



## Project: Electric vehicle charging stations

With the push towards a more sustainable transportation sector, interesting challenges exist in redesigning these transportation networks. Within the realm of personal transportation, a popular sustainable alternative is the use of battery electric vehicles. Battery electric vehicles do, however, have the draw back that they require regular charging and at present not many cities are equipped with sufficient electric vehicle charging stations. The city council of Dundee wants to plan how they should establish their recharging infrastructure and has asked you for recommendations. The goal of this project is therefore to develop a plan for rolling out the development of electric charging stations in the city of Dundee. The city of Dundee council has divided the city into a set of grid squares the index of the grid cells can be visualised graphically in Figure 1.



Figure 1: The index of the demand grids for electric charging stations.

For each square the council has provided an estimate for the total energy requirements for electric vehicle charging in each of the next 4 years together with some information pertaining to the existing number of charging stations, the number of potential charging stations, the number of points of interest in each grid and the distance from each grid to the city centre. This data together with a few other features can be found in `Demand_data.xlsx`. Note the charging infrastructure which has already been established would satisfy some of this demand. Moreover, a graphical visualisation of the distribution the total energy requirements for electric vehicle charging is provided in Figure 2.

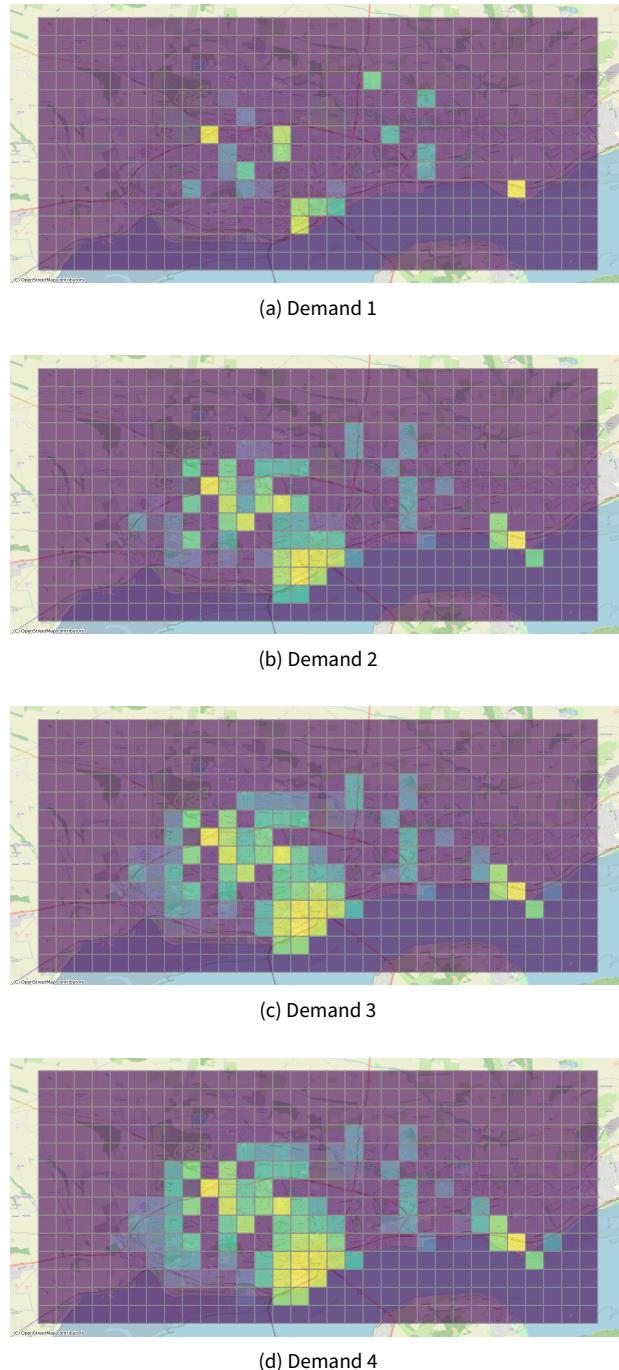


Figure 2: A graphical illustration of the expected demand in each grid square for the next four time periods.

Additionally, the council has provided some extra information on the potential charging locations, the current charging locations and the points of interest around Dundee which can be found in `Charging_points.xlsx`, `Potential_charging_points.xlsx` and `Intrest_points.xlsx`, respectively.

## 1 Additional information

Currently there are three different charging point types called rapid charging points, fast charging points and slow charging points each charging point generally consists of two connectors. At this point the council is unsure of exactly how much demand a single charging station can satisfy. Although their estimates, based on the previous years data, for the yearly demand that can be satisfied by a single connector of each charger type is listed below.

- Slow chargers can satisfy between 2 000 kWh/year and 3 500 kWh/year
- Fast chargers can satisfy between 4 000 kWh/year and 5 200 kWh/year
- Rapid chargers can satisfy between 30 000 kWh/year and 50 500 kWh/year

At this point the council does not have a contract with any company to install electric vehicle charging points, however, the council expects that if the infrastructure for an electric charging point has been established at a potential charging location, the to place another charging points at the same location would come at a reduced cost. The council has not decided on a budget for establishing the electric vehicle recharging infrastructure and would welcome any recommendations.

## 2 Solution requirements

The Dundee council has listed a few of the solution requirements below.

1. The council wants to limit the number of charging point locations in each grid square as this may result in too much traffic in the grid square.
2. The council also to limit the number of charging stations in the city centre. Generally the largest demand for recharging facilities in the centre of town, however, if all this demand is satisfied in the city centre it may result in increase traffic in the city centre.
3. Not all electric vehicles can be charged using rapid charging stations, specifically plug-in hybrid vehicles. The council would like to see a variety of different charger types.
4. The council does not expect to satisfy all of the demand in each grid square, remember this is just an estimate.

## 3 Criteria

We will use the following criteria to evaluate your proposed solution method:

- Does your solution give us a clear path to better charging point location decisions?
- Does your solution scale to the size that it is usable in a city like Dundee?
- Do your suggestions make logical sense?

## 4 Deliverables

You are expected to deliver two things at the end of the project: A *project report* and a *project presentation*.

The *project report* should consist of two parts: an *executive summary* (1 page) and the core *technical report* (8 pages).

The *executive summary* should be understandable to non-technical people that work in town planning and should be self-contained. It should give an overview over your approach and the likely impact it is going to have. Typical things that are contained here are: Important assumptions, main conclusions, and possible next steps towards an implementation.

The *technical report* is addressed to technical experts who would need to evaluate and implement your solution. Therefore, typical elements are: An analysis of the problem, models that were considered, justifications for the models chosen (and not chosen), computational experiments performed (and their results), and detailed conclusions and recommendations.

We ask you to include *code and the data* you used for your computational experiments in your submission.

For the *presentation*, you will present to Diween and Kit. Your presentation should last 10 minutes; we will have five additional minutes for questions.

## 5 Meetings

During your project, you will have two weekly meetings to discuss your project. Diween will be playing the role of somebody who wants to use your tool and will be able to answer questions about the problem. Kit will be there to answer technical questions to help you get your models running etc. We plan that you have one weekly meeting with Diween (15 min length) and one weekly meeting with Kit (15 min length). As 15 minutes are relatively short, we recommend that you plan your questions in advance.

## 6 Methods and Tools

You are free to choose the methods and tools you use to approach this problem. We have chosen the specific problem, because we think that you are able to produce a solution using

only Mosel/Xpress to solve optimization problems and either R, Python or Microsoft Excel to analyze and prepare the data. If you prefer other tools, feel free to use them. Your solution approach should be driven by the problem.

Please note, however, that the more obscure your methods and tools are, the less we can help you with specific problems you encounter.

## 7 Literature use

The problem has been discussed in the OR literature in many variants. You are free to read and use the literature. You must, however, cite everything properly and explain the model you use and its assumptions fully. To be clear, this also means that you have to cite your sources if you base your model on something you read in an article. One word of warning: a substantial part of the literature is devoted to very complex models. You do not have much time for your project, so I urge you to start with a simple model that works and refine from there.