# Define Problem:

Software Solution for Planning and Monitoring of Pothole Repair Process using a fleet of UGVs.

# Data Collection: [csv, json/geojson, osm]

* download a map of neighbourhood (OpenStreetMap)
* information from government’s dataset (*OR randomly generate potholes*)
  + coordinates
  + type of road defect (pothole, crack, dent)
  + dimension (not available in govt data)

# Data Cleaning: [python]

* remove duplicates
* handle missing values
* standardise data items

# Data Preprocessing: [python]

## EDA

## Resource allocation

* Calculation of
  + area & volume of road defects
  + material required to repair
  + time to fix
  + cost (fuel/battery) involved

# Implementation: [python, webots/sumo, csv, json]

## Route Planning and Scheduling:

* create fleet manager
* create fleet of ‘n’ bots
* create pothole repair jobs
  + break jobs if required material exceeds payload capacity
* assign jobs to each bot [task implementation = blackbox]
* return bots to refill materials when needed

## Execute:

* Deploy bots (w/ sensor)
  + GPS
* Real-time Monitoring
  + update at regular interval (heartbeat)
  + update job status, GPS at start and finish of every job
  + load balancing (redistribute remaining workload)
* Record this data

## Simulation:

* normal – happy scenario
* breakdown 1 bot
  + determine based on missing 5 heartbeats.
  + load balancing (redistribute remaining workload)
  + every existing bot has different start coordinates.

# Visualisation and Reporting: [python / tableau]

* EDA for features
  + per vehicle
  + per pothole
  + per unit area
  + per unit time

Data Science concepts involved:

1. DBMS / file handling and other formats
   1. CSV
   2. JSON / NoSQL
   3. GeoJSON (GIS files)
   4. OSM
   5. Webots (wbt, proto)
2. Data collection thru Simulation
3. Real time monitoring
   1. Load balancing
4. Data Analysis
5. Data Visualisation
6. Reporting

Tools/libraries involved:

1. Python, Folium, ORS
2. OSM and ORS (open route service)
3. Webots/ SUMO
4. Tableau
5. deploy 1 bot – A to B – record GPS, other sensor readings.
6. create fleet manager – deploy 2 bots. A to B, A to C – record sensors.
7. generalise
8. bot failure scenario

Task breakdown as discussed w/ Hunar:

1. create 1 bot, 1 road, 1 pothole – simulate using SUMO.
2. see sumo.\_\_\_.xml files – create them using python
3. dataframes – material, logistics, job, time, service – reporting/ scheduling – simulate in SUMO.

**Dissertation: Pothole Repair Process Automation using a Fleet of Bots**

* **Introduction** (1500)
  + Problem statement:
    - Inefficiencies and dangers of traditional pothole repair methods
    - Economic impact of potholes on infrastructure and vehicles
  + Proposed solution:
    - Automation of pothole repair process using a fleet of bots
  + Dissertation objectives and expected outcomes
* **Literature Review** (3000)
  + Existing pothole detection and repair technologies
    - Automated pothole detection systems (cameras, LiDAR)
    - Traditional pothole repair methods and their limitations
  + Research on robotic applications in infrastructure maintenance
    - Case studies of successful robotic deployments
    - Challenges and limitations of existing robotic solutions
* **Methodology** (3000)
  + Design of the pothole repair bots
    - Components and functionalities of the bots (detection, cleaning, filling)
    - Communication and coordination between bots in a fleet
  + Development of the automation process
    - Workflow for pothole detection, repair, and data collection
    - Integration of bots with pothole detection and management systems
  + Simulation and testing of the proposed system
    - Evaluation of the effectiveness and efficiency of the bot fleet
    - Safety considerations and risk mitigation strategies
* **Design and Implementation** (3000)
* **Results and Discussion** (3000)
  + Performance evaluation of the pothole repair bot system
    - Repair speed and accuracy compared to traditional methods
    - Data analysis on bot performance and pothole characteristics
  + Economic and environmental benefits of the proposed solution
    - Cost reduction in pothole repairs and road maintenance
    - Environmental impact of faster and more efficient repairs
  + Discussion of challenges and limitations of the system
    - Technical limitations of the bots
    - Integration challenges with existing infrastructure
    - Social and regulatory considerations for autonomous robots
* **Conclusion** (1000)
  + Summary of the research findings and key achievements
  + The potential impact of the pothole repair bot system on infrastructure maintenance
  + Recommendations for future research and development
* **References**

**Introduction** (1500)

* + **Background** (500)
    - Briefly discuss the prevalence of potholes on roads globally.
    - Highlight the negative impact of potholes on road safety and driving experience.
  + **Project Rationale** (500)
    - Mention the limitations and inefficiencies of traditional pothole repair methods (e.g., time-consuming, labor-intensive, potential traffic disruption).
    - Briefly introduce the concept of automation in infrastructure maintenance.
  + **Problem Statement** (100)
    - Clearly state the problem of inefficient and potentially risky pothole repairs using traditional methods.
    - Quantify the problem if possible (e.g., statistics on pothole-related accidents, economic costs of road damage).
  + **Project Aim** (100)
    - Define the overall goal of your project: to automate the pothole repair process using a fleet of bots.
  + **Project Objectives** (300)
    - List specific, measurable objectives that your project will achieve.
    - These could include:
      * Design and develop a fleet of pothole repair bots.
      * Automate the pothole detection, cleaning, and filling process.
      * Evaluate the effectiveness and efficiency of the bot-based repair system compared to traditional methods.
      * Analyze the economic and environmental benefits of the proposed solution.

**Introduction: Background**

**The Pervasive Problem of Potholes in the UK**

The United Kingdom grapples with a significant and persistent challenge: potholes. These ubiquitous road defects are more than just a nuisance for drivers; they pose a serious threat to road safety and contribute to billions of pounds in vehicle damage annually. Understanding the prevalence and impact of potholes in the UK is crucial to establishing the rationale for this project's proposed solution – a fleet of automated pothole repair bots.

* **A Nationwide Epidemic:** Potholes are a common sight across the UK's road network. The RAC Pothole Index reports a staggering average of six potholes per mile on council-controlled roads in England and Wales alone [1]. This translates to a vast number of defects requiring repair, with estimates suggesting over one million potholes plague UK roads [2].
* **Impact on Road Safety:** The presence of potholes poses a significant safety risk to motorists, cyclists, and pedestrians. Sudden impacts with potholes can cause vehicles to lose control, leading to accidents and injuries. For cyclists and motorcyclists, even small potholes can be particularly dangerous, potentially causing falls or swerving maneuvers that increase the risk of collisions.
* **Economic Burden:** The financial repercussions of potholes are considerable. The RAC reports a 33% rise in pothole-related breakdowns between 2022 and 2023, highlighting the strain placed on vehicles [2]. These breakdowns result in repair costs for drivers, lost productivity, and potential insurance claims. Furthermore, potholes contribute to the overall deterioration of road surfaces, necessitating more extensive and expensive roadworks in the long run.
* **Infrastructure Challenges:** Several factors contribute to the prevalence of potholes in the UK. The aging road network, often dating back decades, is susceptible to cracking and wear due to heavy traffic volumes and harsh weather conditions. Limited funding for road maintenance further exacerbates the problem, as local authorities struggle to keep pace with repairs [3].
* **Inefficiencies of Traditional Repair Methods:** Current pothole repair methods in the UK are often manual and time-consuming. They frequently involve road closures and traffic disruptions, leading to congestion and frustration for drivers. Additionally, the reliance on human labour can be inefficient, with repairs susceptible to inconsistencies and potential safety risks for road workers.

In conclusion, the UK faces a significant problem with potholes that impacts road safety, the economy, and overall infrastructure integrity. Traditional repair methods are proving inadequate to address this widespread issue. This project seeks to explore a novel solution – a fleet of automated pothole repair bots – to address the limitations of current methods and potentially revolutionize pothole repair in the UK.