

# Advanced Analytics and Application – SS 2025

Master of Science WI / IS

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## Team Assignment

This AAA team project is designed to test a representative cross-section of the data analytics and machine learning approaches we will cover during this course. It is based on a real-world problem with high relevance to the current hot topic of smart mobility systems and will act as an illustration of how we can use data in impactful ways to address pressing societal issues.

### 1 Background

Dear students,

Nice to hear from you, and that you are taking up the challenge. As you have already noticed, the smart mobility market is highly competitive. Many large companies and small start-ups such as Uber, Lyft, FreeNow, Lime, Tier, - you name the rest - are active in this industry. Current reports and projects indicate that particularly ride-hailing (in combination with autonomous and electric vehicles) will dominate the market in the near future. The market for this business seems to be huge. Car manufacturers realized that they need to offer comparable mobility services to their customers, otherwise they might be disrupted by tech titans from Silicon Valley (or soon perhaps from China).

For the following team project, we put you in the position of a top-tier management consultancy. As the Data Science Team of Bane & Wayne Partners (BWP), you are experts in the field of Machine Learning and Data Science. **Background:** A renowned German car company is in the process of establishing a platform for ride-hailing mobility services. Initially, the client wants to offer its US customers (as customers from the US market are more receptive for novel business models) a ride-hailing platform using a fully electrified vehicle fleet. However, the customer lacks tactical and strategic know-how in the area of operations management of electrical vehicle fleets. Therefore, our client asks for our help and would like to better understand the dynamics in the field of ride-hailing for a US city in temporal and spatial resolution.

### 2 Description of Dataset

You have been provided with a historical dataset of taxi data from Chicago, USA. Taxis are considered a good-enough proxy for potential ride hailing vehicles. This data was made available by the Chicago Data Portal and contains taxi trips from 2024 onwards. Detailed documentation related to the taxi trip data can be found: [https://data.cityofchicago.org/Transportation/Taxi-Trips-2024-/ajtu-isnz/about\\_data](https://data.cityofchicago.org/Transportation/Taxi-Trips-2024-/ajtu-isnz/about_data).

For your assignment you should also draw on weather data. Part of the work of a data science is to obtain relevant datasets independently. For this purpose, we would like you to collect weather data by your own. There are many resources but we would recommend using open data. You might have a look at the official open data government website (<https://www.ncei.noaa.gov/access/past-weather/chicago>) or on Kaggle (<https://www.kaggle.com/datasets/>), or any other source you find valuable for your research. Bear in

mind, the temporal resolution of your chosen weather data might impact the predictive power of your models.

Also, you should consider to harness Point-Of-Interest data for your project. Many researchers have shown that POI is a highly influential factor effecting customers of urban mobility. A possible source for POI data is OpenStreetMap. However, this is **not!** mandatory; you should decide based on your skills, resources and time plan whether to consider POI data.

### 3 Description of Tasks

1. **Data Collection and Preparation:** You have access to the taxi trip data. As the CSV file might be too large for your computer to open it with Python, you could preprocess the file first with tools like “sed” or “xsv” in order to filter out not needed rows and columns. To obtain hourly weather data, access the links provided above. Also, provide a detailed description of the trip dataset such that there are no pending questions. Due to privacy reasons, spatial data is given only on census tract level. To better analyze location data – specifically in lower dimensions - further discretize the city in scope with the help of suitable tools (such as a matrix of hexagons using h3-Uber). This discretization is crucial for the analysis of the spatial resolution. Furthermore, you should also consider different temporal discretization (e.g., hourly, 4-hourly, daily) etc.
2. **Descriptive (Spatial) Analytics:** Analyze taxi demand patterns: Specifically show how these patterns (start time, trip length, start and end location, price, average idle time between trips, and so on) for the given sample varies in different spatio-temporal resolution (i.e., census tract vs. varying hexagon diameter and/or temporal bin sizes). Give possible reasons for the observed patterns.

Furthermore, can you identify spatial hot spots for trip demand using Gaussian Mixture Models (i.e., using Spatial Kernel Density Estimation)?

3. **Predictive Analytics with a) Support Vector Machines and b) Neural Networks:** Develop two prediction models that predict taxi trip demand using a) support vector machines and b) neural networks (deep learning) in spatio-temporal resolution (i.e., spatial-unit and time buckets). In other words, your method should predict for each spatial unit (hexagon and census tract) and time-basket (e.g., 08am-11.59am) the taxi demand. Also advise a reasonable validation strategy for your prediction model (i.e., definition of test, training data etc).

#### **Approach for SVM:**

- Simply start without a kernel. Then, gradually make your model complex by integrating different kind of kernels. Also, use grid search to find optimal values for your hyperparameters.
- How good is your model? Evaluate your model’s performance and comment on its shortfalls.
- Show how your model’s performance varies as you increase or decrease temporal resolution for the following period length: 1h, 2h, 6h, 24h. Also, vary the length of the hexagon edges. How does your performance change when you only use census tract as spatial units?
- How could the model be improved further? Explain some of the improvement levers that you might focus on in a follow-up project.

#### **Approach for Deep Learning:**

- Repeat the steps from subtask 4a), but this time use a feedforward neural network.
- Is the performance very different from the previous approach?
- With this realization, do you think it is worth to employ a deep-learning approach?

#### 4. **Smart Charging Using Reinforcement Learning:**

Consider an electric taxi driver who can charge her vehicle at home. To simplify the problem, we assume that the vehicle always arrives at home at 2 p.m. and leaves the garage at 4 p.m. each day. We want to design an intelligent charging system (an automated agent). Therefore, instead of a flat charging rate, the charging agent adjusts the charging power every 15 minutes, which is bounded between 0 kW and the highest rate (e.g., 22 kW). Also, the vehicle's battery has a capacity that cannot be exceeded. After leaving the garage, the taxi needs enough energy to complete its working day. The energy demand is a stochastic value following a normal distribution (you should choose the parameters, e.g.,  $\mu = 30$  kWh,  $\sigma = 5$  kWh) and must be generated exactly when the driver wants to leave. The agent’s goal is to avoid

running out of energy (you should consider a very high penalty for running out of energy) and to minimize the recharging cost. The recharging cost follows an exponential function of the power (i.e., charging cost  $(t, p) = \sum_{t \in T} \alpha_t e^p$ ), where  $\alpha_t$  is the time coefficient and  $p$  is the charging rate.

The task is to create the environment (a very simple discrete event simulation) that receives the agent's decisions and returns the reward. In addition, you must define a Markov decision process, including states, actions, and reward function, and solve it using a reinforcement learning algorithm (e.g., deep q-network) to find optimal charging policies. To allow the use of discrete action methods, you can consider only limited charging options such as zero, low, medium, high.

**5. Discussion & Outlook:** Discuss the implications of your results for the potential fleet operator (client). Which further analysis would you consider useful and could be conducted on the given dataset? Which other external data sources might be interesting to consider? Is it sensible to install private charging stations, or should the operator draw on public charging stations?

### ***Notes and tips***

- Make generous use of visualization techniques to clearly illustrate your findings and present them in an appealing fashion.
- Evaluate your methodology and clearly state why you have opted for a specific approach in your analysis.
- Relate your findings to the real world and interpret them for non-technical audiences (e.g. What do the coefficients in your regression model mean? What does the achieved error mean for your model? etc.)
- Make sure to clearly state the implications (i.e., the "so what?") of your findings.
- Do not forget that your goal is to convince the customer of your results.
- You can utilize an Appendix if you want to reference illustrations or even code that is not meant for the main text body but you feel is important.