Object Detection and Autopilot Safety analysis

Part 1 : Object Detection

Import libraries

```
import torch
import os
import shutil
import pathlib
from glob import glob
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import cv2
import numpy as np
import seaborn as sns
import warnings
warnings.filterwarnings('ignore')
```

Define the data paths

```
# For colab execution

zip_file_path = '/content/drive/MyDrive/DL/od.zip'

data_root_colab = '/content/drive/MyDrive/DL/Object Detection'
image_data_path_colab = '/content/drive/MyDrive/DL/Object Detection/Images'
labels_path_colab = f'{data_root_colab}/labels.csv'


#for Kaggle execution
```

```python
image_data_path_kaggle = '/kaggle/input/object-detection/Object Detection/Images'
labels_path_kaggle = '/kaggle/input/object-detection/Object Detection/labels.csv'
data_root_kaggle = '.'


image_data_path = None
data_root = None
labels_path = None


if os.path.exists(image_data_path_kaggle):
    image_data_path = image_data_path_kaggle
    data_root = data_root_kaggle
    labels_path = labels_path_kaggle
    print(f'Using Kaggle data ')
else:
   print('Not on kaggle')
   from google.colab import drive
   drive.mount('/content/drive')
   data_root = data_root_colab
   image_data_path = image_data_path_colab
   labels_path = labels_path_colab
   if not os.path.exists(image_data_path):
         from zipfile import ZipFile
         zip_ref = ZipFile(zip_file_path,'r')
         zip_ref.extractall('/content/drive/MyDrive/DL/')
         zip_ref.close()

   print(f'Using Google Drive data')
print(f'image data path is {image_data_path}')

print(f'labels path is at {labels_path}')
```

```
Not on kaggle
Mounted at /content/drive
Using Google Drive data
image data path is /content/drive/MyDrive/DL/Object Detection/Images
labels path is at /content/drive/MyDrive/DL/Object Detection/labels.csv
```

Create the directory structure for yolo training

```
# create train , validation and test image directories
train_label_path = 'datasets/train/labels'
val_labels_path = 'datasets/val/labels'
train_image_path = 'datasets/train/images'
val_image_path = 'datasets/val/images'
test_image_path = 'datasets/test/images'
```

```
dirs = [train_label_path,val_labels_path,train_image_path,val_image_path,test_image_path]

for d in dirs:
    if os.path.exists(d):
        shutil.rmtree(d)
    os.makedirs(d)
    print(f'created {d}')

if not os.path.exists('datasets/data.yaml'):
    pathlib.Path.touch('datasets/data.yaml')
```

```
created datasets/train/labels
created datasets/val/labels
created datasets/train/images
created datasets/val/images
created datasets/test/images
```

```
%ls datasets
```

```
data.yaml  test/  train/  val/
```

Load the labels csv file

```
import pandas as pd

label_data = pd.read_csv(labels_path,names=['id','name','x_min','y_min','x_max','y_max'])
label_data = label_data.drop_duplicates('id')
label_data['id'] = label_data['id'].astype(str).str.zfill(8)
label_data = label_data.iloc[0:len(os.listdir(image_data_path))]
label_data['image'] = sorted(os.listdir(image_data_path))
```

```
print(label_data.shape)
label_data.head()
```

```
(5626, 7)
```

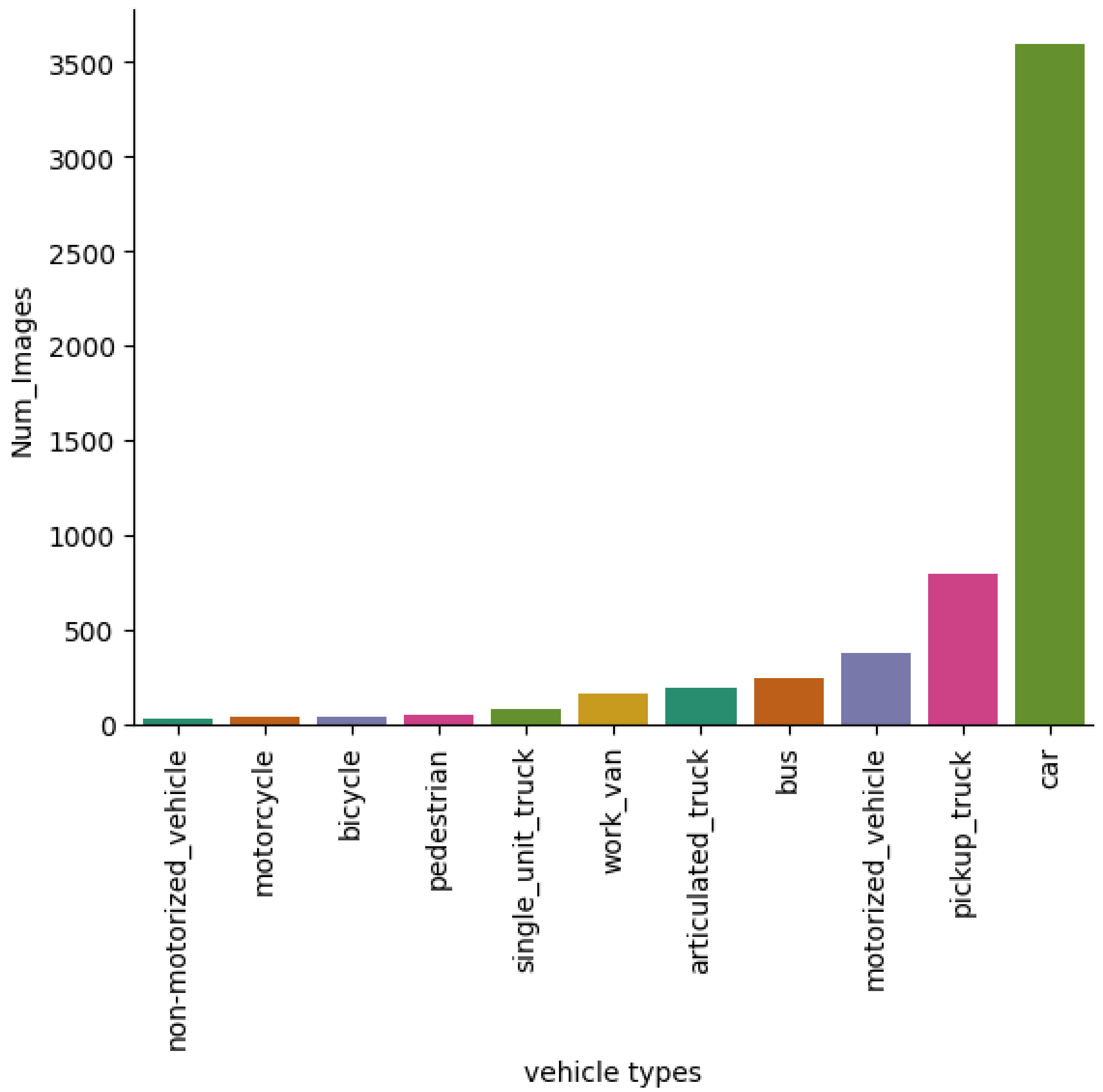
	id	name	x_min	y_min	x_max	y_max	image
0	00000000	pickup_truck	213	34	255	50	00000000.jpg
5	00000001	bus	205	155	568	314	00000001.jpg
11	00000002	motorized_vehicle	334	362	603	479	00000002.jpg
12	00000003	car	480	99	511	120	00000003.jpg
14	00000004	bus	439	32	719	171	00000004.jpg

Estimate Vehicle numbers

```
def copy_image_to_name(row):
  '''
  copies an image to the respective folder
  param : row
  '''
  name = row['name']
  dest = f'{data_root}/image_root/{name}/'
  if os.path.exists(dest):
    shutil.copy(f'{image_data_path}/{row["image"]}',dest)
  else:
    os.makedirs(dest)
    shutil.copy(f'{image_data_path}/{row["image"]}',dest)
_=label_data.apply(copy_image_to_name,axis=1)
```

```
def get_subdirectories(directory) -> list:
    with os.scandir(directory) as entries:
        return [entry.name for entry in entries if entry.is_dir()]

def plot_class_numbers(directory,title) -> pd.DataFrame:
    '''
    Plots the number of images in each class
    :param directory: the directory containing the images
    :param title: the title of the plot
    :return: a dataframe containing the number of images in each class
    '''
    sub_dirs = get_subdirectories(directory)
    images = {}
    image_class = []
    num_images = []
    class_dict = {}

    for d in sub_dirs:
        image_class.append(d)
        num_images.append(len(os.listdir(str(directory)+'/'+d)))

    df = pd.DataFrame({'Image_Class':image_class,'Num_Images':num_images})
    df = df.sort_values(by='Num_Images',ascending=True).reset_index()

    indices = sorted(df['index'].values.tolist())
    class_names = df['Image_Class'].values
    for i in indices:
      class_dict[i] = class_names[i]
    sns.barplot(data=df,x='Image_Class',y='Num_Images',palette=sns.mpl_palette('Dark2'))
    plt.xlabel('vehicle types')
    plt.title(f' {title}' )
    plt.xticks(rotation = 90)
    plt.gca().spines[['top', 'right',]].set_visible(False)
    plt.show()
    return df
```

```
plot_class_numbers(f'{data_root}/image_root','')
```



Num_Images
3500
3000
2500
2000
1500
1000
500
0
non-motorized_vehicle
motorcycle
bicycle
pedestrian
single_unit_truck
work_van
articulated_truck
bus
motorized_vehicle
pickup_truck
car
vehicle types

	index	Image_Class	Num_Images
0	6	non-motorized_vehicle	32
1	10	motorcycle	38
2	3	bicycle	43
3	5	pedestrian	56
4	9	single_unit_truck	80
5	7	work_van	161
6	1	articulated_truck	195
7	4	bus	244
8	8	motorized_vehicle	383
9	0	pickup_truck	801
10	2	car	3593

There is substantial class imbalance

Create a map of vehicle types to index

```python
import pprint
class_names = label_data.name.unique().tolist()
d = {}
for i in range(len(class_names)):
  d[class_names[i]] = i
pprint.pprint(d)
```

```
{'articulated_truck': 4,
 'bicycle': 8,
 'bus': 1,
 'car': 3,
 'motorcycle': 10,
 'motorized_vehicle': 2,
 'non-motorized_vehicle': 7,
 'pedestrian': 6,
 'pickup_truck': 0,
 'single_unit_truck': 9,
 'work_van': 5}
```

Create labels for training and validation

```python
import cv2
import numpy as np
import pathlib
def  get_label_filename(row):
   return row['id']+'.txt'

def normalize_bb(x_min,y_min,x_max,y_max,id):
   img_path = f'{image_data_path}/{id}.jpg'
   if  os.path.exists(img_path):
      img = cv2.imread(img_path)
      image_height,image_width,_ = img.shape
      x_center = (x_min + x_max)/2
      y_center = (y_min + y_max)/2
      width = x_max - x_min
      height = y_max - y_min
      normalized_x_center = x_center / image_width
      normalized_y_center = y_center / image_height
      normalized_width = width / image_width
      normalized_height = height / image_height
      return normalized_x_center, normalized_y_center,  normalized_width , normalized_height


def get_label_data(row):
  dims = normalize_bb(row['x_min'], row['y_min'],row['x_max'],row['y_max'],row['id'])
  class_id = d.get(row['name'])
  yolo_annotaion = f'{class_id} {dims[0]:.3f} {dims[1]:.3f} {dims[2]:.3f} {dims[0]:.3f}'
  return yolo_annotaion

def get_image_width(row):
     img_path = f"{image_data_path}/{row['id']}.jpg"
     img = cv2.imread(img_path)
     return img.shape[1]

def get_image_height(row):
     img_path = f"{image_data_path}/{row['id']}.jpg"
     img = cv2.imread(img_path)
     return img.shape[0]


def create_yaml():
  file_path = 'datasets/data.yaml'
  if os.path.exists(file_path):
    os.remove(file_path)

  train = 'train: train'
  val = 'val: val'
  nc = "nc: 11"
  names = f"names: {str(class_names)}"
  lines_to_append = [train,val,nc,names]

  try:
    with open(file_path, 'a') as file:
      for line in lines_to_append:
          file.write(f'{line}\n')
    print('data.yaml created')
  except Exception as e:
    print(f"An error occurred: {e}")
```

Create data.yaml for training

```
create_yaml()
```

```
data.yaml created
```

```
%cat datasets/data.yaml
```

```
train: train
val: val
nc: 11
names: ['pickup_truck', 'bus', 'motorized_vehicle', 'car', 'articulated_truck', 'work_van', 'pedestrian', 'non-motorized_vehicle', 'bicy
cle', 'single_unit_truck', 'motorcycle']
```

Create annotations in YOLO5 format

```
from glob import glob
import warnings
warnings.filterwarnings('ignore')

num_images = len(glob(f'{image_data_path}/*.jpg'))
num_train_images = int(num_images*0.8)

num_test_images = 60
num_val_images = num_images - num_train_images - num_test_images

print(f'total :{num_images}, train : {num_train_images},  val :{num_val_images}, test:{num_test_images}')

labels_train = label_data.iloc[0:num_train_images]
labels_val = label_data.iloc[num_train_images:num_images-num_test_images]
print(f'train shape : {labels_train.shape}, val shape: {labels_val.shape}')
```

```
total :5626, train : 4500,  val :1066, test:60
train shape : (4500, 7), val shape: (1066, 7)
```

```
labels_train['filename'] = labels_train.apply(get_label_filename,axis=1)
labels_train['text'] = labels_train.apply(get_label_data,axis=1)
labels_train['image_width'] = labels_train.apply( get_image_width,axis=1)
labels_train['image_height'] = labels_train.apply( get_image_height,axis=1)

labels_val['filename'] = labels_val.apply( get_label_filename,axis=1)
labels_val['text'] = labels_val.apply( get_label_data,axis=1)
labels_val['image_width'] = labels_val.apply( get_image_width,axis=1)
labels_val['image_height'] = labels_val.apply( get_image_height,axis=1)
```

```python
print(f'train shape : {labels_train.shape}, val shape: {labels_val.shape}')
labels_train.sample(10)
```

```
train shape : (4500, 11), val shape: (1066, 11)
```

	id	name	x_min	y_min	x_max	y_max	image	filename	text	image_width	image_height
13607	00004345	car	135	259	192	348	00004345.jpg	00004345.txt	3 0.227 0.632 0.079 0.227	720	480
3157	00001001	car	607	147	654	172	00001001.jpg	00001001.txt	3 0.876 0.332 0.065 0.876	720	480
9668	00003069	car	129	62	203	97	00003069.jpg	00003069.txt	3 0.485 0.349 0.216 0.485	342	228
8476	00002708	car	120	94	198	144	00002708.jpg	00002708.txt	3 0.465 0.522 0.228 0.465	342	228
5320	00001672	car	150	172	225	219	00001672.jpg	00001672.txt	3 0.260 0.407 0.104 0.260	720	480
5781	00001828	bicycle	357	136	394	236	00001828.jpg	00001828.txt	8 0.522 0.388 0.051 0.522	720	480
684	00000211	motorized_vehicle	0	244	72	351	00000211.jpg	00000211.txt	2 0.050 0.620 0.100 0.050	720	480
7226	00002261	car	514	159	715	292	00002261.jpg	00002261.txt	3 0.853 0.470 0.279 0.853	720	480
6702	00002114	car	70	130	219	201	00002114.jpg	00002114.txt	3 0.201 0.345 0.207 0.201	720	480
4456	00001412	pickup_truck	42	47	144	91	00001412.jpg	00001412.txt	0 0.272 0.303 0.298 0.272	342	228

Define function to create the yolo label file

```python
from pathlib import Path

# create the label file
def create_label_file(label_path,file_name,text):

 f = Path(f'{label_path}/{file_name}')
 f.write_text(text)
```

Create label files for train and validation images

```python
labels_train.apply(lambda row: create_label_file(train_label_path,row['filename'],row['text']) , axis =1)
_=labels_val.apply(lambda row: create_label_file(val_labels_path,row['filename'],row['text']) , axis =1)
```

Copy the images to train, val and test folders

```python
# copy train images
from tqdm import tqdm


def _copy(src,dest,file_name):
     if not src.startswith('.'):
       src_file = f'{src}/{file_name}'
       if not os.path.isdir(src_file):
          shutil.copy(src_file,dest)

num_train_images = labels_train.shape[0]
num_val_images = labels_val.shape[0]

images = sorted(os.listdir(image_data_path))

print(num_train_images,num_train_images+num_val_images,num_test_images)
print('Copying training images')
for i in tqdm(range(0,num_train_images)):
  _copy(image_data_path,f'{train_image_path}/',images[i])

print('Copying validation images')
```

```python
for i in tqdm(range(num_train_images,num_train_images+num_val_images)):
  _copy(image_data_path,f'{val_image_path}/',images[i])

print('copying test imges')
for i in tqdm(range(num_train_images+num_val_images,num_images)):
  _copy(image_data_path,f'{test_image_path}/',images[i])
```

```
4500 5566 60
Copying training images
100%|██████████| 4500/4500 [00:08<00:00, 504.77it/s]
Copying validation images
100%|██████████| 1066/1066 [00:01<00:00, 533.72it/s]
copying test imges
100%|██████████| 60/60 [00:00<00:00, 542.26it/s]
```

install ultralytics

```
!pip install ultralytics > install.txt
```

Train the model

```python
from ultralytics import YOLO
data_yaml_kaggle = "/kaggle/working/datasets/data.yaml"
data_yaml_colab = "/content/datasets/data.yaml"
epochs = 100
patience = 10
data_yaml = data_yaml_kaggle if os.path.exists(data_yaml_kaggle) else data_yaml_colab
model = YOLO("yolov5su.pt")
train_results=model.train(data=data_yaml, epochs=epochs, patience = patience,imgsz=640)
```

```
Ultralytics 8.3.107 🚀 Python-3.11.11 torch-2.5.1+cu124 CUDA:0 (Tesla T4, 15095MiB)
engine/trainer: task=detect, mode=train, model=yolov5su.pt, data=/kaggle/working/datasets/data.yaml, epochs=100, time=None, patience=10,
batch=16, imgsz=640, save=True, save_period=-1, cache=False, device=None, workers=8, project=None, name=train3, exist_ok=False, pretrain
ed=True, optimizer=auto, verbose=True, seed=0, deterministic=True, single_cls=False, rect=False, cos_lr=False, close_mosaic=10, resume=F
alse, amp=True, fraction=1.0, profile=False, freeze=None, multi_scale=False, overlap_mask=True, mask_ratio=4, dropout=0.0, val=True, spl
it=val, save_json=False, conf=None, iou=0.7, max_det=300, half=False, dnn=False, plots=True, source=None, vid_stride=1, stream_buffer=Fa
lse, visualize=False, augment=False, agnostic_nms=False, classes=None, retina_masks=False, embed=None, show=False, save_frames=False, sa
ve_txt=False, save_conf=False, save_crop=False, show_labels=True, show_conf=True, show_boxes=True, line_width=None, format=torchscript,
keras=False, optimize=False, int8=False, dynamic=False, simplify=True, opset=None, workspace=None, nms=False, lr0=0.01, lrf=0.01, moment
um=0.937, weight_decay=0.0005, warmup_epochs=3.0, warmup_momentum=0.8, warmup_bias_lr=0.1, box=7.5, cls=0.5, dfl=1.5, pose=12.0, kobj=1.
0, nbs=64, hsv_h=0.015, hsv_s=0.7, hsv_v=0.4, degrees=0.0, translate=0.1, scale=0.5, shear=0.0, perspective=0.0, flipud=0.0, fliplr=0.5,
bgr=0.0, mosaic=1.0, mixup=0.0, copy_paste=0.0, copy_paste_mode=flip, auto_augment=randaugment, erasing=0.4, crop_fraction=1.0, cfg=Non
e, tracker=botsort.yaml, save_dir=runs/detect/train3
Overriding model.yaml nc=80 with nc=11

                   from  n    params  module                                       arguments
  0                  -1  1      3520  ultralytics.nn.modules.conv.Conv             [3, 32, 6, 2, 2]
  1                  -1  1     18560  ultralytics.nn.modules.conv.Conv             [32, 64, 3, 2]
  2                  -1  1     18816  ultralytics.nn.modules.block.C3              [64, 64, 1]
  3                  -1  1     73984  ultralytics.nn.modules.conv.Conv             [64, 128, 3, 2]
  4                  -1  2    115712  ultralytics.nn.modules.block.C3              [128, 128, 2]
  5                  -1  1    295424  ultralytics.nn.modules.conv.Conv             [128, 256, 3, 2]
  6                  -1  3    625152  ultralytics.nn.modules.block.C3              [256, 256, 3]
  7                  -1  1   1180672  ultralytics.nn.modules.conv.Conv             [256, 512, 3, 2]
  8                  -1  1   1182720  ultralytics.nn.modules.block.C3              [512, 512, 1]
  9                  -1  1    656896  ultralytics.nn.modules.block.SPPF            [512, 512, 5]
 10                  -1  1    131584  ultralytics.nn.modules.conv.Conv             [512, 256, 1, 1]
 11                  -1  1         0  torch.nn.modules.upsampling.Upsample         [None, 2, 'nearest']
 12             [-1, 6]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 13                  -1  1    361984  ultralytics.nn.modules.block.C3              [512, 256, 1, False]
 14                  -1  1     33024  ultralytics.nn.modules.conv.Conv             [256, 128, 1, 1]
 15                  -1  1         0  torch.nn.modules.upsampling.Upsample         [None, 2, 'nearest']
 16             [-1, 4]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 17                  -1  1     90880  ultralytics.nn.modules.block.C3              [256, 128, 1, False]
 18                  -1  1    147712  ultralytics.nn.modules.conv.Conv             [128, 128, 3, 2]
 19            [-1, 14]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 20                  -1  1    296448  ultralytics.nn.modules.block.C3              [256, 256, 1, False]
 21                  -1  1    590336  ultralytics.nn.modules.conv.Conv             [256, 256, 3, 2]
 22            [-1, 10]  1         0  ultralytics.nn.modules.conv.Concat           [1]
 23                  -1  1   1182720  ultralytics.nn.modules.block.C3              [512, 512, 1, False]
 24        [17, 20, 23]  1   2120305  ultralytics.nn.modules.head.Detect           [11, [128, 256, 512]]
```

```
YOLOv5s summary: 153 layers, 9,126,449 parameters, 9,126,433 gradients, 24.1 GFLOPs

Transferred 421/427 items from pretrained weights
TensorBoard: Start with 'tensorboard --logdir runs/detect/train3', view at http://localhost:6006/
Freezing layer 'model.24.dfl.conv.weight'
AMP: running Automatic Mixed Precision (AMP) checks...
AMP: checks passed ✅
train: Scanning /kaggle/working/datasets/train/labels.cache... 4500 images, 0 backgrounds, 0 corrupt: 100%|██████████| 4500/4500 [00:00
<?, ?it/s]
albumentations: Blur(p=0.01, blur_limit=(3, 7)), MedianBlur(p=0.01, blur_limit=(3, 7)), ToGray(p=0.01, num_output_channels=3, method='we
ighted_average'), CLAHE(p=0.01, clip_limit=(1.0, 4.0), tile_grid_size=(8, 8))
val: Scanning /kaggle/working/datasets/val/labels.cache... 1066 images, 0 backgrounds, 0 corrupt: 100%|██████████| 1066/1066 [00:00<?, ?
it/s]
Plotting labels to runs/detect/train3/labels.jpg...
optimizer: 'optimizer=auto' found, ignoring 'lr0=0.01' and 'momentum=0.937' and determining best 'optimizer', 'lr0' and 'momentum' autom
atically...
optimizer: AdamW(lr=0.000667, momentum=0.9) with parameter groups 69 weight(decay=0.0), 76 weight(decay=0.0005), 75 bias(decay=0.0)
TensorBoard: model graph visualization added ✅
Image sizes 640 train, 640 val
Using 2 dataloader workers
Logging results to runs/detect/train3
Starting training for 100 epochs...

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      1/100      6.65G      1.887      4.267      1.829         12        640: 100%|██████████| 282/282 [01:13<00:00,  3.83it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.28it/
s]
                   all       1066       1066      0.683       0.14     0.0755     0.0385

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      2/100      6.67G      1.631      2.714      1.666         11        640: 100%|██████████| 282/282 [01:11<00:00,  3.97it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.30it/
s]
                   all       1066       1066      0.615     0.0942     0.0654     0.0354

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      3/100      6.67G      1.605      2.582      1.647         11        640: 100%|██████████| 282/282 [01:11<00:00,  3.97it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.19it/
s]
```

```
                 all       1066       1066      0.606     0.0992     0.0592     0.0328

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      4/100      6.67G      1.548      2.476      1.614          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.22it/
s]
                 all       1066       1066      0.522      0.136     0.0906      0.051

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      5/100      6.67G      1.481      2.368      1.554          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.12it/
s]
                 all       1066       1066      0.716      0.112     0.0891     0.0574

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      6/100      6.67G      1.422      2.242       1.52          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.24it/
s]
                 all       1066       1066      0.733      0.114      0.124     0.0804

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      7/100      6.67G      1.376      2.219      1.488          8        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.24it/
s]
                 all       1066       1066      0.624      0.126      0.107       0.07

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      8/100      6.67G      1.338      2.132      1.459          5        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.18it/
s]
                 all       1066       1066       0.69      0.196      0.156     0.0965

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
      9/100      6.67G      1.293      2.081      1.428         11        640: 100%|██████████| 282/282 [01:10<00:00,  4.01it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.29it/
s]
                 all       1066       1066      0.395      0.187       0.14      0.092

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     10/100      6.67G      1.265      2.039      1.412          8        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.18it/
s]
                 all       1066       1066      0.461      0.248      0.174      0.119
      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     11/100      6.67G      1.247      2.026      1.392         12        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.24it/
s]
                   all       1066       1066      0.725      0.149      0.181      0.126

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     12/100      6.67G      1.219      1.952      1.373         12        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.22it/
s]
                   all       1066       1066      0.412      0.257      0.171      0.121

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     13/100      6.67G      1.219      1.929      1.364          7        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.25it/
s]
                   all       1066       1066      0.499      0.287      0.197      0.133

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     14/100      6.67G      1.169      1.855       1.33          6        640: 100%|██████████| 282/282 [01:10<00:00,  4.00it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.28it/
s]
                   all       1066       1066      0.405      0.216      0.196      0.139

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     15/100      6.67G      1.175      1.862      1.333          8        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.19it/
s]
                   all       1066       1066      0.347      0.304      0.217       0.16

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     16/100      6.67G      1.145      1.827      1.311          5        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.27it/
s]
                   all       1066       1066      0.386      0.331      0.235      0.154

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     17/100      6.67G      1.132      1.801      1.305         10        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.21it/
s]
                   all       1066       1066       0.33       0.35      0.243      0.169

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     18/100      6.67G      1.124      1.775      1.294          7        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.32it/
s]
                   all       1066       1066      0.421      0.282      0.238       0.16

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     19/100      6.67G      1.113      1.762      1.285          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.30it/
s]
                   all       1066       1066      0.288      0.337      0.246      0.175

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     20/100      6.67G      1.089      1.743       1.27          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.25it/
s]
                   all       1066       1066       0.49      0.339       0.24      0.168

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     21/100      6.67G       1.07      1.725      1.256         11        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.41it/
s]
                   all       1066       1066      0.575      0.243      0.248      0.168

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     22/100      6.67G      1.085      1.695      1.268         12        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.26it/
s]
                   all       1066       1066      0.443      0.278      0.268      0.189

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     23/100      6.67G      1.041      1.673      1.244          4        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.40it/
s]
                   all       1066       1066      0.321      0.381      0.258      0.184

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     24/100      6.67G      1.058      1.684      1.248         10        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.33it/
s]
                   all       1066       1066      0.506      0.339      0.292      0.208

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     25/100      6.67G      1.043       1.65      1.239          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.00it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.27it/
s]
                   all       1066       1066      0.243      0.376      0.267        0.2

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     26/100      6.67G      1.004      1.594      1.215          9        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.44it/
s]
                   all       1066       1066      0.338      0.375      0.302      0.213

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     27/100      6.67G      1.024      1.646      1.223          7        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.31it/
s]
                   all       1066       1066      0.386      0.281      0.289      0.199

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     28/100      6.67G     0.9985      1.607       1.21          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.01it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.35it/
s]
                   all       1066       1066      0.466      0.349      0.293      0.211

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     29/100      6.67G     0.9956      1.588      1.206         11        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.20it/
s]
                   all       1066       1066      0.425      0.374      0.296      0.214

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     30/100      6.67G      0.994       1.59      1.206          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.14it/
s]
                   all       1066       1066      0.341      0.389      0.299      0.207

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     31/100      6.67G     0.9869      1.575      1.195          8        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.42it/
s]
                   all       1066       1066      0.419       0.41      0.278      0.216

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     32/100      6.67G     0.9588      1.529      1.179          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.30it/
s]
                   all       1066       1066      0.242       0.39       0.28      0.216

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     33/100      6.67G     0.9705      1.541      1.185          5        640: 100%|██████████| 282/282 [01:10<00:00,  4.01it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.24it/
s]
                   all       1066       1066      0.396      0.389      0.322      0.245

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     34/100      6.67G      0.958      1.517      1.183          6        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.36it/
s]
                   all       1066       1066      0.347      0.383      0.311      0.244

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     35/100      6.67G     0.9581      1.541      1.184         10        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.21it/
s]
                   all       1066       1066      0.331       0.41       0.29      0.221

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     36/100      6.67G     0.9421      1.508      1.171          5        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.34it/
s]
                   all       1066       1066       0.26      0.417        0.3      0.234

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     37/100      6.67G     0.9267      1.483      1.158          7        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.32it/
s]
                   all       1066       1066      0.478      0.356      0.308       0.24

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     38/100      6.67G     0.9275      1.468      1.157         10        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.19it/
s]
                   all       1066       1066      0.468      0.346      0.321      0.252

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
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     39/100      6.67G      0.929      1.482      1.156          7        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.36it/
s]
                   all       1066       1066      0.434       0.39      0.326      0.241

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     40/100      6.67G     0.9107      1.433      1.147          5        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.20it/
s]
                   all       1066       1066      0.352      0.418      0.311      0.238

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     41/100      6.67G     0.9006      1.426      1.141          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.35it/
s]
                   all       1066       1066      0.285      0.382      0.321      0.254

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     42/100      6.67G     0.9028      1.436       1.14          8        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.44it/
s]
                   all       1066       1066      0.372      0.356      0.334      0.262

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     43/100      6.67G     0.8907      1.418      1.135          7        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.29it/
s]
                   all       1066       1066      0.411      0.459      0.341      0.265

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     44/100      6.67G     0.8859      1.416      1.128          5        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.43it/
s]
                   all       1066       1066      0.347      0.452      0.354      0.275

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     45/100      6.67G     0.8805      1.381       1.13          7        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.25it/
s]
                   all       1066       1066      0.288      0.447      0.331      0.257

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     46/100      6.67G     0.8838      1.387      1.126          6        640: 100%|██████████| 282/282 [01:10<00:00,  4.01it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.32it/
s]
                   all       1066       1066      0.448      0.343      0.305      0.236

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     47/100      6.67G     0.8759      1.373      1.119          5        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.49it/
s]
                   all       1066       1066      0.393      0.357      0.329      0.257

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     48/100      6.67G     0.8776      1.393      1.124          6        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.47it/
s]
                   all       1066       1066      0.274      0.456      0.323      0.254

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     49/100      6.67G     0.8612      1.352      1.115         11        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.31it/
s]
                   all       1066       1066      0.403      0.451       0.36      0.281

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     50/100      6.67G     0.8492      1.337      1.105          8        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.28it/
s]
                   all       1066       1066      0.325      0.422      0.353      0.271

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     51/100      6.67G     0.8587      1.326      1.116          9        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.36it/
s]
                   all       1066       1066      0.452      0.379      0.353      0.283

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     52/100      6.67G     0.8389      1.334      1.099          9        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.43it/
s]
                   all       1066       1066      0.435       0.39      0.339      0.269

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
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```
     53/100      6.67G     0.8477      1.309      1.107          4        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.46it/
s]
                   all       1066       1066      0.365      0.411      0.354      0.276

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     54/100      6.67G     0.8392      1.309      1.107          4        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.40it/
s]
                   all       1066       1066      0.364        0.4      0.354      0.278

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     55/100      6.67G     0.8323      1.305      1.095          5        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.27it/
s]
                   all       1066       1066      0.276      0.427      0.327      0.253

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     56/100      6.67G     0.8401      1.293      1.095          6        640: 100%|██████████| 282/282 [01:09<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.09it/
s]
                   all       1066       1066      0.469      0.346      0.337      0.269

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     57/100      6.67G     0.8336       1.29      1.089          6        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.33it/
s]
                   all       1066       1066      0.288      0.417      0.348      0.275

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     58/100      6.67G     0.8166      1.266      1.087         11        640: 100%|██████████| 282/282 [01:10<00:00,  4.03it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.44it/
s]
                   all       1066       1066      0.341      0.431      0.349      0.271

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     59/100      6.67G     0.8017      1.245      1.073          9        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.35it/
s]
                   all       1066       1066      0.477       0.39      0.353      0.268

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     60/100      6.67G      0.808      1.234      1.079          7        640: 100%|██████████| 282/282 [01:10<00:00,  4.02it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.23it/
s]
                   all       1066       1066      0.307      0.404      0.336      0.264

      Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
     61/100      6.67G     0.7981       1.24      1.076          4        640: 100%|██████████| 282/282 [01:10<00:00,  4.00it/s]
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  5.28it/
s]
                   all       1066       1066      0.498      0.362      0.347      0.268
EarlyStopping: Training stopped early as no improvement observed in last 10 epochs. Best results observed at epoch 51, best model saved
as best.pt.
To update EarlyStopping(patience=10) pass a new patience value, i.e. `patience=300` or use `patience=0` to disable EarlyStopping.

61 epochs completed in 1.307 hours.
Optimizer stripped from runs/detect/train3/weights/last.pt, 18.5MB
Optimizer stripped from runs/detect/train3/weights/best.pt, 18.5MB

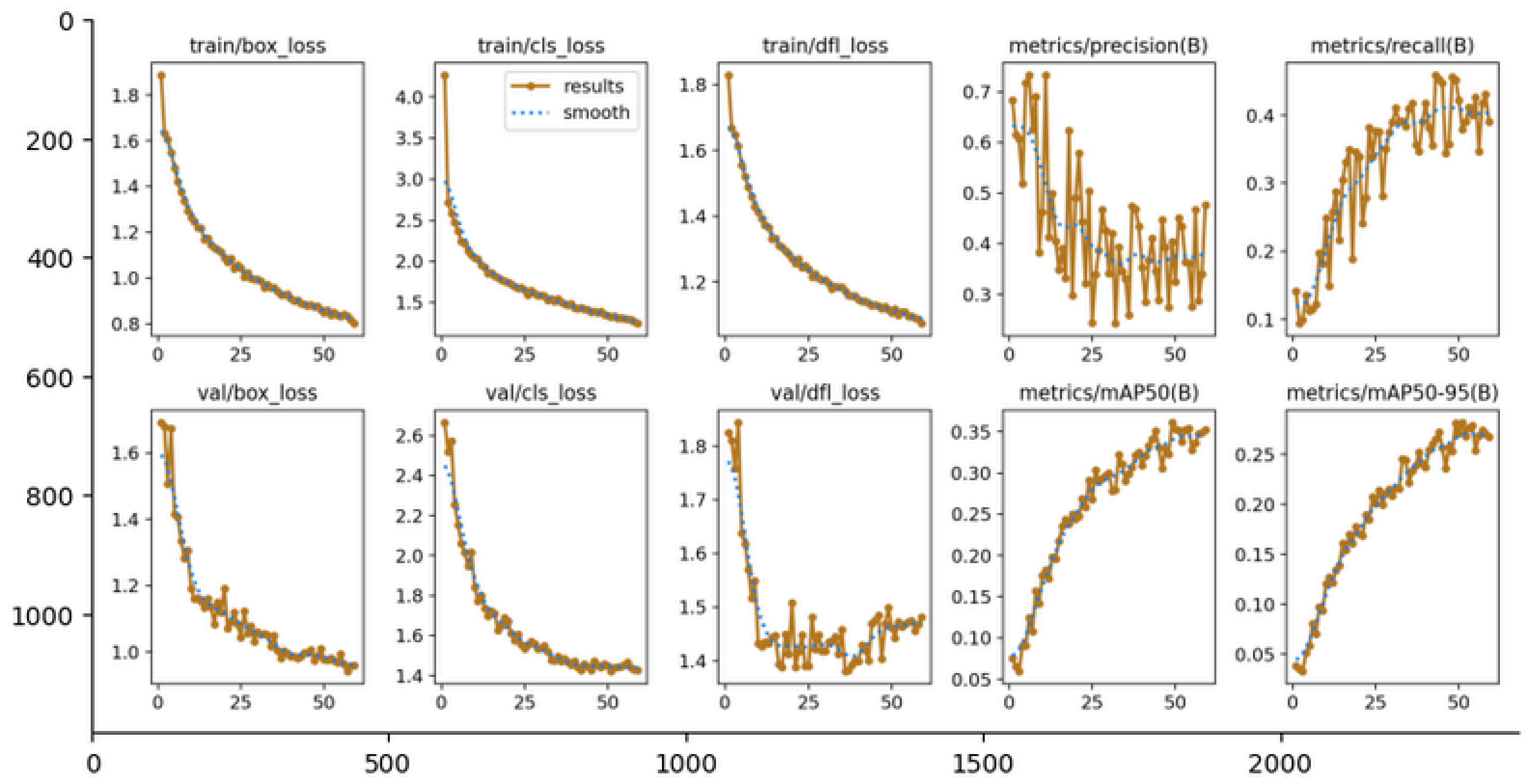
Validating runs/detect/train3/weights/best.pt...
Ultralytics 8.3.107 🚀 Python-3.11.11 torch-2.5.1+cu124 CUDA:0 (Tesla T4, 15095MiB)
YOLOv5s summary (fused): 84 layers, 9,115,793 parameters, 0 gradients, 23.8 GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%|██████████| 34/34 [00:06<00:00,  4.93it/
s]
                   all       1066       1066      0.452      0.378      0.353      0.283
          pickup_truck        154        154      0.436      0.558      0.488      0.424
                   bus         51         51      0.573      0.784       0.63      0.519
     motorized_vehicle         74         74      0.181     0.0811     0.0714     0.0482
                   car        667        667      0.444      0.594      0.518      0.428
     articulated_truck         28         28      0.367       0.56      0.465       0.37
              work_van         39         39      0.491      0.308      0.359      0.305
            pedestrian         13         13      0.293      0.154      0.136     0.0641
 non-motorized_vehicle          6          6          1          0    0.00137   0.000683
               bicycle          8          8      0.418      0.272      0.382      0.294
     single_unit_truck         18         18      0.356      0.222      0.173      0.134
            motorcycle          8          8      0.419      0.625      0.663      0.527
Speed: 0.1ms preprocess, 2.6ms inference, 0.0ms loss, 1.0ms postprocess per image
Results saved to runs/detect/train3
```

```python
from glob import glob
def get_res_dir():
  res_dir_count = len(glob('runs/detect/*'))
```

```
    # print(f'current number of result directories : {res_dir_count}')
    res_dir = f'runs/detect/train{res_dir_count}'
    # print(f"result dir : {res_dir}")
    return res_dir
```

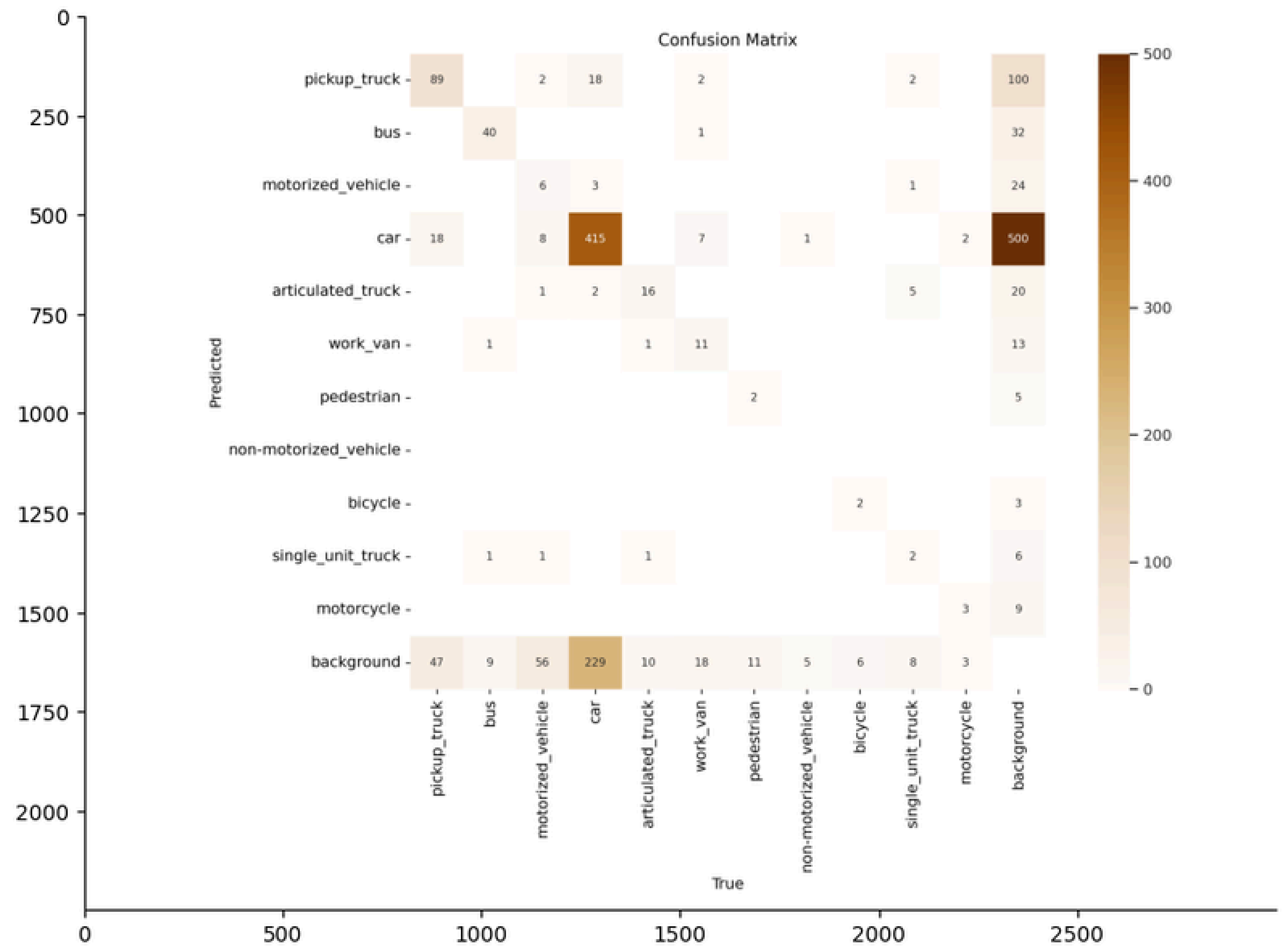
Precision,Recall,Accuracy curves

```
import cv2

plt.figure(figsize = (10,10))
res_dir = get_res_dir()
img = cv2.imread(f'{res_dir}/results.png')
plt.gca().spines[['top', 'right',]].set_visible(False)
_=plt.imshow(img)
```



Confusion Matrix

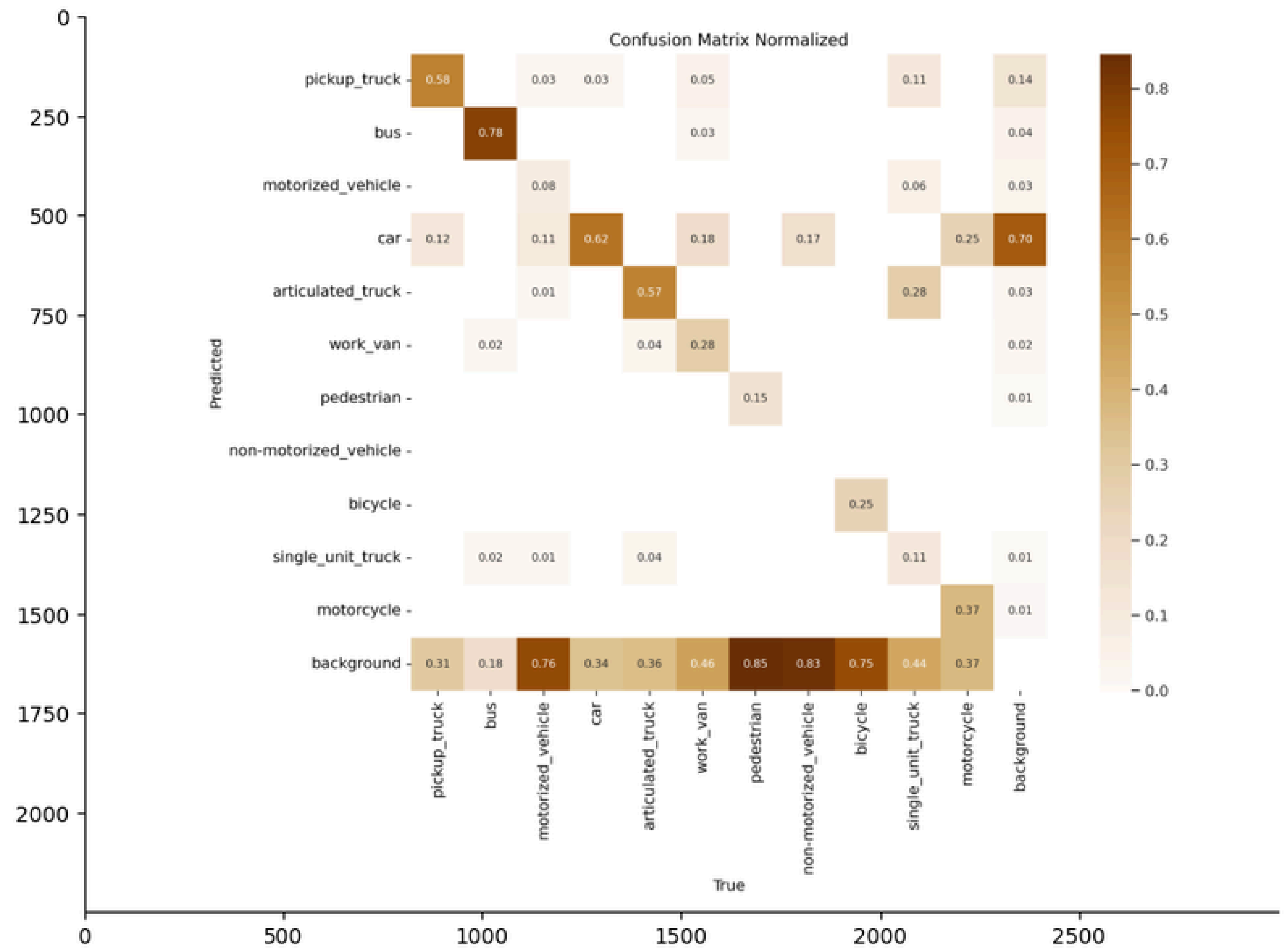
```
plt.figure(figsize = (10,10))
img = cv2.imread(f'{res_dir}/confusion_matrix.png')
plt.gca().spines[['top', 'right',]].set_visible(False)
_=plt.imshow(img)
```



Predicted \ True	pickup_truck	bus	motorized_vehicle	car	articulated_truck	work_van	pedestrian	non-motorized_vehicle	bicycle	single_unit_truck	motorcycle	background
pickup_truck	89		2	18		2				2		100
bus		40				1						32
motorized_vehicle			6	3						1		24
car	18		8	415		7		1			2	500
articulated_truck			1	2	16					5		20
work_van		1			1	11						13
pedestrian							2					5
non-motorized_vehicle												
bicycle									2			3
single_unit_truck		1	1		1					2		6
motorcycle											3	9
background	47	9	56	229	10	18	11	5	6	8	3	

Confusion Matrix Normalized

```python
plt.figure(figsize = (10,10))
img = cv2.imread(f'{res_dir}/confusion_matrix_normalized.png')
plt.gca().spines[['top', 'right',]].set_visible(False)
_=plt.imshow(img)
```



Derive predictions

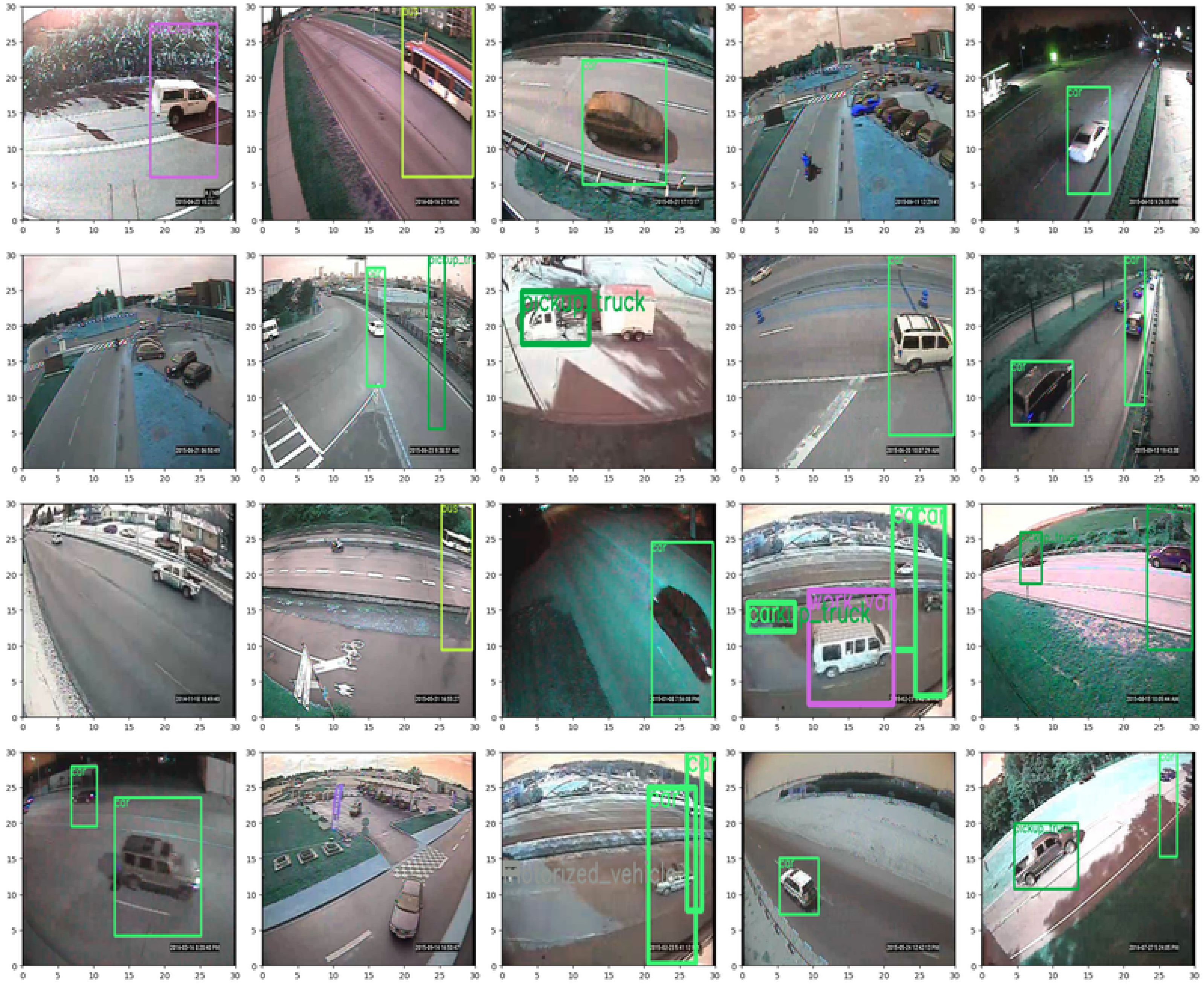
```
results = model.predict(test_image_path)
```

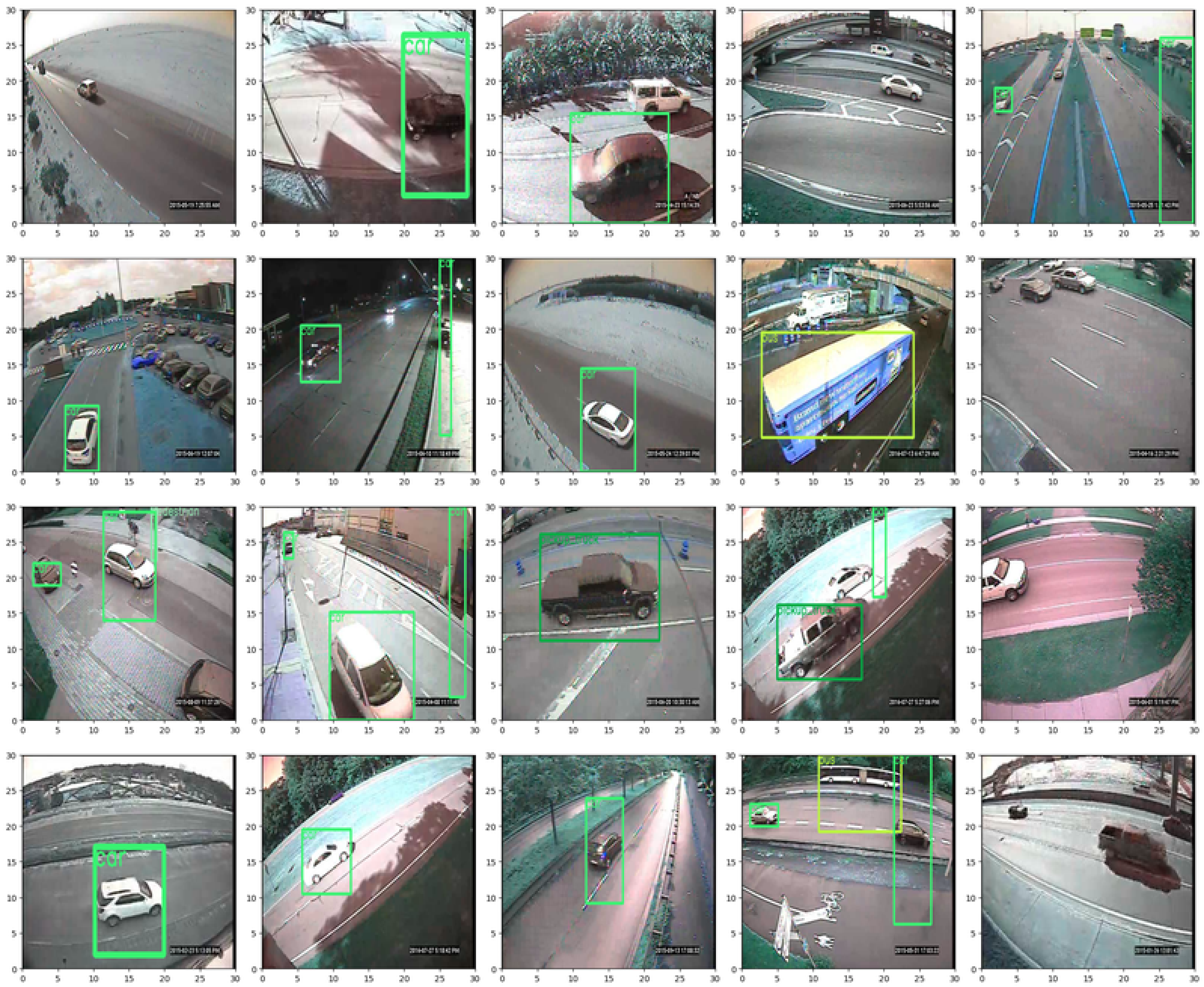
```
image 1/60 /kaggle/working/datasets/test/images/00005598.jpg: 448x640 1 work_van, 11.9ms
image 2/60 /kaggle/working/datasets/test/images/00005599.jpg: 448x640 1 bus, 11.8ms
image 3/60 /kaggle/working/datasets/test/images/00005600.jpg: 448x640 1 car, 11.7ms
image 4/60 /kaggle/working/datasets/test/images/00005601.jpg: 448x640 (no detections), 11.7ms
image 5/60 /kaggle/working/datasets/test/images/00005602.jpg: 448x640 1 car, 11.8ms
image 6/60 /kaggle/working/datasets/test/images/00005603.jpg: 448x640 (no detections), 11.8ms
image 7/60 /kaggle/working/datasets/test/images/00005604.jpg: 448x640 1 pickup_truck, 1 car, 11.7ms
image 8/60 /kaggle/working/datasets/test/images/00005605.jpg: 448x640 1 pickup_truck, 11.8ms
image 9/60 /kaggle/working/datasets/test/images/00005606.jpg: 448x640 1 car, 11.8ms
image 10/60 /kaggle/working/datasets/test/images/00005607.jpg: 448x640 2 cars, 9.2ms
image 11/60 /kaggle/working/datasets/test/images/00005608.jpg: 448x640 (no detections), 9.2ms
image 12/60 /kaggle/working/datasets/test/images/00005609.jpg: 448x640 1 bus, 9.2ms
image 13/60 /kaggle/working/datasets/test/images/00005610.jpg: 448x640 1 car, 9.3ms
image 14/60 /kaggle/working/datasets/test/images/00005611.jpg: 448x640 1 pickup_truck, 3 cars, 1 work_van, 9.2ms
image 15/60 /kaggle/working/datasets/test/images/00005612.jpg: 448x640 2 pickup_trucks, 9.2ms
image 16/60 /kaggle/working/datasets/test/images/00005613.jpg: 448x640 2 cars, 9.2ms
image 17/60 /kaggle/working/datasets/test/images/00005614.jpg: 448x640 (no detections), 9.2ms
image 18/60 /kaggle/working/datasets/test/images/00005615.jpg: 448x640 1 motorized_vehicle, 2 cars, 9.2ms
image 19/60 /kaggle/working/datasets/test/images/00005616.jpg: 448x640 1 car, 9.2ms
image 20/60 /kaggle/working/datasets/test/images/00005617.jpg: 448x640 1 pickup_truck, 1 car, 9.2ms
image 21/60 /kaggle/working/datasets/test/images/00005618.jpg: 448x640 (no detections), 9.3ms
image 22/60 /kaggle/working/datasets/test/images/00005619.jpg: 448x640 1 car, 9.2ms
image 23/60 /kaggle/working/datasets/test/images/00005620.jpg: 448x640 1 car, 9.2ms
image 24/60 /kaggle/working/datasets/test/images/00005621.jpg: 448x640 (no detections), 6.6ms
image 25/60 /kaggle/working/datasets/test/images/00005622.jpg: 448x640 2 cars, 6.6ms
image 26/60 /kaggle/working/datasets/test/images/00005623.jpg: 448x640 1 car, 6.5ms
image 27/60 /kaggle/working/datasets/test/images/00005624.jpg: 448x640 2 cars, 6.4ms
image 28/60 /kaggle/working/datasets/test/images/00005625.jpg: 448x640 1 car, 6.4ms
image 29/60 /kaggle/working/datasets/test/images/00005626.jpg: 448x640 1 bus, 6.3ms
image 30/60 /kaggle/working/datasets/test/images/00005627.jpg: 448x640 (no detections), 6.2ms
image 31/60 /kaggle/working/datasets/test/images/00005628.jpg: 448x640 2 cars, 1 pedestrian, 6.4ms
image 32/60 /kaggle/working/datasets/test/images/00005629.jpg: 448x640 3 cars, 6.3ms
image 33/60 /kaggle/working/datasets/test/images/00005630.jpg: 448x640 1 pickup_truck, 6.4ms
image 34/60 /kaggle/working/datasets/test/images/00005631.jpg: 448x640 1 pickup_truck, 1 car, 7.0ms
image 35/60 /kaggle/working/datasets/test/images/00005632.jpg: 448x640 (no detections), 6.5ms
image 36/60 /kaggle/working/datasets/test/images/00005633.jpg: 448x640 1 car, 6.9ms
image 37/60 /kaggle/working/datasets/test/images/00005634.jpg: 448x640 1 car, 6.6ms
image 38/60 /kaggle/working/datasets/test/images/00005635.jpg: 448x640 1 car, 6.5ms
image 39/60 /kaggle/working/datasets/test/images/00005636.jpg: 448x640 1 bus, 2 cars, 6.5ms
image 40/60 /kaggle/working/datasets/test/images/00005637.jpg: 448x640 (no detections), 6.7ms
image 41/60 /kaggle/working/datasets/test/images/00005638.jpg: 448x640 2 articulated_trucks, 6.7ms
image 42/60 /kaggle/working/datasets/test/images/00005639.jpg: 448x640 (no detections), 6.8ms
image 43/60 /kaggle/working/datasets/test/images/00005640.jpg: 448x640 4 cars, 6.7ms
image 44/60 /kaggle/working/datasets/test/images/00005641.jpg: 448x640 1 bus, 6.5ms
image 45/60 /kaggle/working/datasets/test/images/00005642.jpg: 448x640 2 cars, 6.4ms
image 46/60 /kaggle/working/datasets/test/images/00005643.jpg: 448x640 2 cars, 6.7ms
image 47/60 /kaggle/working/datasets/test/images/00005644.jpg: 448x640 2 cars, 6.5ms
image 48/60 /kaggle/working/datasets/test/images/00005645.jpg: 448x640 1 car, 6.4ms
image 49/60 /kaggle/working/datasets/test/images/00005646.jpg: 448x640 1 pickup_truck, 2 cars, 6.5ms
image 50/60 /kaggle/working/datasets/test/images/00005647.jpg: 448x640 1 pickup_truck, 6.5ms
image 51/60 /kaggle/working/datasets/test/images/00005648.jpg: 448x640 1 car, 6.7ms
image 52/60 /kaggle/working/datasets/test/images/00005649.jpg: 448x640 1 pickup_truck, 1 bus, 6.3ms
image 53/60 /kaggle/working/datasets/test/images/00005650.jpg: 448x640 1 car, 6.6ms
image 54/60 /kaggle/working/datasets/test/images/00005651.jpg: 448x640 (no detections), 6.4ms
image 55/60 /kaggle/working/datasets/test/images/00005652.jpg: 448x640 (no detections), 6.7ms
image 56/60 /kaggle/working/datasets/test/images/00005653.jpg: 448x640 2 cars, 6.5ms
image 57/60 /kaggle/working/datasets/test/images/00005654.jpg: 448x640 (no detections), 6.5ms
image 58/60 /kaggle/working/datasets/test/images/00005655.jpg: 448x640 1 car, 6.8ms
image 59/60 /kaggle/working/datasets/test/images/00005656.jpg: 448x640 2 cars, 6.3ms
image 60/60 /kaggle/working/datasets/test/images/00005657.jpg: 448x640 2 cars, 6.5ms
Speed: 1.7ms preprocess, 8.0ms inference, 0.9ms postprocess per image at shape (1, 3, 448, 640)
```

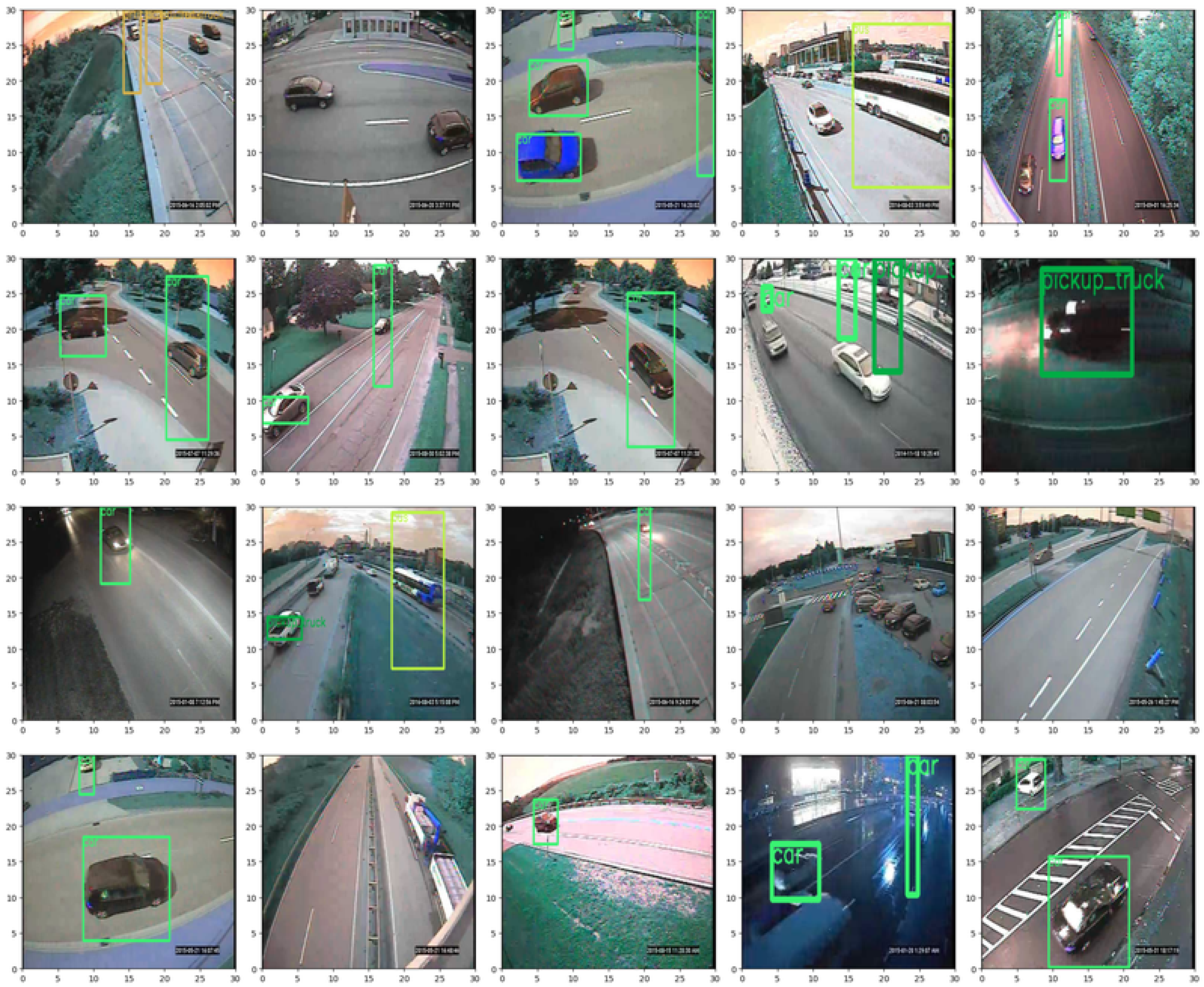
```python
def plot_box(image,boxes,labels):
    h,w,_ = image.shape
    for box_num,box in enumerate(boxes):
        xyxy = box.xyxy.int().tolist()
        xmin,ymin,xmax,ymax = xyxy[0][0], xyxy[0][1],xyxy[0][2],xyxy[0][3]
        width = xmax-xmin
        height = ymax-ymin
        class_name = class_names[int(labels[box_num])]
        color = COLORS[int(labels[box_num])]
        cv2.rectangle(image,(xmin,ymin),(xmax,ymax),color,5)
        font_scale = 1#min(1,max(3,int(w/500)))
        font_thickness = 2#min(2,max(10,int(w/50)))
        font = cv2.FONT_HERSHEY_SIMPLEX
        # p1,p1 = (int(xmin+1.5*width),ymin), (int(xmin+width),ymin-int(1.5*height))
        text_width = cv2.getTextSize(class_name,font,font_scale,font_thickness)[0][0]
        text_height = cv2.getTextSize(class_name,font,font_scale,font_thickness)[0][1]
        cv2.putText(image,class_name,(xmin,ymin+20),font,font_scale,color,font_thickness)
    names[path] = temp
    return image
```

```python
def get_identified_names(image,boxes,labels):
    h,w,_ = image.shape
    temp = []
    for box_num,box in enumerate(boxes):
        xyxy = box.xyxy.int().tolist()
        xmin,ymin,xmax,ymax = xyxy[0][0], xyxy[0][1],xyxy[0][2],xyxy[0][3]
        width = xmax-xmin
        height = ymax-ymin
        class_name = class_names[int(labels[box_num])]
        temp.append(class_name)

    return temp
```

```python
COLORS = np.random.uniform(0,255,size=(len(class_names),3))
slices = []
count = 0
d = list()
images_per_row = 5
for j,res in enumerate(results):
    d.append(res)
    if len(d) == images_per_row:
      slices.append(d)
      d = list()



for i in (range(len(slices))):
  fig,axes = plt.subplots(nrows=1,ncols=images_per_row,figsize=(20,10),constrained_layout=True)
  results_ = slices[i]
  for j in range(len(results_)):
    res = results_[j]
    image = res.orig_img
    boxes = res.boxes
    confidences = boxes.conf
    classes = boxes.cls
    path = res.path
    box_img = plot_box(image,boxes,classes)
    axes[j].imshow(box_img, extent=[0, 30, 0, 30])
```


bus
car
pickup_truck
work_van
motorized_vehicle
0
5
10
15
20
25
30


car
bus
pickup_truck
pedestrian



car
bus
pickup_truck

Part 2 : Tesla Auto pilot and Road Safety

Data wrangling

```
import pandas as pd
import torch
torch.device('cpu')
url = 'https://raw.githubusercontent.com/tksundar/autonomous_driving/refs/heads/master/Tesla%20-%20Deaths.csv'
data = pd.read_csv(url, skip_blank_lines=True, skipinitialspace=True)
data.isna().sum()
data.columns = data.columns.str.rstrip()
nan_counts = data.isna().sum()
columns_to_drop = ['Unnamed: 16','Unnamed: 17','Source','State']
columns_to_drop.extend(nan_counts[nan_counts >= 220].index)
data.drop(columns_to_drop,axis=1,inplace=True)
# Remove rows that does not have a case number
# The values in these rows are outliers
data = data.dropna(subset=['Case #'])
print(data.shape)
print(data.isna().sum())
```

```
(294, 15)
Case #                                                             0
Year                                                               0
Date                                                               0
Country                                                            0
Description                                                        0
Deaths                                                             0
Tesla driver                                                       5
Tesla occupant                                                     9
Other vehicle                                                      4
Cyclists/ Peds                                                     3
TSLA+cycl / peds                                                   2
Model                                                              0
Autopilot claimed                                                 18
Verified Tesla Autopilot Deaths                                    4
Verified Tesla Autopilot Deaths + All Deaths Reported to NHTSA SGO     1
dtype: int64
```

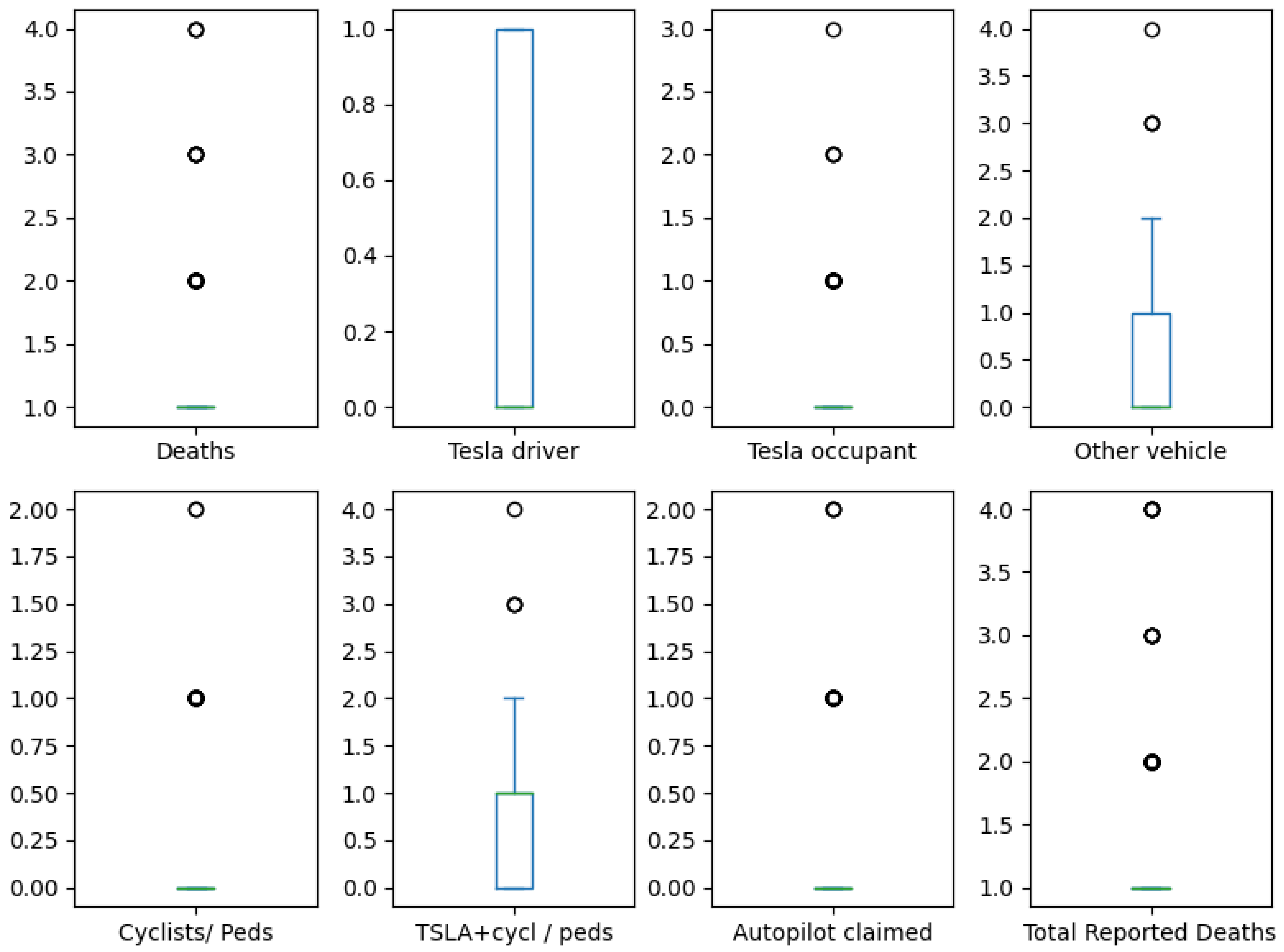
```python
import numpy as np
import matplotlib.pyplot as plt
columns = ['Deaths','Tesla driver', 'Tesla occupant', 'Other vehicle', 'Cyclists/ Peds',
       'TSLA+cycl / peds', 'Model', 'Autopilot claimed',
       'Verified Tesla Autopilot Deaths',
       'Verified Tesla Autopilot Deaths + All Deaths Reported to NHTSA SGO']
for col in columns:
  data[col] = data[col].apply(lambda x : '0' if  x in ['-',','] else x)
  data[col] = pd.to_numeric(data[col], errors='coerce')
  data[col] = data[col].fillna(0)
year_mode = data['Year'].mode()[0]
data['Year'] = data['Year'].apply(lambda x: year_mode if np.isnan(x) else x)
data['Year'] = data['Year'].apply(lambda x: year_mode if x == 202 else x)
data['Year'] = data['Year'].astype(int)
print(data.isna().sum())
```

```
Case #                                                         0
Year                                                           0
Date                                                           0
Country                                                        0
Description                                                    0
Deaths                                                         0
Tesla driver                                                   0
Tesla occupant                                                 0
Other vehicle                                                  0
Cyclists/ Peds                                                 0
TSLA+cycl / peds                                               0
Model                                                          0
Autopilot claimed                                              0
Verified Tesla Autopilot Deaths                                0
Verified Tesla Autopilot Deaths + All Deaths Reported to NHTSA SGO    0
dtype: int64
```

Distribution of numeric columns

```
data['Country'] = data['Country'].str.rstrip()
data['Date'] = pd.to_datetime(data['Date'])
mod = data['Date'].mode()[0]
data['Date'] = data['Date'].fillna(mod)
data['Total Reported Deaths'] = data.apply(lambda row: row['Deaths']+row['Verified Tesla Autopilot Deaths + All Deaths Reported to NHTSA
```

```
columns = ['Deaths','Tesla driver','Tesla occupant','Other vehicle','Cyclists/ Peds','TSLA+cycl / peds','Autopilot claimed','Total Report
_=data[columns].plot(kind='box',
                        subplots=True,
                        layout=(2,4),
                        sharex=False,
                        sharey=False,
                        figsize=(8,6),)

plt.tight_layout()
```


Deaths
Tesla driver
Tesla occupant
Other vehicle
Cyclists/ Peds
TSLA+cycl / peds
Autopilot claimed
Total Reported Deaths

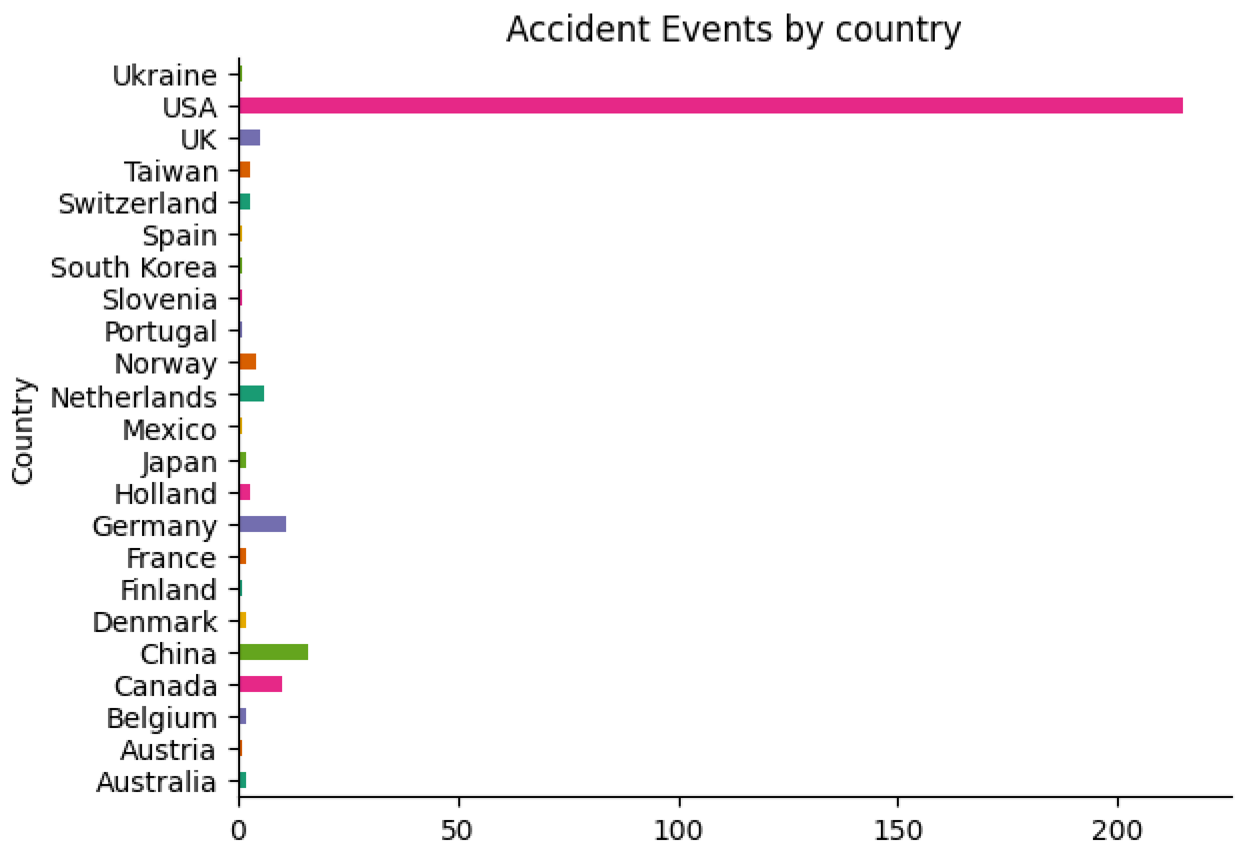
```
data.head()
```

	Case #	Year	Date	Country	Description	Deaths	Tesla driver	Tesla occupant	Other vehicle	Cyclists/ Peds	TSLA+cycl / peds	Model	Autopilot claimed	Verified Tesla Autopilot Deaths	Verified Tesla Autopilot Deaths + All Deaths Reported to NHTSA SGO	To Report Deat
0	294.0	2022	2023-01-17	USA	Tesla crashes into back of semi	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	
1	293.0	2022	2023-01-07	Canada	Tesla crashes	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	
2	292.0	2022	2023-01-07	USA	Tesla hits pole, catches on fire	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	
3	291.0	2022	2022-12-22	USA	Tesla crashes and burns	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	
4	290.0	2022	2022-12-19	Canada	Tesla crashes into storefront	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	

Accident Events by country

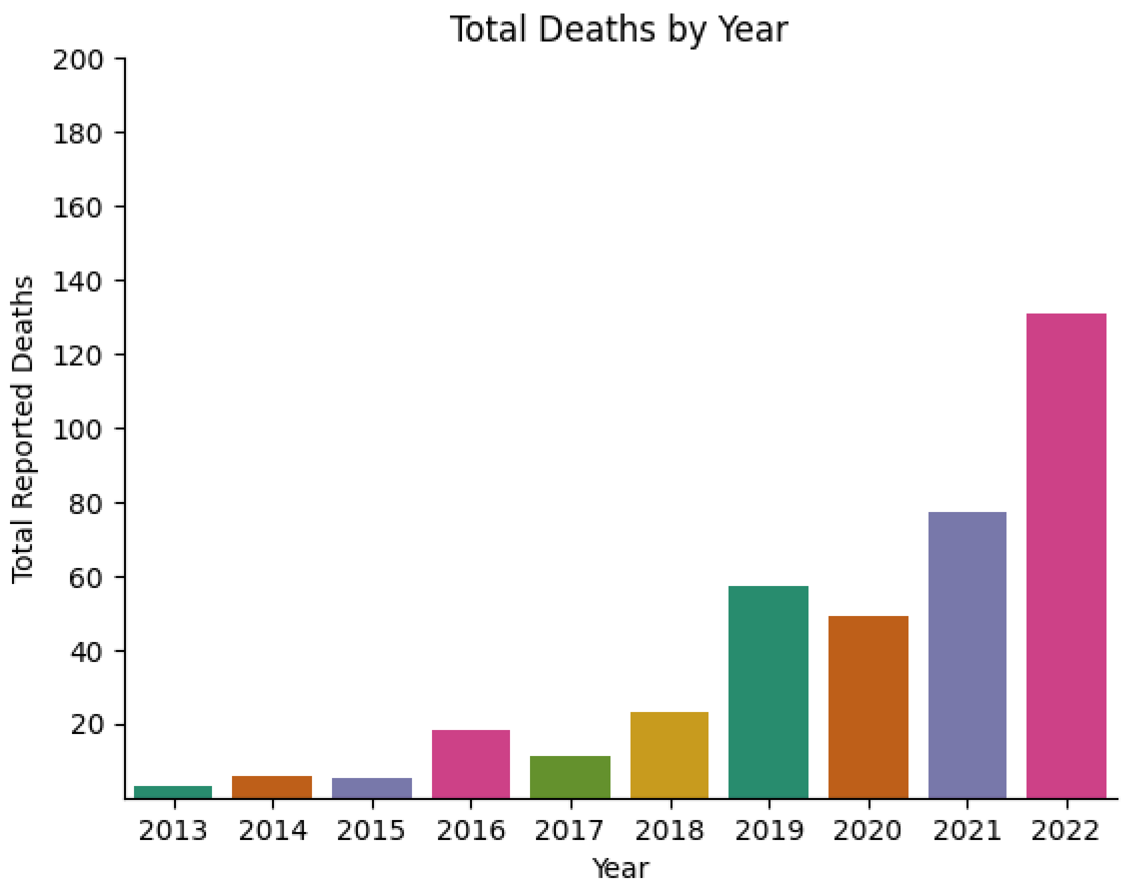
```
from matplotlib import pyplot as plt
import seaborn as sns
data.groupby('Country').size().plot(kind='barh', color=sns.palettes.mpl_palette('Dark2'))
```

```
plt.gca().spines[['top', 'right',]].set_visible(False)
_=plt.title('Accident Events by country')
```



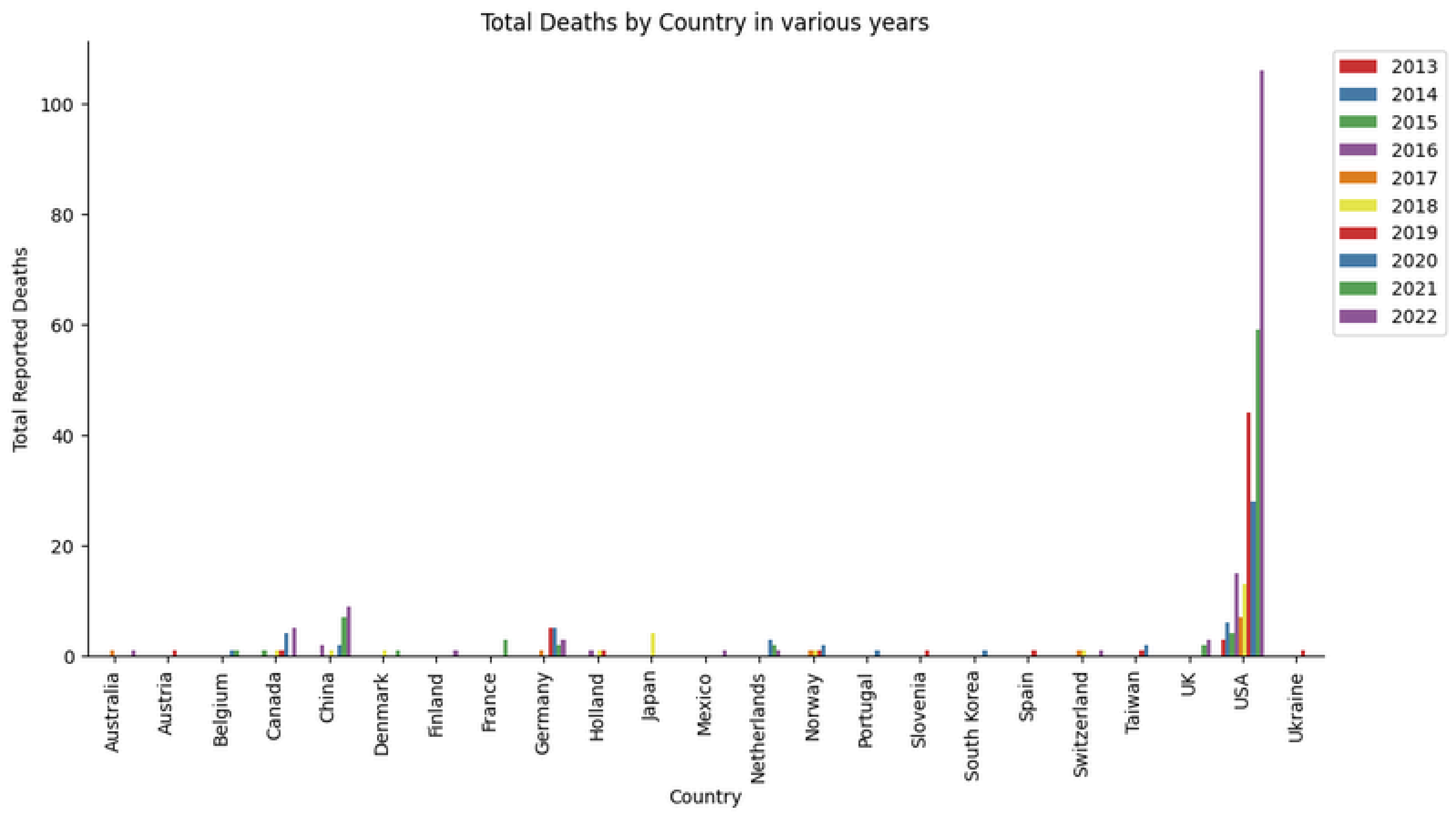
Deaths by year

```
import seaborn as sns
import warnings
warnings.filterwarnings('ignore')
deaths_by_year = pd.DataFrame(data.groupby('Year')['Total Reported Deaths'].sum()).reset_index()
plt.gca().spines[['top', 'right',]].set_visible(False)

fig=sns.barplot(data = deaths_by_year, x='Year', y='Total Reported Deaths' , palette = sns.mpl_palette('Dark2'))
plt.title('Total Deaths by Year')
plt.yticks(np.arange(20,220,20))
plt.show()
```



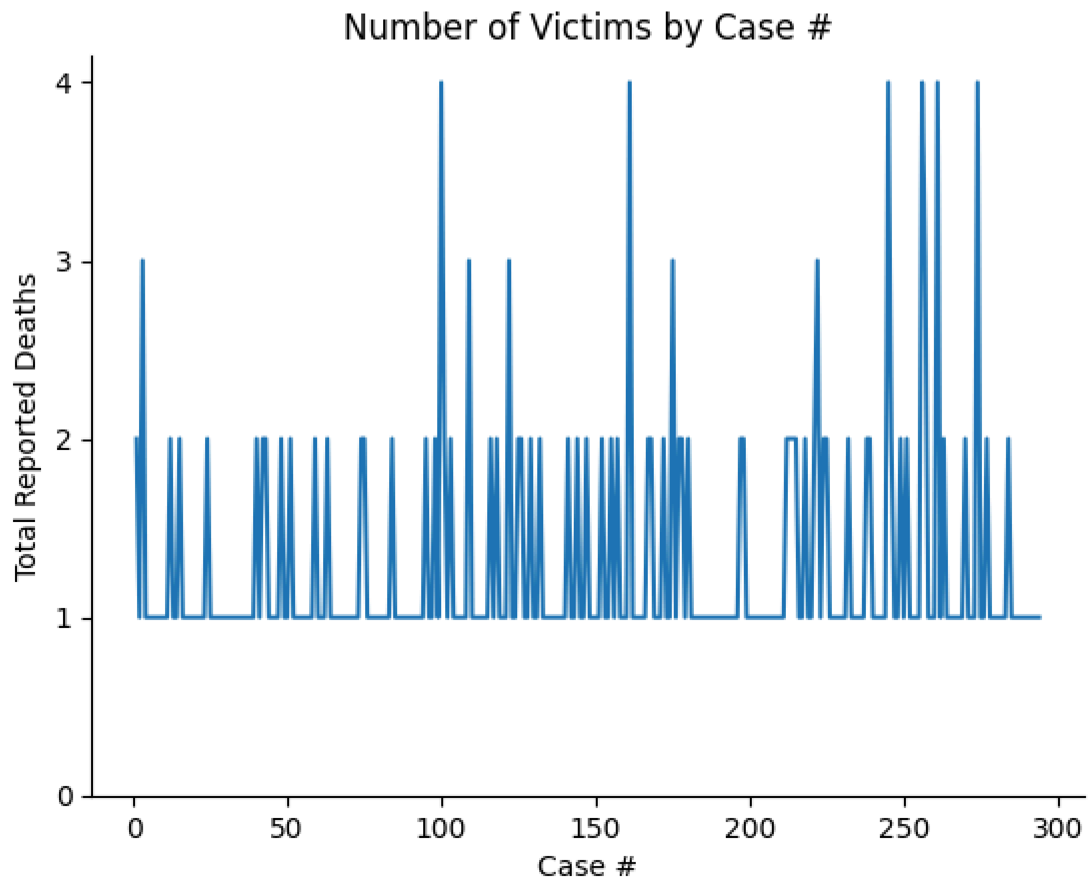
Deaths by country and year

```
deaths_by_year = pd.DataFrame(data.groupby(['Country','Year'])['Total Reported Deaths'].sum()).reset_index()

plt.figure(figsize = (12,6))
fig=sns.barplot(data = deaths_by_year, x='Country', hue = "Year", y='Total Reported Deaths',  palette = sns.mpl_palette('Set1'))
plt.title('Total Deaths by Country in various years')
plt.xticks(rotation=90)
plt.legend(bbox_to_anchor=(1, 1), loc="upper left")
plt.gca().spines[['top', 'right',]].set_visible(False)
plt.show()
```



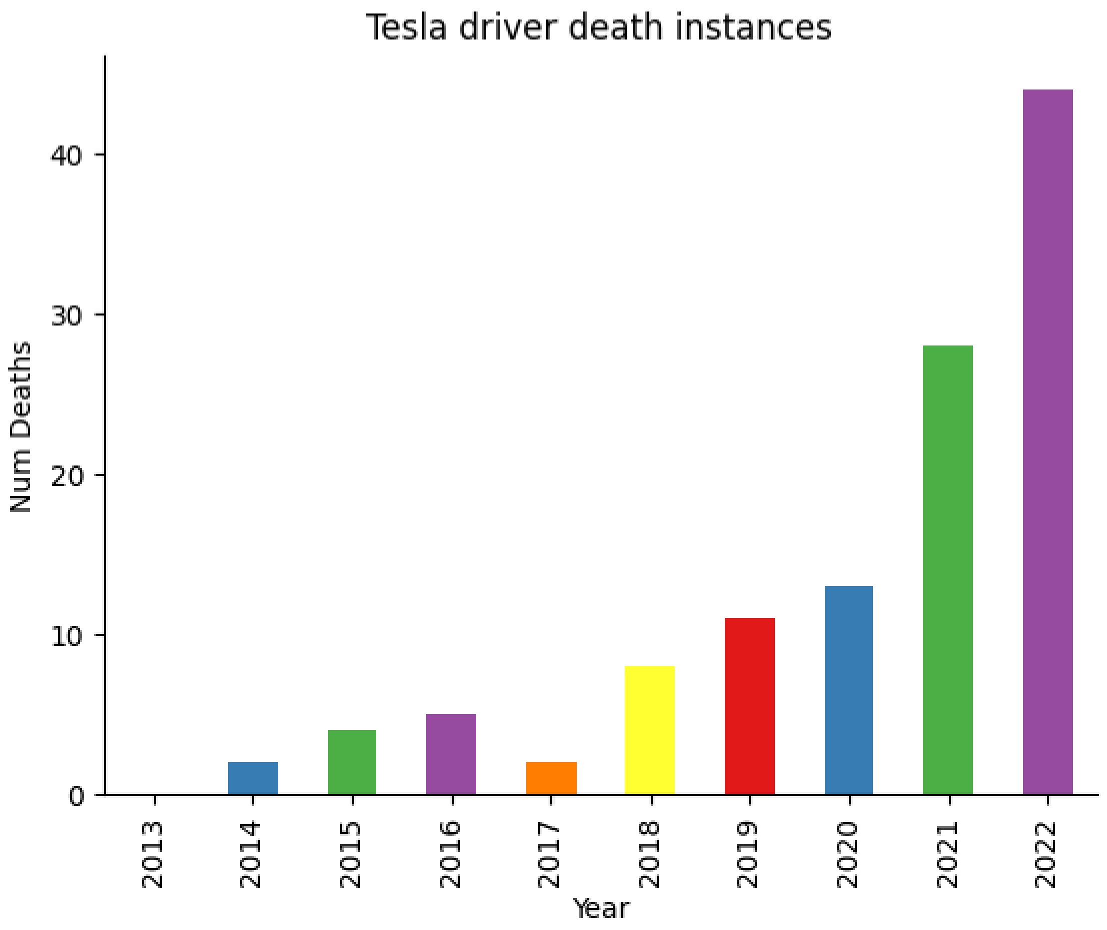
Number of victims per accident

```
df = data [['Case #','Total Reported Deaths']].sort_values(by='Case #')
sns.lineplot(data=df , x= 'Case #', y='Total Reported Deaths')
plt.gca().spines[['top', 'right',]].set_visible(False)
plt.yticks(np.arange(0,5))
_=plt.title('Number of Victims by Case #')
```



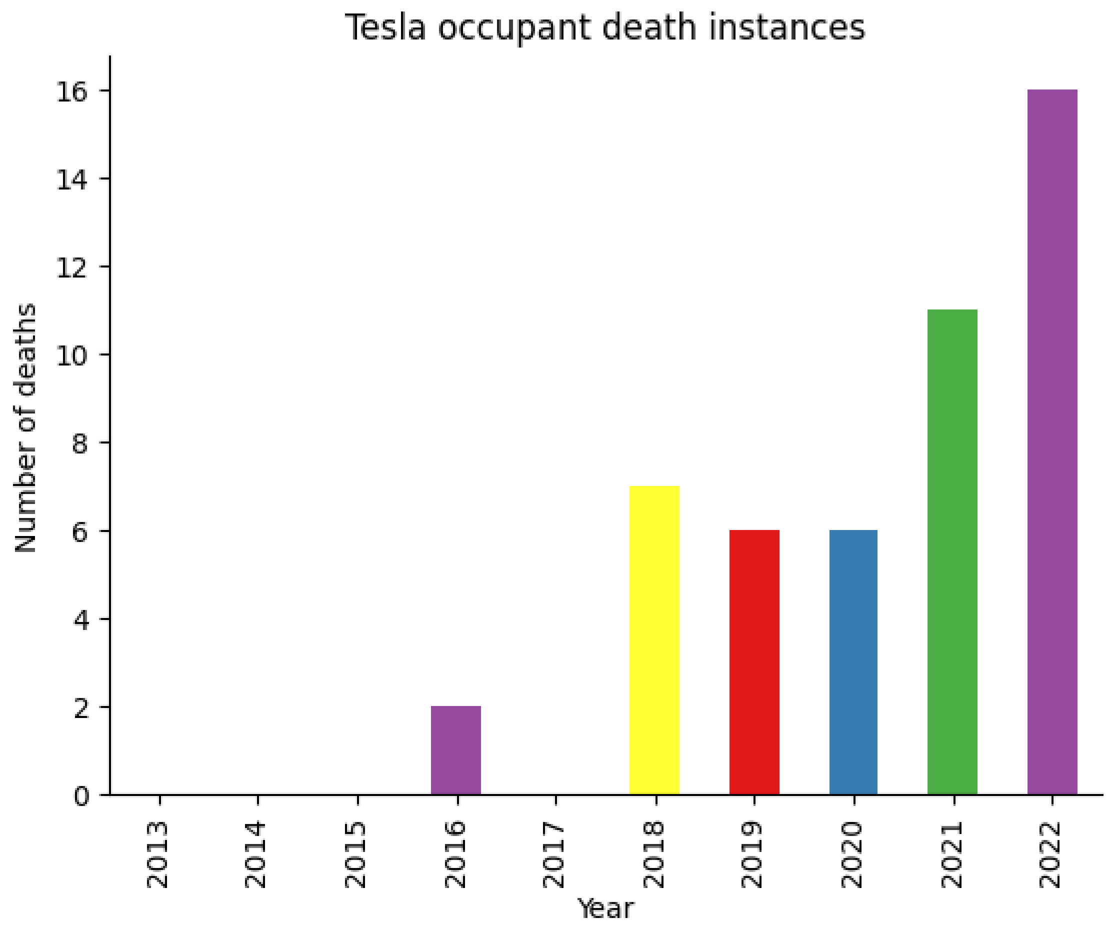
Instances of Tesla driver deaths

```
_=data.groupby('Year')['Tesla driver'].sum().plot(kind='bar', color = sns.mpl_palette('Set1'))
plt.title('Tesla driver death instances')
plt.xlabel('Year')
plt.ylabel('Num Deaths')
plt.gca().spines[['top', 'right',]].set_visible(False)
```



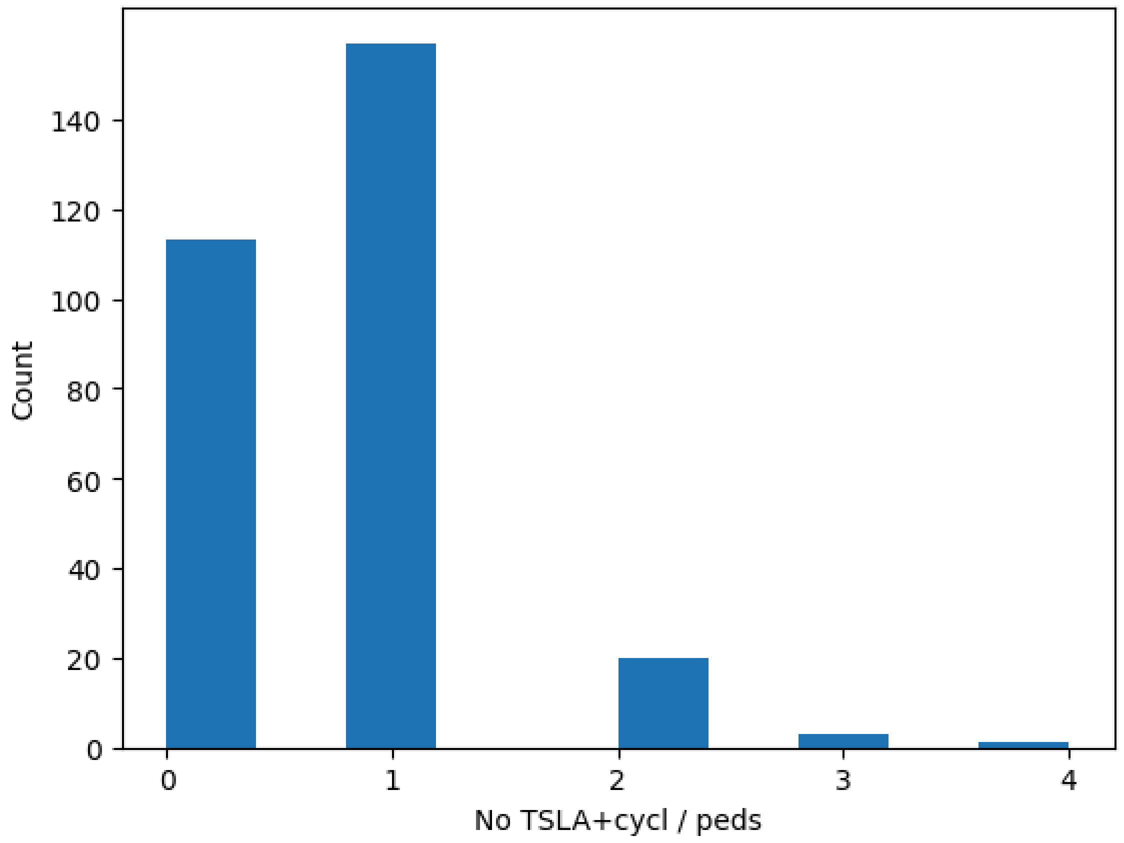
Instances of Tesla occupant deaths

```
data.groupby('Year')['Tesla occupant'].sum().plot(kind='bar', color = sns.mpl_palette('Set1'))
plt.title('Tesla occupant death instances')
plt.ylabel('Number of deaths')
plt.gca().spines[['top', 'right',]].set_visible(False)
```



Distribution of events in which the vehicle hit a cyclist or a pedestrian

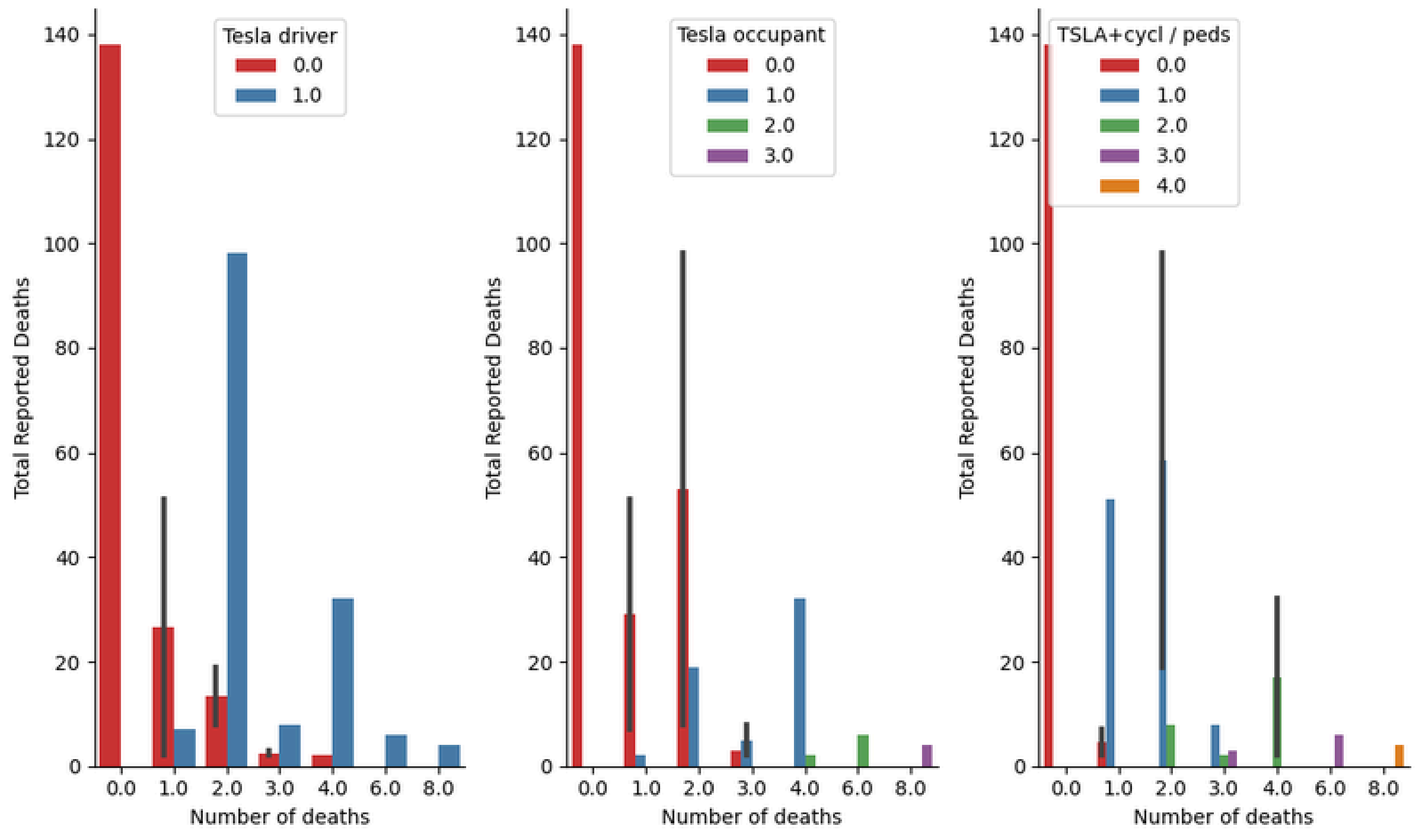
```
_=data['TSLA+cycl / peds'].hist(bins=10,grid=False)
_=plt.xlabel('No TSLA+cycl / peds')
_=plt.xticks(np.arange(0,5,1))
_=plt.ylabel('Count')
_=plt.yticks(np.arange(0,160,20))
```



Deaths of occupant, driver of a Tesla along with a cyclist or pedestrian

```
columns = ['Tesla driver','Tesla occupant','TSLA+cycl / peds']
grp = pd.DataFrame(data.groupby(columns)['Total Reported Deaths'].sum()).reset_index()
grp['Cumulative'] = grp.apply(lambda row: row['Tesla driver'] + row['Tesla occupant'] + row['TSLA+cycl / peds'],axis = 1)
plt.figure(figsize=(10,6))
for i,col in enumerate(columns):
   plt.subplot(1,3,i+1)
   _=sns.barplot(data = grp , x = 'Cumulative',y='Total Reported Deaths',hue=col,palette = sns.mpl_palette('Set1'))
   _=plt.xlabel('Number of deaths')
   plt.gca().spines[['top', 'right',]].set_visible(False)
```

```
  plt.tight_layout()
```



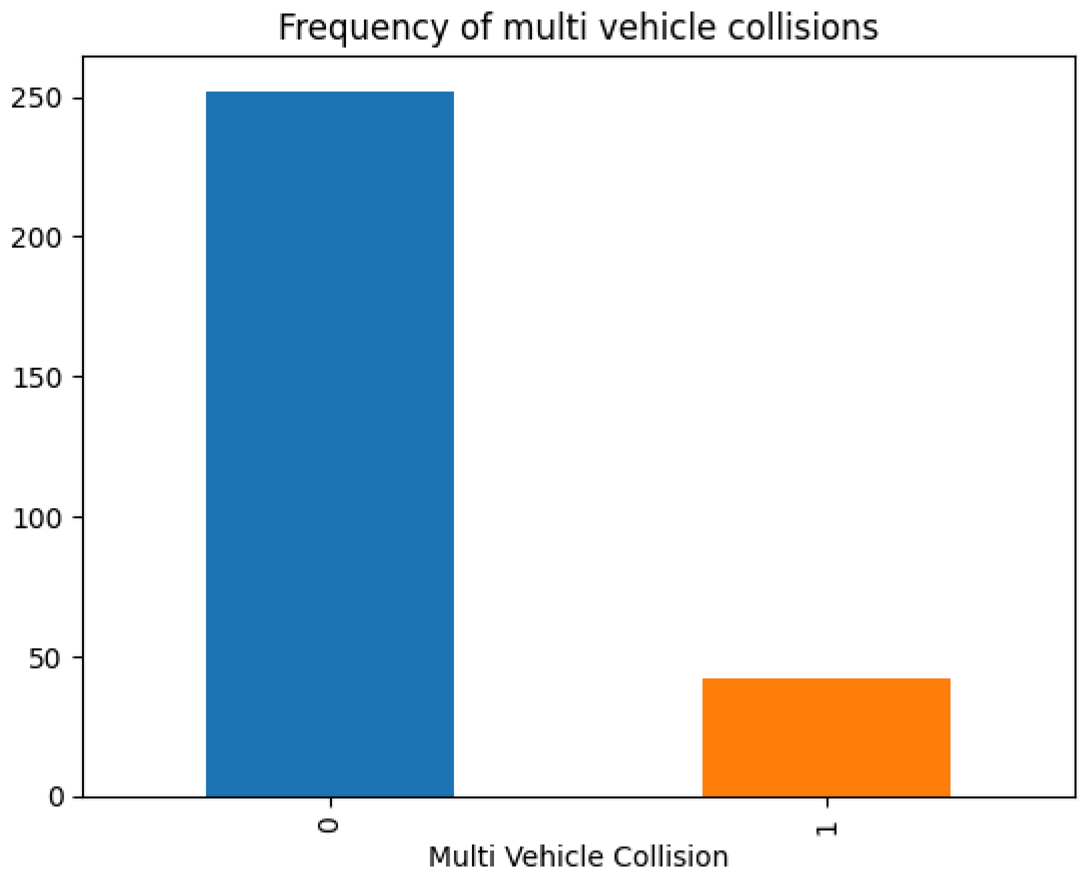
```
def check_for_two__vehicles(description):
  vehicles = []
  count = 0
  description_lower = description.lower()  # For case-insensitive matching
  temp = []
  for object_ in objects:
     if object_.lower() in description_lower:
       temp.append(object_)
```

```
        if(len(temp)>= 2):
          return 1
  return 0



url_labels = 'https://raw.githubusercontent.com/tksundar/autonomous_driving/refs/heads/master/labels.csv'
labels = pd.read_csv(url_labels, names = ['id','name','xmin','ymin','xmax','ymax'])

objects = labels['name'].unique().tolist()
objects.remove('pedestrian')
objects.append('Tesla')
objects.append('Semi')
```

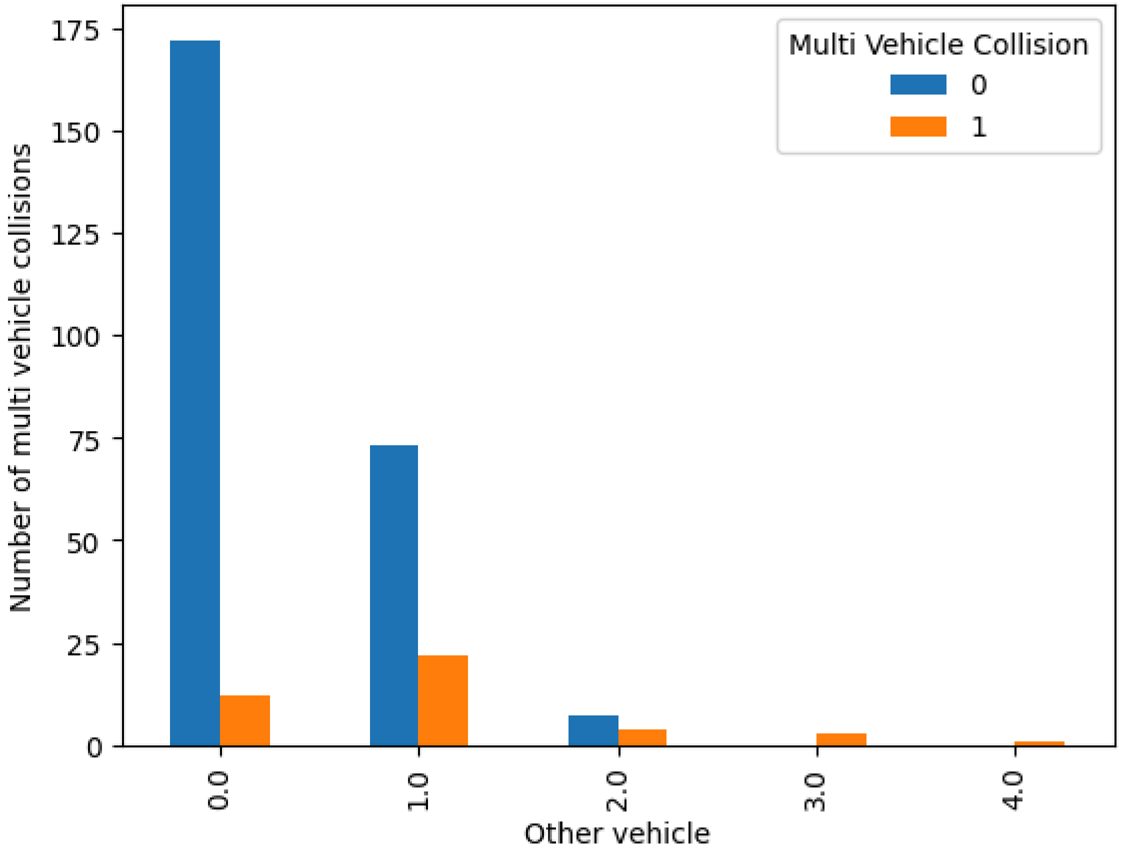
Frequency of Tesla colliding with other vehicles

```
data['Multi Vehicle Collision'] = data.apply(lambda row: check_for_two__vehicles(row['Description']),axis=1)
_=data.groupby(['Multi Vehicle Collision']).size().plot(kind = 'bar', color = sns.mpl_palette('tab10'))
plt.title('Frequency of multi vehicle collisions')

print(f"Total multi vehicle collisions : {data['Multi Vehicle Collision'].sum()}\n")
```

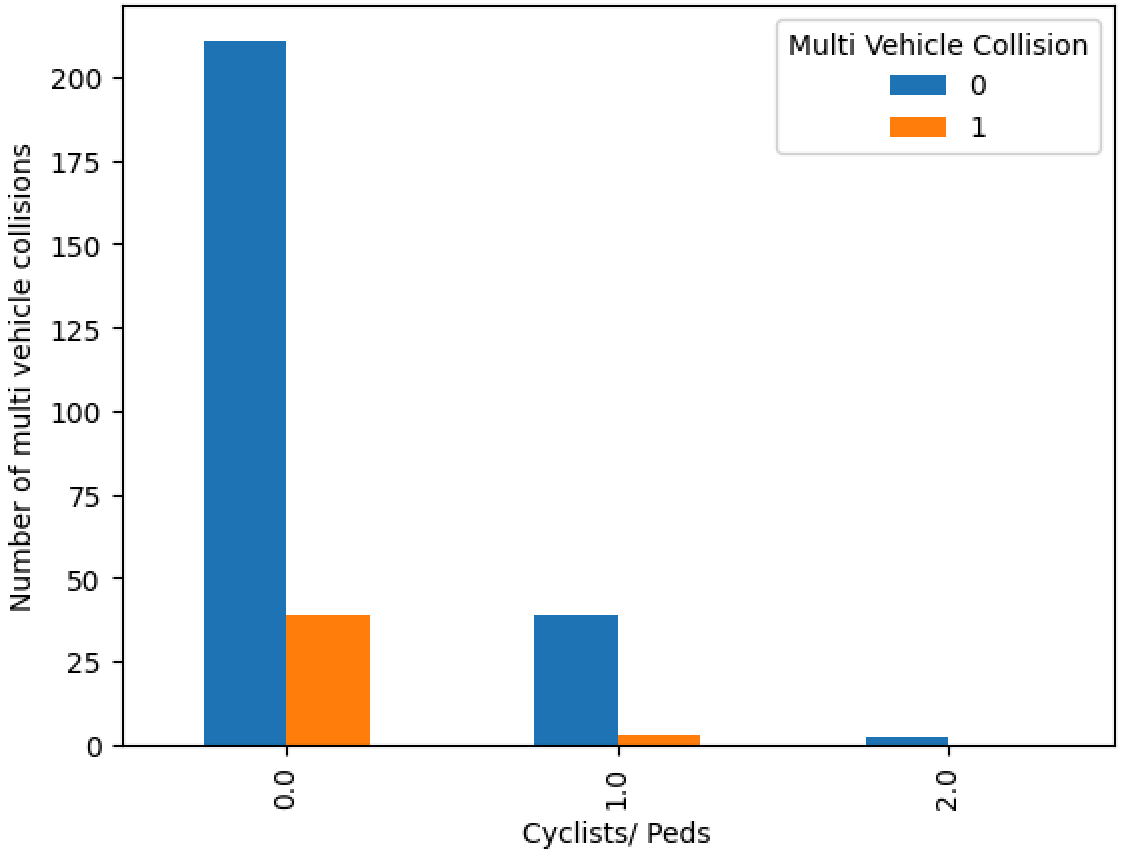
```
Total multi vehicle collisions : 42
```



```
_=pd.crosstab(data['Other vehicle'],data['Multi Vehicle Collision']).plot(kind='bar')
plt.ylabel('Number of multi vehicle collisions')
_=pd.crosstab(data['Cyclists/ Peds'],data['Multi Vehicle Collision']).plot(kind='bar')
_=plt.ylabel('Number of multi vehicle collisions')
```



Multi Vehicle Collision
0
1
Number of multi vehicle collisions
175
150
125
100
75
50
25
0
0.0
1.0
2.0
3.0
4.0
Other vehicle


Multi Vehicle Collision
0
1
Number of multi vehicle collisions
200
175
150
125
100
75
50
25
0
0.0
1.0
2.0
Cyclists/ Peds