Consider the trajectory dataset in the CSV file named “trajectories.csv.” This data contains 63 minutes of video trajectories (all recorded users). Each trajectory contains the following information:

COLUMN NAME	DESCRIPTION
OBJECT_ID	A Unique ID for each Road User
USER_CLASS	Predicted Road User Class, where **Pedestrian** is **0**; **Bicyclist** is **1**; **Car** is **2**
FRAME_NUMBER	The frame number that the road user is detected in the video (not that the frame rate of the camera was **15 frames-per-second**),
X_COORDINATE	X Coordinate of the Road User at each Frame (the value is in meter)
Y_COORDINATE	Y Coordinate of the Road User at each Frame (the value is in meter)

For example, the following sample from the CSV file means that the ID of the road user is **604**, the class of the road user is **Bicyclist (2)**, and the road user is detected at 11543rd Frame (which means that 11543/14=824.5 seconds from the beginning of video recording):

User_ID	*User_Class*	*Frame_Number*	*X_Coordinate*	*Y_Coordinate*
604	2	11543	39.35	39.75

Please answer the following questions:

1. How many pedestrians, cyclists, and vehicles are observed in this dataset?

2. Scatter plot all the trajectories at the same plot while points of each user type are in the same color (one color for pedestrians, one color for Bicyclist, and one color for cars).

3. Calculate the speed of each road user at each Frame $i+1$ in km/hr. i start from 1, therefore $i+1$ starts from the 2nd Frame to the last frame number of the road user trajectory.

$$SPEED_{i+1} = fps \times \left(3.6 \frac{km \times sec}{meter \times hr}\right) \times \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

   For the first Frame that road user appears, use the speed of the second Frame:

$$SPEED_{frame_1} = SPEED_{frame_2}$$

4. Plot the histogram of the average speed of the pedestrian, bicyclists, and vehicles on the same graph (use 1km/hr as bin width).

5. If the speed limit at this intersection is 30 km/hr, how many vehicles are over speeding in at least one sample (maximum speed of the vehicle can be used for this purpose)? Plot the histogram of maximum speeds of only vehicles and speed limit (30 km/hr) as a vertical line on the same graph (use 1km/hr as bin width).

6. Compute **Post-Encroachment Time (PET)** (**check the next page**):

    i. Compute the PET conflict between vehicle and pedestrian **while the pedestrian arrives first**, and then the vehicle arrives. Exclude conflicts if $PET > 10s$.

    ii. Compute the PET conflict between vehicle and pedestrian **while the bicyclist arrives first**, and then the vehicle arrives. Exclude conflicts if $PET > 10s$.

    iii. How many vehicle-pedestrian conflicts with $PET \leq 5s$ do exist?

    iv. How many vehicle-pedestrian conflicts with $PET \leq 2s$ do exist?

    v. How many vehicle-bicyclist conflicts with $PET \leq 5s$ do exist?

    vi. How many vehicle-bicyclist conflicts with $PET \leq 2s$ do exist?

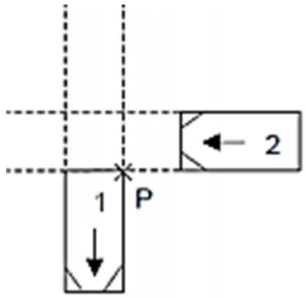
    vii. Plot the histogram of PET for all vehicle-pedestrian conflict, where the horizontal axis is PET in seconds, and the vertical axis is the number of conflicts. Use 0.5s as bin width.

You can use **PYTHON** or **MATLAB** to answer the questions of this problem. The provided data are **CONFIDENTIAL**, and please delete them after submitting your report. Please provide a PDF of the answers, codes, and results in excel files. If you have any questions, please do not hesitate to ask me by email.

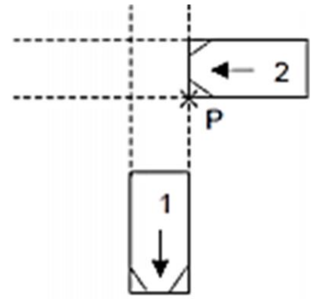
Post-Encroachment Time (PET) is defined as the time difference that two road users visit one spot.

$$PET = \left|t_{user_2} - t_{user_1}\right|$$

where t_{user_1} and t_{user_2} are the time that both road users visit the same point of conflict:



Condition at t_{user_1}: road user 1 leaves first



Condition at t_{user_2}: road user 2 arrives second

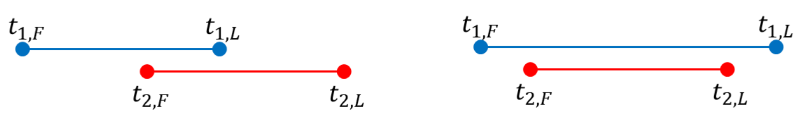
To find out if two users visit the same spot but at different times, we can use a buffer (a circle with a radius of 2 meters). If the distance between the trajectories of the **<u>1</u>**st road user at frame i and **<u>2</u>**nd road user at frame j, is less than R (**3 meters**), then these two users will have conflict, and PET can be calculated:

IF $distance(1,2) = \sqrt{\left(X_1(f_i) - X_2(f_j)\right)^2 + \left(Y_1(f_i) - Y_2(f_j)\right)^2} < R$:

$$PET = |t_2 - t_1| = \frac{|f_2 - f_1|}{fps}$$

Instead of checking this condition for every two road users, we can consider only road users that have overlap in time using the following conditions using first and last time of road users in video data:

1) **If $\boldsymbol{t_{1,F} < t_{2,F} < t_{1,L}}$** – road user **<u>1</u>** arrives first, and before leaving the intersection, road user **<u>2</u>** arrives**:**



2) **If $\boldsymbol{t_{2,F} < t_{1,F} < t_{2,L}}$** – road user **<u>2</u>** arrives first, and before leaving the intersection, road user **<u>1</u>** arrives:

3) **If $\boldsymbol{\left|t_{1,L} - t_{2,F}\right| < 5sec}$** –road user 1 leaves the intersection and road user **<u>2</u>** arrives in less than 5s after **OR** road user 2 leaves the intersection and road user **<u>1</u>** arrives in less than 5s after: