region from 2019 to 2021.

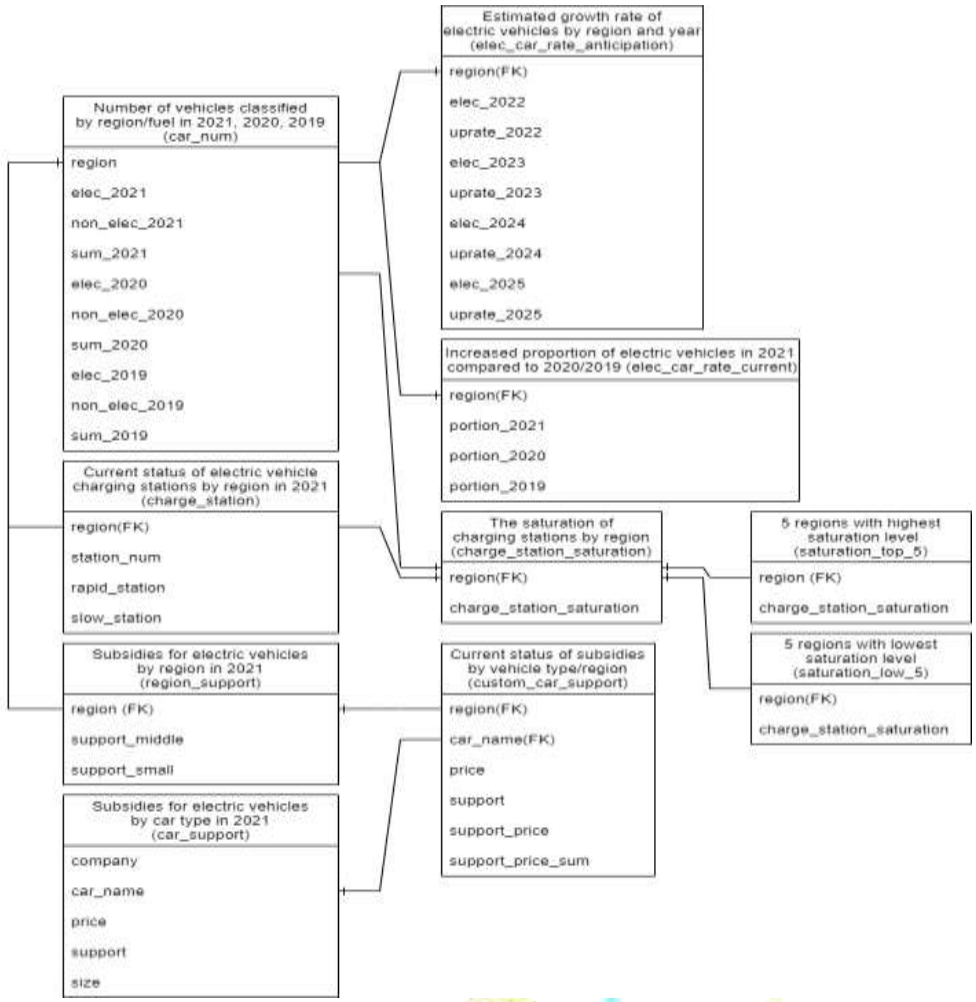

Fig. 1. Entity-Relationship diagram for electric vehicle database

The entity ‘charge_num’, the current status of electric vehicle charging stations by region 2021, set attributes as the regional name, the sum of fast charging stations, slow charging stations, and charging stations [15, 16].

The entity ‘region_support’ and ‘car_support’, 2021 regional electric vehicle subsidy, consisted of subsidy attributes provided to regions, small and medium-sized cars [4, 17]. Electric vehicle subsidies for each vehicle in 2021 consisted of the manufacturer's name, vehicle name, price, and subsidies provided by the company and vehicle level. The basic key was the ‘region attribute’ of the number of vehicles by region/fuel, the current status of charging stations by region, and the total number of electric vehicle subsidies by region were the ‘region’ of the number of vehicles.

Using these four tables, the study could create the expected annual electric vehicle growth rate by region, an increase in the proportion of electric vehicles in 2021 compared to 2020/2019, the saturation of charging stations by region, the top five and bottom five regions, and a table of subsidies by vehicle type/region. All of these tables had ‘region’ as their foreign key, and only the table on the status of subsidies by vehicle type/region set an additional foreign key as the ‘car_name attribute’ of the subsidy entity for each vehicle.

III. REPRESENTATIVES OF USEFUL INFORMATION

3.1 The Increasing proportion of electric vehicles in 2021 compared to 2020/2019 by region

As illustrated in Table 1, extracting data on the proportion of electric vehicles by region helped to establish promotion policy directions, such as extracting data on the proportion of electric vehicles in the order of 2019, 2020, and 2021, and injecting additional subsidies in areas with low proportion. The SQL query and result are shown in Fig. 2 and Table 1.

```
select region, round(((elec_2021 / sum_2021) * 100),2) as 'portion_2021(%)',
               round(((elec_2020 / sum_2020) * 100),2) as 'portion_2020(%)',
               round(((elec_2019 / sum_2019) * 100),2) as 'portion_2019(%)'
from car_num$
where region IS NOT NULL;
```

Fig. 2. SQL query for the increasing proportion of electric vehicles in 2021 compared to 2020/2019 by region

Table 1. Result for the Increasing proportion of electric vehicles in 2021 compared to 2020/2019 by region

region	'portion_2021(%)'	'portion_2020(%)'	'portion_2019(%)'
Jongno-gu	0.99	0.56	0.29
Jung-gu	1.43	1.38	0.55
Yongsan-gu	0.98	0.6	0.47
Seongdong-gu	1.2	0.9	0.47
Gwangjin-gu	0.48	0.3	0.14
Dongdaemun-gu	0.5	0.32	0.12
Jungnang-gu	0.51	0.36	0.12
Seongbuk-gu	0.62	0.44	0.16
Gangbuk-gu	0.53	0.4	0.12
Dobong-gu	0.54	0.37	0.13
Nowon-gu	0.48	0.32	0.12
Eunpyeong-gu	0.54	0.37	0.13
Seodaemun-gu	0.62	0.42	0.17
Mapo-gu	0.67	0.48	0.2
Yangcheon-gu	0.53	0.36	0.15
Gangseo-gu	0.61	0.41	0.14
Guro-gu	1.46	0.7	0.12
Geumcheon-gu	0.59	0.49	0.16
Yeongdeungpo-gu	1.46	1.33	0.05
Dongjak-gu	0.53	0.37	0.04

3.2 Current status of subsidies by vehicle type/region

Subsidies of the electric vehicle consisted of sum of subsidies by vehicle type and by region and at the time of purchase. So, when consumers consider purchasing electric vehicles, various options are presented so that they can check the vehicle price and subsidies by vehicle to make choices that suit their personal circumstances. The SQL query and result are shown in Fig. 3 and Table 2. In Fig. 3, region_support$.region implies subsidy for electric vehicles by region, region_support$.support_middle implies subsidy for medium-sized electric vehicles by region, region_support$.support_small implies subsidy for small-sized electric vehicles by region, and car_support$.car_name implies subsidy for electric vehicles.

```
select region_support$.region, car_support$.car_name, car_support$.price, car_support$.car_type_sub
                                                                    As ‘subsidy by car_type’
case
when car_support$.size = 'support_middle' then region_support$.support_middle
when car_support$.size = 'support_small' then region_support$.support_small
End As 'subsidy by region’
case
when car_support$.size= 'support_middle' then region_support$.support_middle +
car_support$.support
when car_support$.size = 'support_small' then region_support$.support_small + car_support$.support
End As 'subsidy_sum’
from car_support$, region_support$
where car_support$.car_name IS NOT NULL
   and region_support$.region IS NOT NULL;
```

Fig. 3. SQL query for the current status of subsidies by vehicle type/region

Table 2. Result for the current status of subsidies by vehicle type/region

region	car_name	price	subsidy by car_type	subsidy by region	subsidy_sum'
Seoul	EV6 Long Range 2WD 19Inch	5000	800	1700	2500
Busan	EV6 Long Range 2WD 19Inch	5000	800	1700	2500
Daegu	EV6 Long Range 2WD 19Inch	5000	800	1800	2600
Incheon	EV6 Long Range 2WD 19Inch	5000	800	1800	2600
Gwangju	EV6 Long Range 2WD 19Inch	5000	800	1900	2700
Daejeon	EV6 Long Range 2WD 19Inch	5000	800	1900	2700
Ulsan	EV6 Long Range 2WD 19Inch	5000	800	1700	2500
Sejong	EV6 Long Range 2WD 19Inch	5000	800	1900	2700
Gyeonggi-do	EV6 Long Range 2WD 19Inch	5000	800	1700	2500
Gangwon-do	EV6 Long Range 2WD 19Inch	5000	800	2040	2840
Chungcheongbuk	EV6 Long Range 2WD 19Inch	5000	800	2200	3000
Chungcheongnam	EV6 Long Range 2WD 19Inch	5000	800	2200	3000
Jeollabuk-do	EV6 Long Range 2WD 19Inch	5000	800	1800	2600
Jeollanam-do	EV6 Long Range 2WD 19Inch	5000	800	2300	3100
Gyeongsangbuk-d	EV6 Long Range 2WD 19Inch	5000	800	2100	2900
Gyeongsangnam-c	EV6 Long Range 2WD 19Inch	5000	800	2100	2900
Jeju	EV6 Long Range 2WD 19Inch	5000	800	1800	2600
Seoul	EV6 Long Range 2WD 20Inch	5100	800	1700	2500
Busan	EV6 Long Range 2WD 20Inch	5100	800	1700	2500
Daegu	EV6 Long Range 2WD 20Inch	5100	800	1800	2600

3.3 Saturation of charging stations by region

To determine the current status of electric vehicle charging stations, the number of electric vehicles used per charging station in each region was calculated after dividing the country by city and province. The SQL query and result are shown in Fig. 4. In Fig. 4, car_num$.elec_2021 means the number of electric vehicles in 2021, charge_station$.station_num means the number of charging stations for electric vehicles in 2021, and elec_2021 / station_num means the number of electric vehicles that charging stations have to take care of by region.

```
select car_num$.region, round((car_num$.elec_2021 / charge_station$.station_num),2)
        as charge_station_saturation'
from car_num$, charge_station$
where car_num$.region = charge_station$.region
order by 'charge_station_saturation' desc;
```

Fig. 4. SQL query for the saturation of charging stations by region

3.4 Predicting whether the target for supplying electric vehicles in 2025 would be achieved

```
Select region, round(elec_2021 * power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,1),2) as elec_2022,
        round(power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,1),2) as uprate_2022,
        round(elec_2021 * power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,2),2) as elec_2023,
        round(power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,2),2) as uprate_2023 ,
        round(elec_2021 * power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,3),2) as elec_2024,
        round(power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,3),2) as uprate_2024,
        round(elec_2021 * power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,4),2) as elec_2025,
        round(power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9,4),2) as uprate_2025
```

```
From car_num$
where elec_2021 is not null;
```

Fig. 5. SQL query for predicting whether the target for supplying electric vehicles in 2025 will be achieved

The database implemented in the study could predict the possibility of the Government's 4th Basic Plan for Eco-Friendly Vehicles aimed at 2025. The SQL query and result are shown in Fig. 5 and Table 3. In Fig. 5, elec_2021 implies the number of electric vehicles in 2021. And calculation of power((elec_2021 - elec_2020) / (elec_2020 - elec_2019) * 0.9, n) implies, as of 2021, the rate of increase or decrease in the number of electric vehicles in that year when n years have passed. And the number 0.9 implies an optional ratio derived on the assumption that 10% of buyers will decrease if the subsidy policy is the same.

Table 3. Result for predicting whether the target for supplying electric vehicles in 2025 will be achieved

region	elec_2022	uprate_2022	elec_2023	uprate_2023	elec_2024	uprate_2024	elec_2025	uprate_2025
Jongno-gu	705.74	1.42	998.97	2.01	1421.42	2.86	2012.85	4.05
Jung-gu	264.43	0.31	85.3	0.1	25.59	0.03	8.53	0.01
Yongsan-gu	1804.11	2.31	4186.16	5.36	9684.4	12.4	22406.89	28.69
Seongdong-gu	835.25	0.65	539.7	0.42	346.95	0.27	231.3	0.18
Gwangjin-gu	447.45	0.95	423.9	0.9	405.06	0.86	381.51	0.81
Dongdaemun-gu	405.08	0.82	335.92	0.68	276.64	0.56	227.24	0.46
Jungnang-gu	312.66	0.54	167.91	0.29	92.64	0.16	52.11	0.09
Seongbuk-gu	410.85	0.55	224.1	0.3	119.52	0.16	67.23	0.09
Gangbuk-gu	172	0.43	72	0.18	32	0.08	12	0.03
Dobong-gu	327.68	0.64	204.8	0.4	133.12	0.26	81.92	0.16
Nowon-gu	507.5	0.7	355.25	0.49	253.75	0.35	174	0.24
Eunpyeong-gu	461.44	0.64	288.4	0.4	187.46	0.26	115.36	0.16
Seodaemun-gu	376.04	0.68	259.91	0.47	176.96	0.32	121.66	0.22
Mapo-gu	505.92	0.62	310.08	0.38	195.84	0.24	122.4	0.15
Yangcheon-gu	568.71	0.71	400.5	0.5	280.35	0.35	200.25	0.25
Gangseo-gu	821.04	0.66	547.36	0.44	360.76	0.29	236.36	0.19
Guro-gu	2433.68	1.16	2853.28	1.36	3314.84	1.58	3860.32	1.84
Geumcheon-gu	147.28	0.28	42.08	0.08	10.52	0.02	5.26	0.01
Yeongdeungpo-gu	192.15	0.09	21.35	0.01	0	0	0	0
Dongjak-gu	241.23	0.43	106.59	0.19	44.88	0.08	16.83	0.03
Gwanak-gu	267.3	0.45	118.8	0.2	53.46	0.09	23.76	0.04
Seocho-gu	1808.04	0.61	1096.68	0.37	681.72	0.23	414.96	0.14

The uprate was a figure showing how many times the number of electric vehicles by region in 2021 would be increased in that future year. Therefore, the central government should prepare additional measures to supply electric vehicles intensively in areas where an uprate was lower than 1, especially for Jung-gu, Yeongdeungpo-gu, etc.

3.5 Regions of the lowest growth rate 5 regions

The database implemented could identify the lowest five areas of the expected number of electric vehicles, as of 2022. So the government should expand policy support in these areas to achieve the goal in 2025.

IV. CONCLUSIONS

4.1 Overall Conclusions

Based on data extracted from the past and present electric vehicle promotion policies, the study not only analyzed the current situation of the Korean government's electric vehicle promotion policy, but also presented a rough image and roadmap for the future situation. For the study, data tables such as the number of vehicles by region & by fuel, current status of electric vehicle charging stations by region, electric vehicle subsidies by region and electric vehicle subsidies were processed through formulas and database skills to produce significant data that could evaluate the government's promotion policy judgment.

In areas such as Gangnam-gu, where the profitability of electric vehicle charging stations was not stabilized and maintenance costs were high, the number of charging stations has proven to be relatively insufficient, and different GDP by region might differ in purchasing power.

Each district had different subsidies, electric vehicle charging stations, etc. depending on policies, and by comparing the increasing trend of electric vehicle charging stations, meaningful data, such as policy direction to invest additional subsidies into low growth areas of the electric vehicle could be derived.

4.2 Contributions

This study deserves high utility value in grasping the overall flow of the electric vehicle market in Korea.

Using the database implemented in the study, it is possible to present future policy directions by identifying through data whether electric vehicle demand and related facilities are secured due to the effect of current electric vehicle-related policies.

From the governmental perspective, the effectiveness of the government's subsidy policy can be confirmed, and meaningful information can be given to the policy judgment process, such as expanding the charging infrastructure for electric vehicles by region and improving the subsidy system for electric vehicles by region.

From the consumer′s perspective, those who wish to purchase electric vehicles can purchase electric vehicles that are most suitable for their situation by comparing the vehicle purchase amount and the subsidy system by vehicle/region.

From the Electric vehicle manufacturing company′s perspective, significant information can be obtained in the manufacturing quantity/price determination process of the electric vehicle.

4.3 Limitations

If open data of all cities and provinces subdivided in the electric vehicle policies the analysis method suggested in this study could be applied, even though data of only Seoul Metropolitan City were subdivided by district in this study. In addition, if external factors for the saturation of charging stations and the lack of electric vehicle numbers were considered the study would derive more accurate results.

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