How a Hidden Markov Model (HMM) could be used in my capstone project

Capstone idea 1: Tracking Urban Service Quality
This project aims to develop a predictive system for monitoring the gradual deterioration of urban services (electricity, water supply, road maintenance) before public complaints become urgent. A Hidden Markov Model (HMM) is well-suited for this task due to its ability to model systems where the underlying state is not directly observable but can be inferred from a sequence of observable events.

1. Describe the Observations:
The model will use measurable, time-sequenced citizen feedback data about public services such as water supply, electricity, or road conditions. Examples of measurable observations include:

- Electricity: Frequency and duration of power outages, voltage fluctuations, reported repair times.
- Water Supply: Frequency and duration of interruptions, water pressure readings, water quality parameters, pipe burst reports.
- Road Maintenance: Number of new potholes/cracks, road roughness index, frequency of repair requests.
- General/Cross-Service: Citizen complaints (normalized), response times, maintenance budget data.

2. Type of HMM Problem:
The model has to discover the hidden states from patterns in the observed complaints over time, so it is a Learning/Training problem.

3. Training Algorithm: Baum-Welch
a. Known values at the start:
- The observed complaint sequences
- The number of hidden states
- Number of possible observations

b. Unknown values to be learned:
- Transition probabilities between hidden states
- Emission probabilities
- Initial probability distribution

4. Parameter Updates:
The HMM training process will update:
- The transition matrix (A): probabilities of moving between hidden states
- The emission matrix (B): probabilities of observing a specific complaint pattern
- The initial state distribution (π): the likelihood of starting in each hidden state

These parameters will allow the model to estimate the underlying condition of services over time and support predictive maintenance and decision-making in urban infrastructure management.