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Method for the Definition of the Optimal Sites for Fast Chargers

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Executive Summary

The next wave of EVs with a real-life range higher than 300 km, combined with a fast charging network, will break forever the equation EV = city car. The availability of a fast charger network can dramatically increase the attractiveness of EVs, as Tesla demonstrates with its Supercharger network. Moreover, fast chargers may have a positive business case. There are different types of fast chargers and different business models, thus the locations where to deploy the charging stations have to be carefully selected in order to create an effective fast charging network. The method presented in this paper starts from the definition of measurable and objective criteria. Then, for each site a score is assigned to the criteria. The last step is the ranking of the sites. Criteria are clustered into 3 categories and the final ranking is done through a weighted sum of the score that each site has got in the 3 categories. This procedure has been introduced because, according to the type of charging station and the business model of the investors, a category may be more important than another. The application of the method has demonstrated that it is particularly suitable in those situations where different types of fast chargers have to be deployed and where the sites have to be consistent with the goal of the already defined business models.

Key words: EVSE (Electric Vehicle Supply Equipment), fast charging, market development, case-study, business model

1. Introduction

The next wave of EVs with a real-life range higher than 300 km, combined with a fast charging network, will break forever the equation EV = city car. i.e. an EV will be able to cover most of, if not all, the individual mobility needs. This is what Protoscar is directly experiencing as EV driver: Combining the high range of the company car (a Tesla) with its Supercharger network, all the car-mobility needs of the

company can be satisfied by an EV. The combination of high range with a fast charging network is the direction other OEMs are pursuing as well.

As soon as fast chargers reach a certain threshold of daily usage, they can have a positive business model. Thus, it is important to define an objective method to find the possible locations for fast chargers, allowing getting a positive business case. The conditions allowing a positive business case for fast chargers, the methods to define the best sites for their deployment, an example of application in a region of Switzerland and a checklist of actions, which are required to begin the deployment process, are investigated in this paper.

2. Classification of fast charging

There is no unanimous and codified definition of what fast charging means. Looking at the products on the market, the power of the charging stations sold as "fast charger" ranges from 22kW to 150kW or even higher. On one side the OEMs [1] are pushing to the higher range of power to shorten the gap between fuelling times and charging times. On the other side our experience shows that fast charging demand can be satisfied in different ways, because users have different needs and the investors have different strategies and business models. Thus, we consider two typologies of fast chargers:

- espresso&charge: Charging points allowing to charge 100 km range in 10 minutes or faster, aimed to cover the fast charging demand of people that have to minimize the charging time. The charging power for an espresso&charge charging station varies from 60 to 150 kW. An example of a charging station that currently offers a power outlet that can be flexibly upgraded to 150 kW is the charging station installed by GOtthard FASTcharge. The charging station has typically three outlets for electric vehicles (CHAdeMO, Combo2 and Type 2 AC). [2]
- coffee&charge: Charging points allowing to charge up to 100 km range in 30-60 minutes, aimed to cover the fast charging demand of people that can accept longer charging times. The charging power for a coffee&charge charging station varies from 22 to 50 kW. The charging station has typically three outlets (CHAdeMO, Combo2 and Type 2 AC). Although, the DC power output is quite different, both of them are included in the coffee&charge typology, because in some circumstances the charging time is comparable. [3]

3. Conditions for a positive business case

An essential precondition is that the sites have to be selected in order to get a positive business case. On one hand, the capital expenditures (CAPEX) and the OPEX (operating expenses) for the charging station and on the other hand the revenues have to be evaluated. The final goal is to find a suitable location that simultaneously maximizes the revenues due to its accessibility and attractiveness and minimizes the CAPEX and OPEX due to its feasibility and sustainability. Among the CAPEX, the ones related to the hardware of the fast charging station and to the grid connection have the highest impact on the profitability of the site. Among the costs related to the grid connection, the grid connection as such, the grid contribution cost and the ditch and surface covering are the highest cost bulks. Among the OPEX, the costs for the customer service (hotline), maintenance, access and payment system, insurance and the energy costs per kWh are the highest and can be scaled if the operator is part of an international network.

Given the investment, installation costs and operation costs, the ultimate criterion to assess whether a positive business case can be reached with the fast charger is thereby the number of possible daily charging sessions. Different sources indicate that a positive business case can be reached with six to eight charging sessions per day [4], [5]. In order to see where in an urban area a fast charging station can be placed and to see whether the potential areas could generate the required number of charging sessions, Protoscar developed a method to determine the amount of charging sessions with few necessary input data. Starting from the daily traffic at a certain area, the numbers of battery electric vehicles can be determined with EV penetration rates. Locally adjusted penetration rates can be applied by evaluating local influencing factors (such as the GDP per capita, projects in e-mobility). In order to determine the number of charging sessions

out of these BEVs that pass the location, further reduction efforts have to be undertaken. Initially, the vehicles that are not fast-charge capable have to be deducted. A part of the vehicles have to be deducted as well because they have their own proprietary systems (e.g. Tesla and eventually other OEMs). Thereafter, the willingness to undertake long trips with an electric vehicle has to be evaluated because mainly the long-distance travellers are interested in fast charging. After that, the need to charge, which can be specified with the state of charge, has to be considered because vehicles will only stop for fast charging if the state of charge is below a certain limit. Eventually, the market share of the area has to be estimated. One has to bear in mind that the traffic flow, the EV penetration rates as well as the limiting factors evolve over time. After having considered these factors, the daily charging sessions can be determined. However, in order to determine more accurately the expected amount of charging sessions, the attractiveness of the site (see detailed description of the criteria in chapter 4) has to be incorporated as well. This is why an "attractiveness bonus" that positively influences the number of charging sessions or an "attractiveness malus" that negatively influences the number of charging sessions is considered. Subsequently, the accurate expected daily charging sessions can be determined over time. Recent analysis and statistics related to the usage of the fast charging stations conducted by Protoscar and other studies [5] revealed that an attractive location with a daily traffic flow of about 30'000 vehicles enables between 1.5 to 2 charging sessions per day in Switzerland in 2017. Having the same conditions in 2020, around 8 charging sessions can be expected so that a positive business case will be given. In locations where these conditions are fulfilled, a payback period of about 7 years can be expected.

4. Criteria and method for the definition of the best location

Potential investors in fast charging infrastructure quite often have already defined a list of possible locations. Mainly because they own them or they are closed to their facilities. Once this "long list" has been defined, they need to know what the best locations to get a positive business case are, i.e. to rank them. Moreover, as explained in chapter 3, the fast chargers are offered with different power levels, thus the investors are interested to know both, the best locations and the best-suited charger for each site.

Some authors have already investigated how to define the optimal locations [e.g. 9, 10], but their methods were not directly applicable to get answers to the questions of the investors. Those methods have been designed to pick the optimal locations, given a certain area, without considering differences in charging stations. In this case the task was to define the optimal locations starting from a pre-defined list and, even more important, to define what charger matches better a certain site. Therefore it was necessary to develop a new method.

The proposed method starts from a set of criteria that have been selected in order to identify the conditions of a positive business case, i.e.:

- Maximizing the probability of getting a daily usage higher than the minimum required for profitability;
- Minimizing the costs for the connection to the grid and more in general for the installation.

Most of the criteria are basically the same used by other authors with some additions deriving from our experience, for instance the ones that take into account important aspects from an investor's point of view. The possible competition with other investors is an important aspect and has been evaluated considering the access and visibility of the site and the distance to other fast chargers (today and in the future). Other examples are the duration of the contract for the site area (rental or concession, in case the investor does not own the site) and the possibility to increase the number of charging stations. In order to identify what is the optimal charging station for each site, the method groups the criteria into three macro categories:

- Accessibility, i.e. to what extent the site can catch the traffic flows. It is quantified by the following micro criteria: Transit vehicles per day, access to main street, visibility from the street, distance to the next motorway entrance.
- Attractiveness, i.e. degree to which the site is able to offer things to do while the vehicle is charging. It is quantified by the following micro criteria: Availability of infrastructure in the perimeter of 50 to 70 meters from the chosen spot and its opening hours (restaurants, bars, shops and others), availability of public toilets and its opening hours.

- Economic sustainability and technical feasibility, i.e. the potential cost of grid connection and other installation costs, existing and potential competitors. It is quantified by the following micro criteria: Available power, distance from the transformer to the charging station, road surface, expansion possibility of the area for further parking places, distance to other existing fast chargers, distance to existing motorway service areas.

Points are assigned to each criterion. However, depending on the power outlet, (espresso&charge vs. coffee&charge, see chapter 2), the macro categories are weighted differently. In order to assess potential espresso&charge locations with a power outlet of up to 150 kW, the accessibility of the location is the essential criterion. The reason lies on the fact that these stations target users who need to stop for a very short time and the additional services of the site, i.e. the attractiveness is less important. Considering the total number of points, the accessibility of the location accounts for 50% of the points and the attractiveness and economic sustainability account for 25% each. In order to assess potential coffee&charge locations with a power outlet of up to 50 kW, the attractiveness of the location is the decisive criterion, because they target users who can afford longer charging time. Considering the total number of points, the attractiveness of the location accounts for 50% of the points, and the accessibility and economic sustainability account for 25% each. Weighting the points as described above, each location gets two scores: one for espresso&charge and one for coffee&charge. At the end the potential investors can evaluate both, whether a certain location is attractive for fast charging and also to see whether it is more suitable for an espresso&charge or for a coffee&charge kind of station.

5. Evaluation of the sites

The macro categories accessibility, attractiveness and economic sustainability were outlined in chapter 4. This chapter intends to give a better understanding of the examination process by describing the score that is assigned to each micro criterion. Since for the espresso&charge locations the accessibility is the most important criterion it is weighted twice as much as the attractiveness. For the coffee&charge locations the attractiveness is weighted twice as much as the accessibility, because these are the locations where electric car drivers are willing to spend more time. In the table, the macro categories with the micro criteria and the respective espresso&charge and coffee&charge points are displayed.

Table 1: Overview of the categories and the criteria

Criteria	Points espresso&charge	Points coffee&charge
Accessibility	***max. 50 P***	***max. 25 P***
Transit vehicles per day	max. 9 P	max. 10 P
Access to main street	max. 6 P	max. 5 P
Visibility from the street	max. 3 P	max. 5 P
Distance to the next motorway entrance	max. 32 P	max. 5 P
Attractiveness (infrastructure in the close environment)	***max. 25 P***	***max. 50 P***
Restaurant, bar (50-70m)	max. 3 P per Rest./Bar	max. 6 P per Rest./Bar
Public toilets (50-70m)	max. 3 P	max. 6 P
Opening hours (50-70m)	max. 2 P	max. 4 P
Further (incl. shopping opportunities, 50-70 m)	2 P per infrastructure	4 P per infrastructure
Economic sustainability and technical feasibility	***max. 25 P***	***max. 25 P***
Available power	max. 4 P	max. 4 P
Distance from transformer to the charging station	max. 7 P	max. 7 P
Road surface	max. 2 P	max. 2 P
Expansion possibility of the area for further places	max. 3 P	max. 3 P
Duration of contract	max. 3 P	max. 3 P
Distance to other existing fast charger	max. 3 P	max. 3 P
Distance to existing motorway service areas	max. 3 P	max. 3 P
Theoretical maximum of points (Number of points that a perfect location could reach)	**max. 100 P (1 P = 1%)**	**max. 100 P (1 P = 1%)**

The points have been assigned according to real benchmark cases (i.e. existing fast charging stations and Tesla Supercharger locations in Switzerland). The assigned maximum points were based on experts' evaluations, on the exchange of opinions with investors as well as on the literature. The points have been assigned after an accurate analysis and several calculation loops. The score of at least 70 points out of 100 (70%) has been evaluated as realistic for those existing successful fast charging sites.

5.1. Accessibility

The transit vehicles per day gets the maximum number of points if the site is frequented by more than 20'000 vehicles per day und gets no point if the daily traffic is below 10'000 vehicles per day.

If there is direct access and visibility from the street, the maximum number of points is assigned, since it is an additional advertising aspect, if not, no point is assigned.

The criterion related to the distance to the next motorway entrance is rewarded with the maximum number of points if the driving distance is below 1 km. If the driving distance is above 2 km, no points are assigned since from the customer point of view this could already be 10 minutes extra time to get to the charging station from the motorway, which should be avoided in fast charging.

Within the macro category "accessibility", the distance to the next motorway is the decisive criterion for potential espresso&charge locations. For potential coffee&charge locations, the traffic flow per days has the biggest impact on the accessibility.

5.2. Attractiveness

The availability of restaurants and bars is important for the attractiveness of a fast charging site. The number of points is assigned depending on the number of restaurants and bars within a radius of 50 to 70 meters with a fixed number of points per entity. An additional bonus or malus is applied by considering the trip advisor rating of the restaurant or bar.

If there is a public toilet in the perimeter of 50 to 70 meters then the maximum number of points is assigned, otherwise no point is given. Additional points are assigned if the public toilet has extensive opening hours.

Further points are given if the site has other shopping opportunities such as a retail store, bank or a post office.

Within the macro category "attractiveness" the number of restaurants and bars and the availability of other shopping opportunities are the determining criteria.

5.3. Economic sustainability and technical feasibility

A crucial criterion is that enough power is available. The maximum number of points is assigned if the power is free for up to 8 charging stations with a power outlet of 50 kW (coffee&charge) / 150 kW (espresso&charge) each. If the available power is not given for at least two charging stations, no points are assigned.

An additional criterion is the distance of the transformer station to the charging station. If the distance is below 30 meters, the maximum number of points is allocated. If the distance is above 150 meters, no points are assigned since the grid connection costs would be very high.

Since the road surface structure has an influence on the costs, this is considered as a criterion. If a bitumen road surface already exists at the potential fast charging site, additional points are assigned.

Besides this, it is also important that the site has expansion possibilities for further places because an upgrade, especially in highly frequented locations, is very likely. In fact, also the Tesla Superchargers locations usually install more than 12-14 places. If the upgrade will be feasible, the maximum number of points is assigned otherwise no point is given.

In addition, the length of the contract with the landlord of the location (if there is no purchase contract) is also a key criterion, because the charging stations should be operated in a long-term. 30 years has been

considered as a feasible long-term period of time. If a duration of more than 30 years is possible, the maximum number of points is given. If the duration is less than 15 years, no points are assigned.

In order to take into account the activities of the competitors that are already on the market, the distance to other charging stations has been considered in the evaluation. If the distance to another fast charging station is above 1 km driving distance, the site gets the maximum number of point. If the next fast charging station is closer than 500 meters to the location to be evaluated, no point is assigned. Moreover, the impact of competitors willing to deploy charging stations in the framework of the EVITE project [7] and the existing or planned charging stations both, in the interested area and in the surroundings [8], is considered.

Furthermore, in order to consider the market developments and possible competitors, also the distance to existing motorways has been considered, since it is very likely that sooner or later a fast charging station will be installed there (if there is not already a fast charging station). If the distance is above 20 km in both directions of the motorway, the maximum number of points is given. If the distance is below 20 km in both directions, no point is assigned.

Within the macro category "economic sustainability and technical feasibility" the weight of the micro criteria is equally distributed. The attention should be directed to the available power and to the distance of the transformer to the charging station, to the expansion possibilities and to the duration of contract.

5.4. Examples of application

The following table presents the scores assigned to two real sites.

Table 2: Application of the method at two real locations

Criteria	Location 1			Location 2		
	Situation	Points espresso&charge	Points coffee&charge	Situation	Points espresso&charge	Points coffee&charge
Accessibility		***39***	***14***		***13***	***7***
Transit vehicles per day	13'962	4	4	8'361	0	0
Access to main street	No	0	0	No	0	0
Visibility from the street	Yes	3	5	Yes	3	5
Distance to motorway entrance	400m	32	5	1.7km	10	2
Attractiveness		***13***	***24***		***17***	***44***
Restaurant, bar	1	3	6	3	3	18
Public toilets	Yes	4	6	Yes	4	6
Opening hours	6-23	2	4	5:30-24	2	4
Further	2	4	8	4	8	16
Economic sustainability		***13***	***13***		***18***	***18***
Available power	>400kVA	4	4	>400kVA	4	4
Distance of trafo station	120m	2	2	20m	7	7
Road surface	Asphalt	2	2	Asphalt	2	2
Expansion possibility	Limited	0	0	Limited	0	0
Duration of contract	Unlimited	3	3	Unlimited	3	3
Distance to other existing fast charger	>1km	2	2	>1km	2	2
Distance to existing motorway service areas	17km	0	0	15km	0	0
Total		***65***	***51***		***48***	***69***

Location 1 has by far less services but it is very close to the motorway entrance and has a higher traffic flow. Therefore it gets the highest "Accessibility" score. Location 2 has a lot of services around, thus it gets the maximum score for the "Attractiveness". Weighting these scores it is possible to see which kind of charging station is more suitable for each site, i.e. espresso&charge for Location 1 and coffee&charge for

Location 2. The economic sustainability is better for Location 2, due to the shorter distance from the MV/LV transformer. Duration of contract is unlimited because the investor in both locations owns the area.

6. WWZ case study: Application of the method to a region in central Switzerland

WWZ Energie AG, a power utility operating in central Switzerland (Canton Zug, see Figure 1 below) decided to evaluate possible fast charging locations within their area. They already had defined a "long list" of potential locations and their goal was to get a "short list" of the best ones. The long list consisted of 19 potentially interesting locations for fast charging stations in their area.

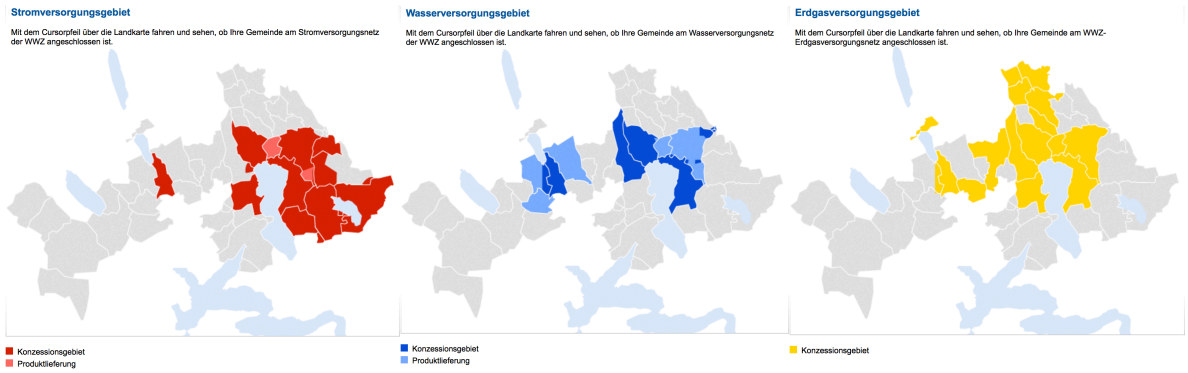

Figure 1: WWZ serves four different reference areas for electricity, gas, water and TV / Internet.

The criteria described in chapter 4 were evaluated for each site. All the micro criteria were assessed using secondary data [6], conducting research and also with inputs coming from WWZ. Each one of the 15 micro criteria was assessed at every location of the long list.

The score assigned to each criteria and the weight of the categories were defined considering also the preferred business model of WWZ, especially concerning the category "economic sustainability" because WWZ wants to act as a long-term player in the field of electric mobility. After having evaluated all the 19 sites with the described 15 micro criteria for a potential coffee&charge as well as an espresso&charge fast charging site, a final ranking could be established. Two favoured locations emerged from the process of analysis for potential coffee&charge locations as well as for a potential espresso&charge locations.

The first top locations to install an espresso&charge charging station have been ranked respectively with 64% and 63%. The following locations scored under 50%. For sites suitable for a coffee&charge charging station the first top locations have been ranked respectively 59% and 50%. The gap between the first two coffee&charge locations to the third is not as big as the one for the espresso&charge locations. The gap only accounts for 2%.

After Protoscar suggested different possible business models with business case calculations, WWZ decided to deploy a first espresso&charge pilot site. Therefore, a checklist of actions and information required for the implementation of a station has been prepared. The checklist of actions incorporated the following steps that are being undertake by WWZ:

- Choice of appropriate business model (build-own-operate vs. franchising)
- Contact of landlord and determine, if possible, a long-term contract (more than 30 years)
- Choice of partners (for hardware, access and payment system, etc.)
- Ask for building permit (depends on the necessary grid connection and amount of parking spaces)
- Installation of the charging station

7. Conclusions

In order to identify attractive locations for the two types of fast charging stations, espresso&charge and coffee&charge, Protoscar developed this method that is based on measurable parameters grouped into three macro categories: Accessibility, Attractiveness and Economic Sustainability and Technical Feasibility. For the espresso&charge locations the accessibility is the most important criterion, it is in fact weighted twice as much as the attractiveness. For the coffee&charge locations the attractiveness is weighted twice as much as the accessibility. In order to reach a positive business model also the economic sustainability and the technical feasibility are very important criteria.

All the approaches for the definition of the best sites for charging stations deployment apply the same method: Definition of the criteria, evaluation and ranking (see for instance [9] and [10]). These approaches are very useful tools for a first screening of bigger areas, providing basically the "long list" of possible sites. Instead, the method described in this paper has been developed to provide answers to the potential investors, in situations where the "long list" has been already done, where different types of fast chargers have to be deployed and where the sites have to be consistent with the goal of already defined business models. Further, this method can be extended also to situations where there is no previously defined "long list" of locations. It is possible to identify locations dividing the area of interest and evaluate each sub-area applying this method.

The strengths of this method, compared to other approaches, can be summarized as follows. First of all, this method considers not all the fast charging stations as the same, but stresses the market development in considering the different power of the charging stations and divides them in two different categories (espresso&charge and coffee&charge). Second, the method takes into account criteria related to the investors' point of view: The competition with other investors (access and visibility of the location, how far away are other fast chargers, today or in the future), the requirements of a long-term business model (duration of the contract to get the use of the surface where the chargers are installed (when the investors do not own the surface) and the possibility of the expansion of the area for further places.

Through an analysis of the real usage of the installed charging stations, it will be possible to do a verification of the data. The weight system of the scores of this method can thereby be updated according to the results of the real use of the stations.

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9. Authors

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Marco Piffaretti studied car design at the Scuola d'Arte Applicata e Design, in Torino and at the Art Centre College of Design, in La Tour de Peilz. In 1987 he created Protoscar and is managing director. From 1994 to 2001 he was also director of the large market pilot project for electric vehicles in Mendrisio, VEL-1, one of the biggest pilot projects achieving an market share of 8%.

Remo Müller holds a Master's Degree in Electrical, Electronic and Communications Engineering Technology/Technician. He joined WWZ Energie AG in 2015 and currently he covers the position of eMobility and Renewable Energy Manager at WWZ.

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Domenic Lanz holds a bachelor's degree in Business Administration from the University of St. Gallen and a MBA in Finance and Economics from the University of Oregon (USA). Before joining the GOFAST in 2016 to help build and operate the best EV fast charging network in Switzerland, he worked in the financial industry in Europe, Asia and the USA.