1. Overview

This project analyzes aircraft accidents and incidents from 1948 to 2022. It is part of the initial phase of the FlatIron Data Science bootcamp, with the requirement to investigate the provided dataset. The goal is to derive three business recommendations for strategic investments in the aircraft industry. The business problem is to identify low-risk aircraft for a company looking to expand into commercial and private aviation.

2. Business Understanding

The main objective is to discern which aircraft present the lowest risk for the company's venture into aviation. This expansion requires a thorough risk assessment to make informed decisions on aircraft acquisition. The findings will be translated into actionable insights for the head of the new aviation division to guide purchase decisions. The investigation centers on assessing the risk profiles of various aircraft, with the aim of providing three informed business recommendations. These recommendations will specifically address which types of aircraft the company should consider for investment based on historical safety data. The ultimate goal is to guide the company towards aircraft options that minimize risk and potential liability, thereby supporting safe and sound investment decisions in the aviation sector.

Our primary stakeholders are the board members of the company as they are the ones to decide whether to carry out the investment or not.

3. Data Understanding

3.1 Data Description

For the project, the data source is drawn from Kaggle, which encompasses a comprehensive collection of aircraft accidents and incidents. The timeline of this dataset spans an extensive period, covering events from the year 1948 through to 2022.

The dataset has undergone a meticulous cleaning procedure to ensure the quality and relevance of the data. This process included a filter to retain only those incidents and accidents that occurred within the United States. Additionally, the data was refined by filtering out events to include only those that resulted in fatal injuries or serious injuries, thus focusing on the most severe occurrences.

Now let's dive into the data to better understand it and arrive to the business recommendations.

3.2 SetUp

3.3 Import necessary libraries

In [2]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
```

In [3]:
```
pd.set_option('display.max_columns', 500)
```

3.4 Define global variables

In [4]:
```
INPUT_PATH = "../../Data_Project_Phase1/AviationData.csv"
```

In [5]:
```
!pwd
```

```
/c/Users/Usuario/Desktop/FlatIron/DataScience_FlatIron_Curso/Phase_1/Phase1-Project/Aircraft_safety_analysis/notebooks
```

3.5 Functions

In [6]:
```
def categorize_data(column):
    """
    Function: This function will return the string 'zero' if the value of the argumer
    'one or more' if the value of 'column' is not zero

    Argument (data series): The column to evaluate

    Result (string): The category label for the value

    """
    if column==0:
        return 'Zero'
    elif pd.isna(column):
        return 'Unknown'
    else:
        return 'One or More'
```

In [7]:
```
def plot_bar_graph_for_columns(columns):

    """
    Function: This function creates a bar graph for a column.

    Argument (data series): The columns to evaluate.

    Returns: Bar plot for the column

    """


    plt.figure()
    df[columns].value_counts().plot(kind='bar')
    plt.xlabel(columns)
    plt.ylabel('Frequency')
    plt.xticks(rotation=90)
    plt.title(f'Bar Graph of {columns}')
```

In [8]:
```
def plot_column_data(df, column, kind_of_graph):

    """
    Function: This function creates a value_counts and the desired graph for a columr

    Argument (data series): The data frame, the coolumn and the kind of graph wished

    Returns: Value_counts of the column and the desired graph representation
    """

    # Print the normalized value counts including NaN values
    value_counts = df[column].value_counts(normalize=True, dropna=False)
    print(value_counts)
    print()

    # Plot the graph
    if kind_of_graph == 'bar':
        plt.figure()
        value_counts.plot(kind='bar')
    elif kind_of_graph == 'pie':
        plt.figure()
        value_counts.plot(kind='pie')
    elif kind_of_graph == 'line':
        plt.figure()
        value_counts.plot(kind='line')

    # Show the plot
    plt.title(f'Graph of {column}')
    plt.ylabel('Frequency')
    plt.xlabel(column)
    plt.xticks(rotation=90)
    plt.show();
```

In [9]:
```
def plot_feature(df: pd.DataFrame,
                 column_name: str,
                 column_type: str,
                 variable_target1: str,
                 variable_target2: str):
    """
    Visualize a variable with faceting on two target variables.

    Parameters:
        df (pd.DataFrame): The dataframe containing the data.
        column_name (str): The name of the column to be visualized.
        column_type (str): The type of the column ('continuous' or 'categorical').
        variable_target1 (str): The name of the first target variable for faceting.
        variable_target2 (str): The name of the second target variable for faceting.
    """
    f, (ax1, ax2, ax3) = plt.subplots(nrows=1, ncols=3, figsize=(18,6), dpi=90)

    # Plot without target variables
    if column_type == 'continuous':
        sns.distplot(df.loc[df[column_name].notnull(), column_name], kde=False, ax=ax
    else:
        categories_to_consider = list(df[column_name].value_counts().index[:15])
        df = df[df[column_name].isin(categories_to_consider)]
        sns.countplot(x=df[column_name], order=sorted(categories_to_consider),
                      color='#5975A4', saturation=1, ax=ax1)
    ax1.set_xlabel(column_name)
    ax1.set_ylabel('Count')
    ax1.set_title(f"Distribution of {column_name}")
    ax1.tick_params(axis='x', rotation=90)

    # Plot with the first target variable
    if column_type == "continuous":
        sns.boxplot(x=column_name, y=variable_target1, data=df, ax=ax2)
    else:
        data = df.groupby(column_name)[variable_target1].value_counts(normalize=True)
        data.plot(kind='bar', stacked=True, ax=ax2)
    ax2.set_ylabel(f"Proportion of {variable_target1}")
    ax2.set_title(f"{column_name} by {variable_target1}")
    ax2.tick_params(axis='x', rotation=90)

    # Plot with the second target variable
    if column_type == "continuous":
        sns.boxplot(x=column_name, y=variable_target2, data=df, ax=ax3)
    else:
        data = df.groupby(column_name)[variable_target2].value_counts(normalize=True)
        data.plot(kind='bar', stacked=True, ax=ax3)
    ax3.set_ylabel(f"Proportion of {variable_target2}")
    ax3.set_title(f"{column_name} by {variable_target2}")
    ax3.tick_params(axis='x', rotation=90)

    plt.tight_layout()
    plt.show()
```

3.6 Code

In [10]:
```
df = pd.read_csv(INPUT_PATH, encoding="latin-1")
df
```

```
C:\Users\Usuario\AppData\Local\Temp\ipykernel_22212\281516245.py:1: DtypeWarning: Col
umns (6,7,28) have mixed types. Specify dtype option on import or set low_memory=Fals
e.
  df = pd.read_csv(INPUT_PATH, encoding="latin-1")
```

Out[10]:

	Event.Id	Investigation.Type	Accident.Number	Event.Date	Location	Country	La
0	20001218X45444	Accident	SEA87LA080	1948-10-24	MOOSE CREEK, ID	United States	
1	20001218X45447	Accident	LAX94LA336	1962-07-19	BRIDGEPORT, CA	United States	
2	20061025X01555	Accident	NYC07LA005	1974-08-30	Saltville, VA	United States	36.9
3	20001218X45448	Accident	LAX96LA321	1977-06-19	EUREKA, CA	United States	
4	20041105X01764	Accident	CHI79FA064	1979-08-02	Canton, OH	United States	
...	...	...	...	...	...	...	
88884	20221227106491	Accident	ERA23LA093	2022-12-26	Annapolis, MD	United States	
88885	20221227106494	Accident	ERA23LA095	2022-12-26	Hampton, NH	United States	
88886	20221227106497	Accident	WPR23LA075	2022-12-26	Payson, AZ	United States	34
88887	20221227106498	Accident	WPR23LA076	2022-12-26	Morgan, UT	United States	
88888	20221230106513	Accident	ERA23LA097	2022-12-29	Athens, GA	United States	

88889 rows × 31 columns

In [11]:
```
print(f"This dataset has {df.shape[0]} rows and {df.shape[1]} columns")
```

```
This dataset has 88889 rows and 31 columns
```

In [12]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 88889 entries, 0 to 88888
Data columns (total 31 columns):
 #   Column                  Non-Null Count  Dtype
---  ------                  --------------  -----
 0   Event.Id                88889 non-null  object
 1   Investigation.Type      88889 non-null  object
 2   Accident.Number         88889 non-null  object
 3   Event.Date              88889 non-null  object
 4   Location                88837 non-null  object
```

```
 5   Country                 88663 non-null  object
 6   Latitude                34382 non-null  object
 7   Longitude               34373 non-null  object
 8   Airport.Code            50132 non-null  object
 9   Airport.Name            52704 non-null  object
 10  Injury.Severity         87889 non-null  object
 11  Aircraft.damage         85695 non-null  object
 12  Aircraft.Category       32287 non-null  object
 13  Registration.Number     87507 non-null  object
 14  Make                    88826 non-null  object
 15  Model                   88797 non-null  object
 16  Amateur.Built           88787 non-null  object
 17  Number.of.Engines       82805 non-null  float64
 18  Engine.Type             81793 non-null  object
 19  FAR.Description         32023 non-null  object
 20  Schedule                12582 non-null  object
 21  Purpose.of.flight       82697 non-null  object
 22  Air.carrier             16648 non-null  object
 23  Total.Fatal.Injuries    77488 non-null  float64
 24  Total.Serious.Injuries  76379 non-null  float64
 25  Total.Minor.Injuries    76956 non-null  float64
 26  Total.Uninjured         82977 non-null  float64
 27  Weather.Condition       84397 non-null  object
 28  Broad.phase.of.flight   61724 non-null  object
 29  Report.Status           82505 non-null  object
 30  Publication.Date        75118 non-null  object
dtypes: float64(5), object(26)
memory usage: 21.0+ MB
```

Now, I am going to clean the column names by making them be in lower case and using an underscore

In [13]:
```
df.columns = df.columns.str.lower().str.replace('.', '_')
df.columns
```

Out[13]:
```
Index(['event_id', 'investigation_type', 'accident_number', 'event_date',
       'location', 'country', 'latitude', 'longitude', 'airport_code',
       'airport_name', 'injury_severity', 'aircraft_damage',
       'aircraft_category', 'registration_number', 'make', 'model',
       'amateur_built', 'number_of_engines', 'engine_type', 'far_description',
       'schedule', 'purpose_of_flight', 'air_carrier', 'total_fatal_injuries',
       'total_serious_injuries', 'total_minor_injuries', 'total_uninjured',
       'weather_condition', 'broad_phase_of_flight', 'report_status',
       'publication_date'],
      dtype='object')
```

In [14]:
```
df
```

Out[14]:

	event_id	investigation_type	accident_number	event_date	location	country	lat
0	20001218X45444	Accident	SEA87LA080	1948-10-24	MOOSE CREEK, ID	United States	
1	20001218X45447	Accident	LAX94LA336	1962-07-19	BRIDGEPORT, CA	United States	
2	20061025X01555	Accident	NYC07LA005	1974-08-30	Saltville, VA	United States	36.9
3	20001218X45448	Accident	LAX96LA321	1977-06-19	EUREKA, CA	United States	

	event_id	investigation_type	accident_number	event_date	location	country	lat
4	20041105X01764	Accident	CHI79FA064	1979-08-02	Canton, OH	United States	
...	...	...	...	...	...	...	
88884	20221227106491	Accident	ERA23LA093	2022-12-26	Annapolis, MD	United States	
88885	20221227106494	Accident	ERA23LA095	2022-12-26	Hampton, NH	United States	
88886	20221227106497	Accident	WPR23LA075	2022-12-26	Payson, AZ	United States	34
88887	20221227106498	Accident	WPR23LA076	2022-12-26	Morgan, UT	United States	
88888	20221230106513	Accident	ERA23LA097	2022-12-29	Athens, GA	United States	

3.6.1 Descriptive Statistics

In [15]:
```
df.describe()
```

Out[15]:

	number_of_engines	total_fatal_injuries	total_serious_injuries	total_minor_injuries	total_uninjur
count	82805.000000	77488.000000	76379.000000	76956.000000	82977.0000
mean	1.146585	0.647855	0.279881	0.357061	5.3254
std	0.446510	5.485960	1.544084	2.235625	27.9136
min	0.000000	0.000000	0.000000	0.000000	0.0000
25%	1.000000	0.000000	0.000000	0.000000	0.0000
50%	1.000000	0.000000	0.000000	0.000000	1.0000
75%	1.000000	0.000000	0.000000	0.000000	2.0000
max	8.000000	349.000000	161.000000	380.000000	699.0000

Even though Number of Engines is continuous, it could be considered as descrete because it doesn't make much sense to talk about a mean of 1.14 of number of engines.

Other noticeable things are that there is a mean of almost 1 total fatal injury for all the accidents, and data seems to be coherent because there aren't negative values.

3.6.2 Making a primary key

In [16]:
```
df['event_id'].value_counts()
```

Out[16]:
```
event_id
20001212X19172    3
20001214X45071    3
```

```
20220730105623    2
20051213X01965    2
20001212X16765    2
                 ..
20001211X14216    1
20001211X14239    1
20001211X14207    1
20001211X14204    1
20221230106513    1
```

In [17]:
```
df['accident_number'].value_counts()
```

Out[17]:
```
accident_number
CEN22LA149    2
WPR23LA041    2
WPR23LA045    2
DCA22WA214    2
DCA22WA089    2
             ..
LAX92FA065    1
ANC92T#A12    1
MIA92LA049    1
NYC92LA048    1
ERA23LA097    1
Name: count, Length: 88863, dtype: int64
```

In [18]:
```
df['registration_number'].value_counts()
```

Out[18]:
```
registration_number
NONE      344
UNREG     126
UNK        13
USAF        9
N20752      8
          ...
N93478      1
N519UA      1
N8840W      1
N21040      1
N9026P      1
Name: count, Length: 79104, dtype: int64
```

In [19]:
```
df[df['accident_number']=='CEN22LA149']
```

Out[19]:

	event_id	investigation_type	accident_number	event_date	location	country	latituc
87548	20220323104818	Accident	CEN22LA149	2022-03-18	Grapevine, TX	United States	032530
87549	20220323104818	Accident	CEN22LA149	2022-03-18	Grapevine, TX	United States	032530

In [20]:
```
df['primary_key'] = df['accident_number'] + '_' + df['registration_number']
df
```

Out[20]:

	event_id	investigation_type	accident_number	event_date	location	country	lat

	event_id	investigation_type	accident_number	event_date	location	country	lat
0	20001218X45444	Accident	SEA87LA080	1948-10-24	MOOSE CREEK, ID	United States	
1	20001218X45447	Accident	LAX94LA336	1962-07-19	BRIDGEPORT, CA	United States	
2	20061025X01555	Accident	NYC07LA005	1974-08-30	Saltville, VA	United States	36.9
3	20001218X45448	Accident	LAX96LA321	1977-06-19	EUREKA, CA	United States	
4	20041105X01764	Accident	CHI79FA064	1979-08-02	Canton, OH	United States	
...	...	...	...	...	...	...	
88884	20221227106491	Accident	ERA23LA093	2022-12-26	Annapolis, MD	United States	
88885	20221227106494	Accident	ERA23LA095	2022-12-26	Hampton, NH	United States	
88886	20221227106497	Accident	WPR23LA075	2022-12-26	Payson, AZ	United States	34
88887	20221227106498	Accident	WPR23LA076	2022-12-26	Morgan, UT	United States	
88888	20221230106513	Accident	ERA23LA097	2022-12-29	Athens, GA	United States	

In [21]:
```
df['primary_key'].value_counts()
```

Out[21]:
```
primary_key
SEA87LA080_NC6404     1
SEA05CA166_N2094K     1
CHI05CA172_N7446      1
DEN05CA122_N2584B     1
DEN05LA121_N5754S     1
                     ..
MIA91LA225_N2983U     1
ATL91LA180_N62108     1
ATL91LA181A_N26004    1
ATL91LA181B_N67174    1
ERA23LA097_N9026P     1
Name: count, Length: 87507, dtype: int64
```

We haven't found a primary key, but I have created one by combining 2 columns: accident_number and registration_number

3.6.3 Duplicates study

Checking for duplicates

In [22]:
```
df.duplicated().sum()
```

Out[22]: 0

3.6.4 Null-values analysis

Checking for null values

In [23]:
```
df.isnull().sum()/len(df)*100
```

Out[23]:
```
event_id                  0.000000
investigation_type        0.000000
accident_number           0.000000
event_date                0.000000
location                  0.058500
country                   0.254250
latitude                 61.320298
longitude                61.330423
airport_code             43.601570
airport_name             40.708074
injury_severity           1.124999
aircraft_damage           3.593246
aircraft_category        63.677170
registration_number       1.554748
make                      0.070875
model                     0.103500
amateur_built             0.114750
number_of_engines         6.844491
engine_type               7.982990
far_description          63.974170
schedule                 85.845268
purpose_of_flight         6.965991
air_carrier              81.271023
total_fatal_injuries     12.826109
total_serious_injuries   14.073732
total_minor_injuries     13.424608
total_uninjured           6.650992
weather_condition         5.053494
broad_phase_of_flight    30.560587
report_status             7.181991
publication_date         15.492356
primary_key               1.554748
dtype: float64
```

I will proceed to create a list to drop certain columns that have too many null values and that I perceive not to be usefull for the analysis.

Latitude, Longitude, airpot_code, airport_name, and publication_date I decide to drop mainly because they are not useful for the case study. Schedule and air_carrier I decide to drop because they have more than 80% of null values

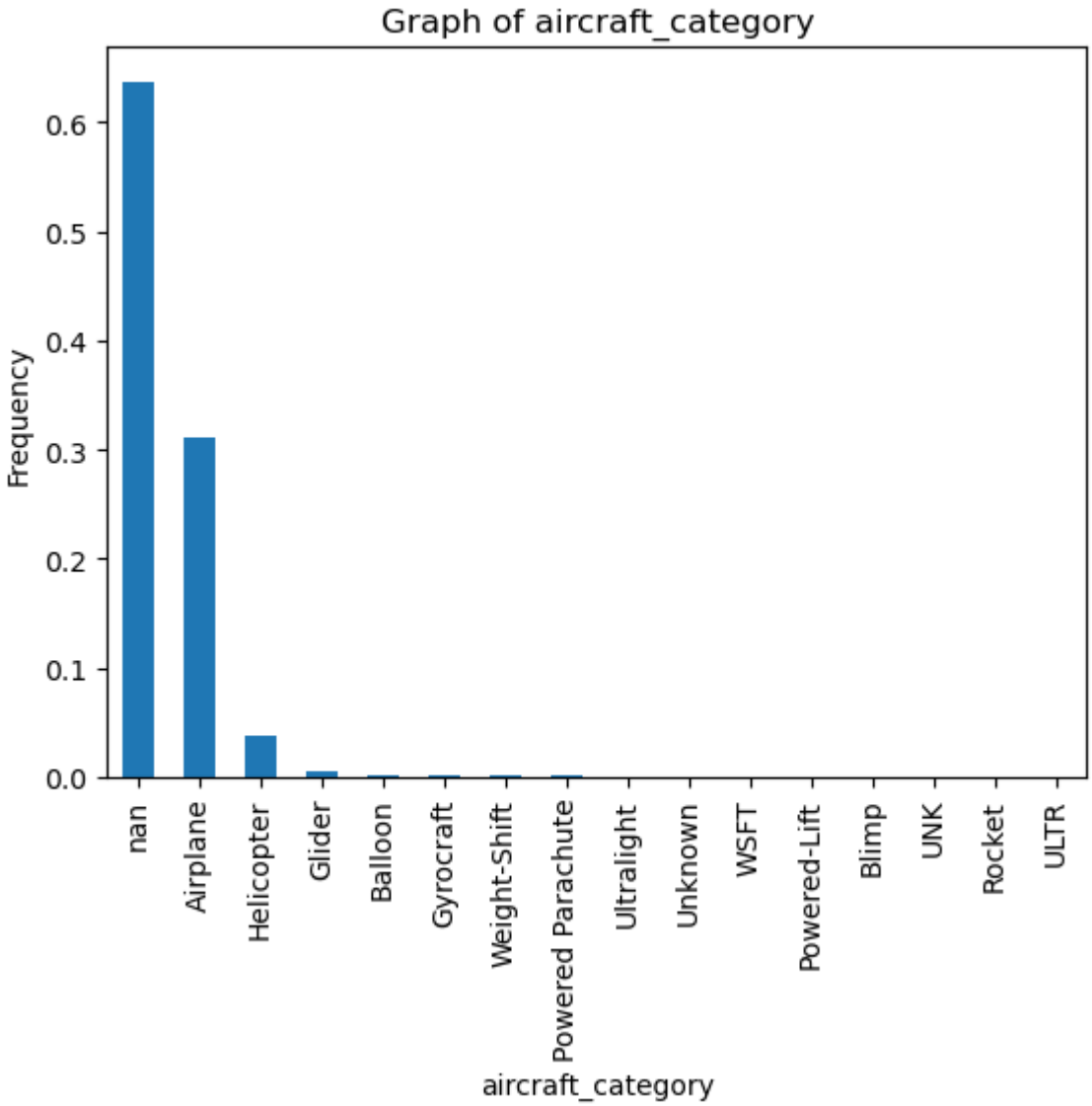
In [24]:
```
drop_columns = ['latitude','longitude','airport_code','airport_name','schedule','air_
```

Now I will study other columns that have a high percent of null values to determine whether they still can give good insights. These columns are: aircraft_category, far_description, and broad_phase_of_flight

Aircraft_category

In [25]:
```
plot_column_data(df,'aircraft_category', 'bar')
```

```
aircraft_category
NaN                  0.636772
Airplane             0.310691
Helicopter           0.038700
Glider               0.005715
Balloon              0.002599
Gyrocraft            0.001946
Weight-Shift         0.001811
Powered Parachute    0.001024
Ultralight           0.000337
Unknown              0.000157
WSFT                 0.000101
Powered-Lift         0.000056
Blimp                0.000045
UNK                  0.000022
Rocket               0.000011
ULTR                 0.000011
Name: proportion, dtype: float64
```



It's observable that only the airplanes and the helicopters have considerable numbers of registrations in the aircraft category. Moreover, as can be seen most of the aircrafts are airplanes.

Given that there 64% of NaN values, I will drop this column too

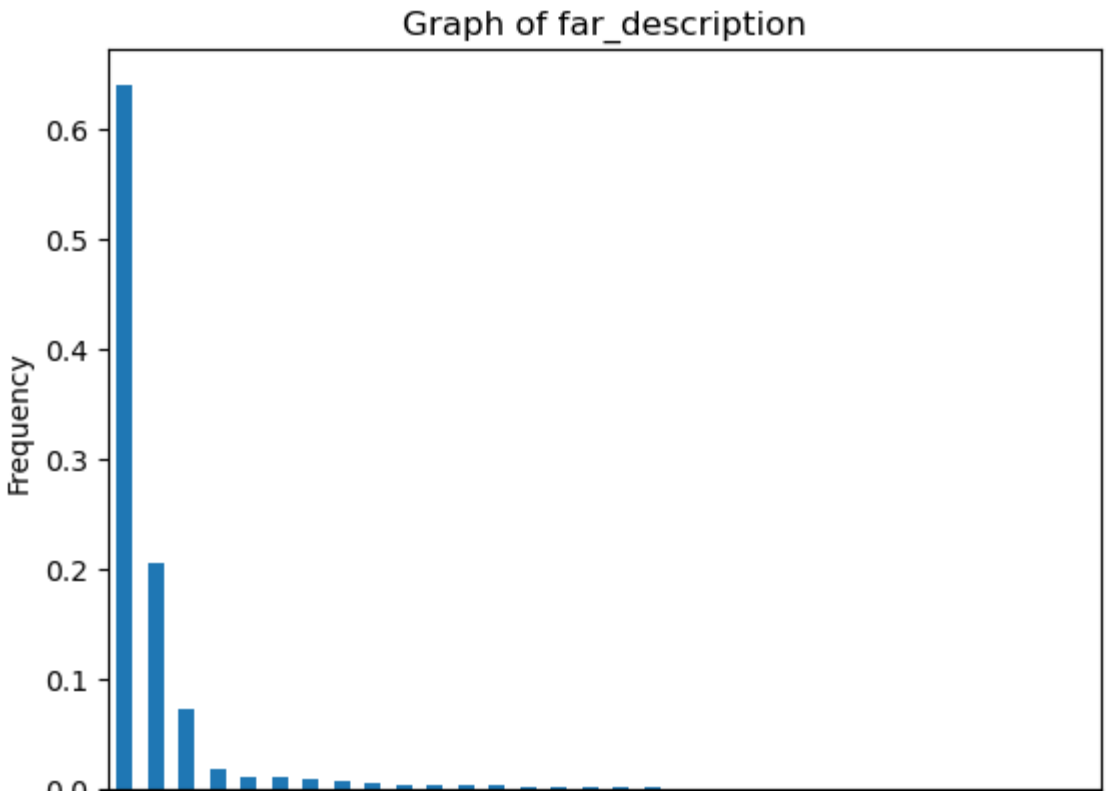
In [26]:
```
drop_columns.append('aircraft_category')
```

3.6.5 Further study of the rest of the columns

Far Description column

In [27]:
```
plot_column_data(df,'far_description', 'bar')
```

```
far_description
NaN                                0.639742
091                                0.204986
Part 91: General Aviation          0.072967
NUSN                               0.017820
NUSC                               0.011396
137                                0.011362
135                                0.008392
121                                0.007639
Part 137: Agricultural             0.004916
UNK                                0.004174
Part 135: Air Taxi & Commuter      0.003352
PUBU                               0.002846
129                                0.002767
Part 121: Air Carrier              0.001856
133                                0.001204
Part 129: Foreign                  0.001125
Non-U.S., Non-Commercial           0.001091
Non-U.S., Commercial               0.001046
Part 133: Rotorcraft Ext. Load     0.000360
Unknown                            0.000247
Public Use                         0.000214
091K                               0.000157
ARMF                               0.000090
Part 125: 20+ Pax,6000+ lbs        0.000056
125                                0.000056
107                                0.000045
103                                0.000022
Public Aircraft                    0.000022
Part 91 Subpart K: Fractional      0.000011
Part 91F: Special Flt Ops.         0.000011
437                                0.000011
Armed Forces                       0.000011
Name: proportion, dtype: float64
```



I interpret that the 091 and Part 91: General Aviation are the same norm of aviation. Basing myself in these research:

https://www.risingup.com/fars/info/

Subchapter F – Air Traffic and General Operating Rules

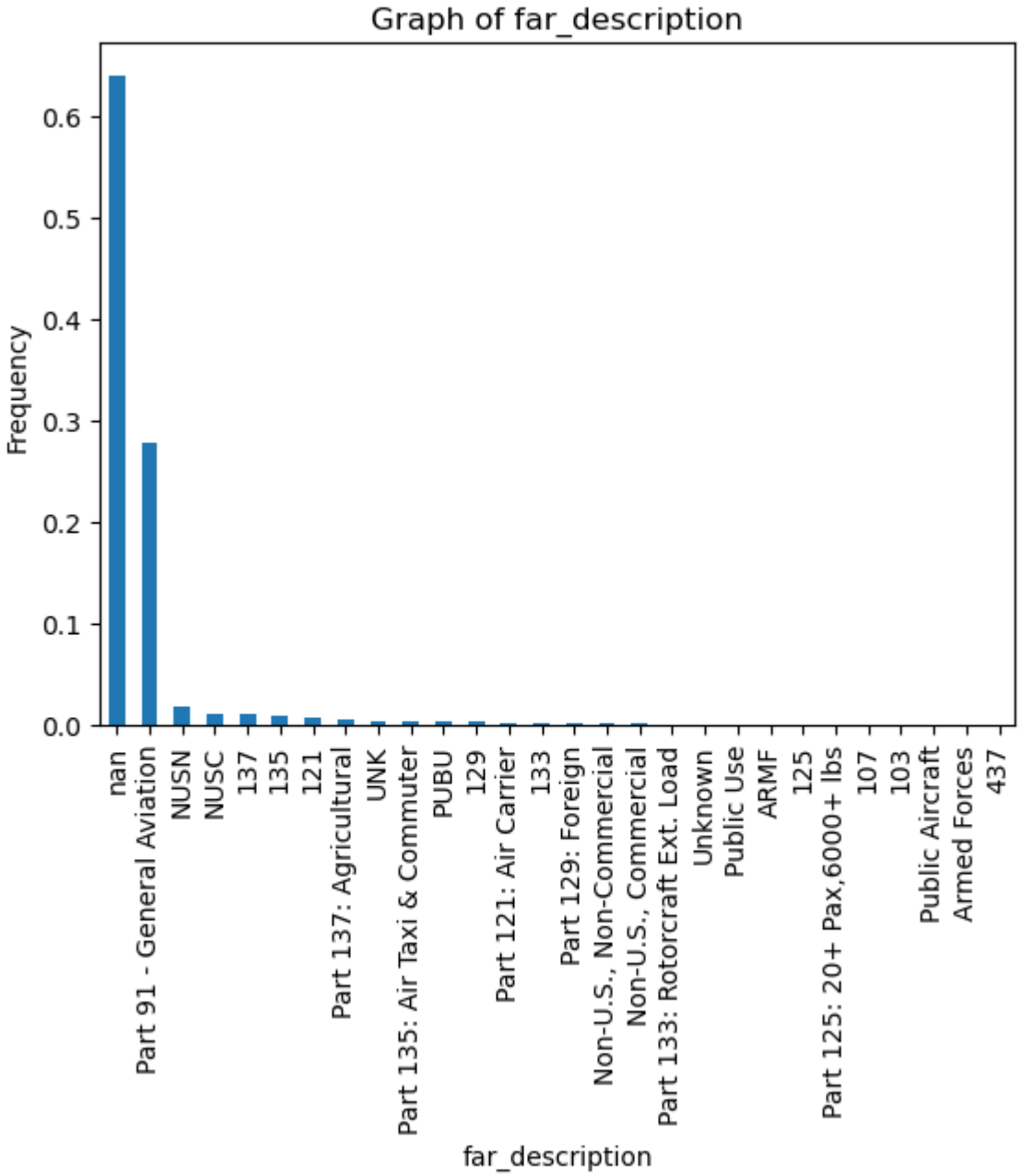
- Part 91 - GENERAL OPERATING AND FLIGHT RULES
- Part 93 - SPECIAL AIR TRAFFIC RULES
- Part 95 - IFR ALTITUDES
- Part 97 - STANDARD INSTRUMENT APPROACH PROCEDURES
- Part 99 - SECURITY CONTROL OF AIR TRAFFIC
- Part 101 - MOORED BALLOONS, KITES, UNMANNED ROCKETS AND UNMANNED FREE BALLOONS
- Part 103 - ULTRALIGHT VEHICLES
- Part 105 - PARACHUTE OPERATIONS

I will proceed to join both of these values and print the result

In [28]:
```
df['far_description'] = df['far_description'].map(lambda x: 'Part 91 - General Aviati
plot_column_data(df,'far_description', 'bar')
```

```
far_description
NaN                              0.639742
Part 91 - General Aviation       0.278133
NUSN                             0.017820
NUSC                             0.011396
137                              0.011362
135                              0.008392
121                              0.007639
Part 137: Agricultural           0.004916
UNK                              0.004174
Part 135: Air Taxi & Commuter    0.003352
```

```
PUBU                                0.002846
129                                 0.002767
Part 121: Air Carrier               0.001856
133                                 0.001204
Part 129: Foreign                   0.001125
Non-U.S., Non-Commercial            0.001091
Non-U.S., Commercial                0.001046
Part 133: Rotorcraft Ext. Load      0.000360
Unknown                             0.000247
Public Use                          0.000214
ARMF                                0.000090
125                                 0.000056
Part 125: 20+ Pax,6000+ lbs         0.000056
107                                 0.000045
103                                 0.000022
Public Aircraft                     0.000022
Armed Forces                        0.000011
437                                 0.000011
Name: proportion, dtype: float64
```



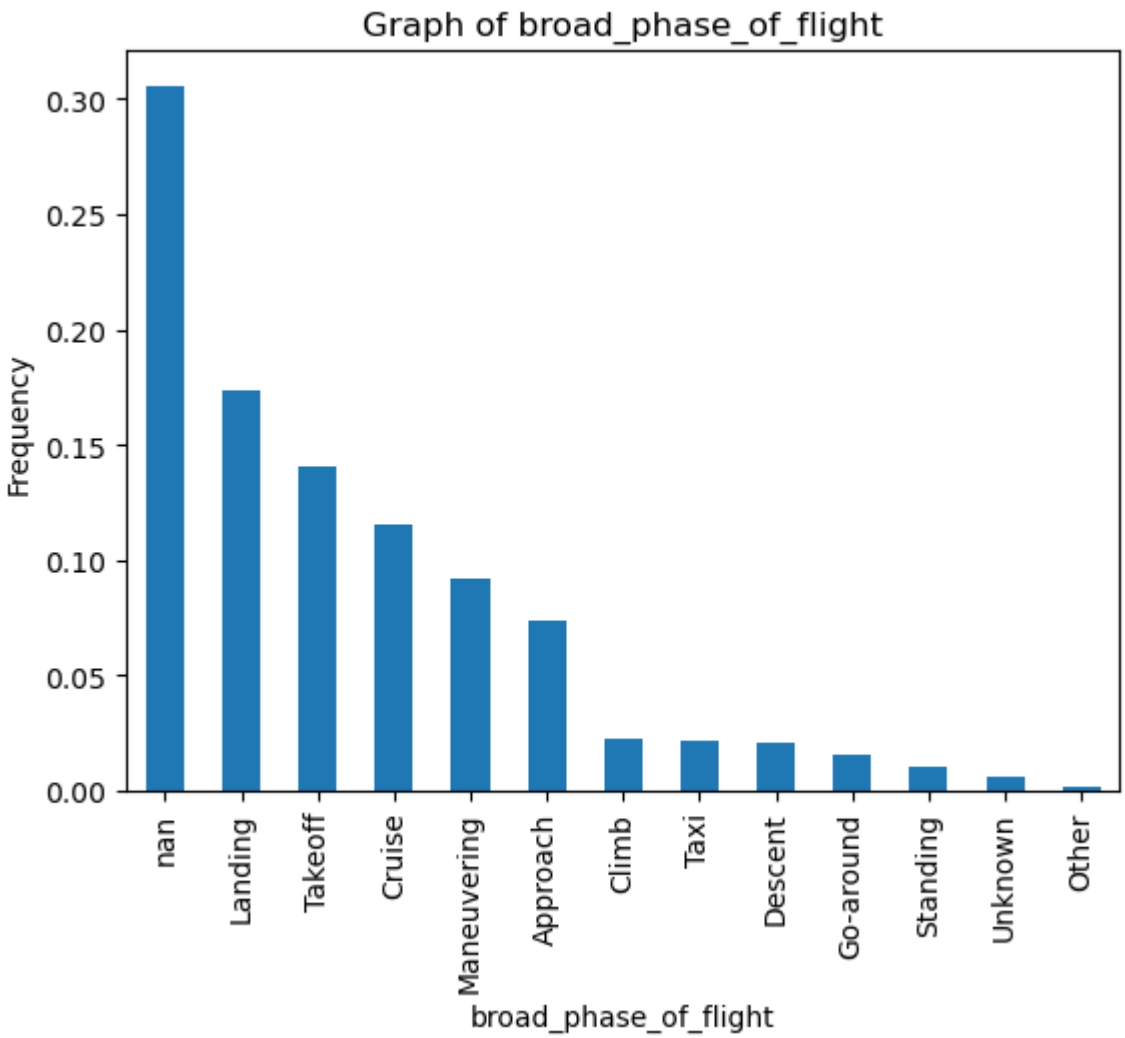
As is visible, the aircrafts under 91 regulations encompass the most part of the dataset about aviation accidents. Given that the far description has 64% of null values, I will add this column to the drop list

In [29]:
```
drop_columns.append('far_description')
```

Broad Phase of Flight

In [30]:
```
plot_column_data(df,'broad_phase_of_flight', 'bar')
```

```
broad_phase_of_flight
NaN             0.305606
Landing         0.173565
Takeoff         0.140546
Cruise          0.115526
Maneuvering     0.091620
Approach        0.073642
Climb           0.022882
Taxi            0.022027
Descent         0.021229
Go-around       0.015221
Standing        0.010631
Unknown         0.006165
Other           0.001339
Name: proportion, dtype: float64
```



The most important causes of accidents happened either during: landing, takeoff, cruise, maneuvering or approach. I consider 30% of null values to not be too excesive and believe that the 5 phases mentioned before could be of use. I will not drop these columns

In [31]:
```
df['broad_phase_of_flight'].fillna('Unknown', inplace=True)
```

The study of the columns in question have been done and I will now proceed to drop said

columns. I will also append to the drop columns the previous id columns that are now unnecessary with the new primary_key column

In [32]:
```
drop_columns = drop_columns + ['accident_number', 'registration_number', 'event_id']

df = df.drop(drop_columns, axis=1)
```

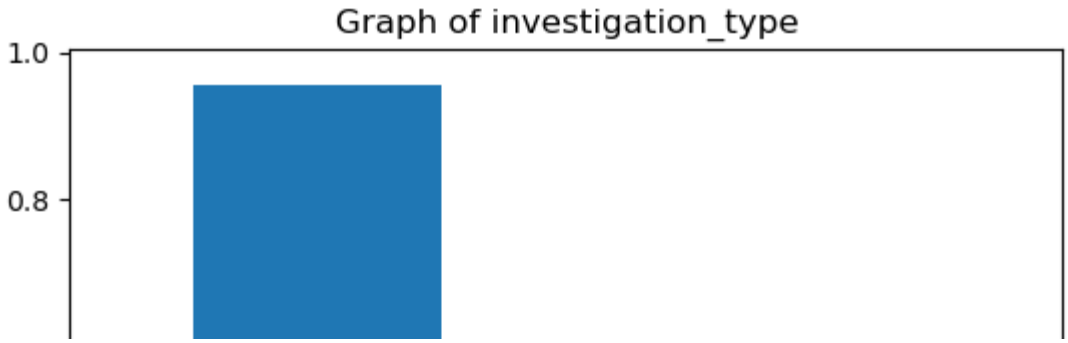
In [33]:
```
df.isnull().sum()/len(df)*100
```

Out[33]:
```
investigation_type         0.000000
event_date                 0.000000
location                   0.058500
country                    0.254250
injury_severity            1.124999
aircraft_damage            3.593246
make                       0.070875
model                      0.103500
amateur_built              0.114750
number_of_engines          6.844491
engine_type                7.982990
purpose_of_flight          6.965991
total_fatal_injuries      12.826109
total_serious_injuries    14.073732
total_minor_injuries      13.424608
total_uninjured            6.650992
weather_condition          5.053494
broad_phase_of_flight      0.000000
report_status              7.181991
primary_key                1.554748
dtype: float64
```

Investigation type

In [34]:
```
plot_column_data(df,'investigation_type', 'bar')
```

```
investigation_type
Accident    0.956418
Incident    0.043582
Name: proportion, dtype: float64
```



After doing some reasearch, we have noticed that an accident is a unintentional event that results in harm whereas an incident although it might be unintentional doesn't necessarily result in harm

Moreover, we can see that all of the registrations in the dataset are all accidents (in 96% of it's totality)

Event Date

In [35]:
```
df['event_date'].min()
```

Out[35]:
```
'1948-10-24'
```

In [36]:
```
df['event_date'].max()
```

Out[36]:
```
'2022-12-29'
```

In [37]:
```
df['event_date'].value_counts(normalize=True, dropna=False)
```

Out[37]:
```
event_date
1984-06-30    0.000281
1982-05-16    0.000281
2000-07-08    0.000281
1983-08-05    0.000270
1984-08-25    0.000270
                ...
2014-03-16    0.000011
2014-03-15    0.000011
2014-03-12    0.000011
2014-03-10    0.000011
2022-12-29    0.000011
Name: proportion, Length: 14782, dtype: float64
```

In [38]:
```
df['event_date'].isna().any()
```

Out[38]:
```
False
```

We have realized that we have accidents or incidents from 1948 to 2022

In [39]:
```
df['event_date'] = df['event_date'].astype('object')
```

I would like to investigate the number of accidents per year and month

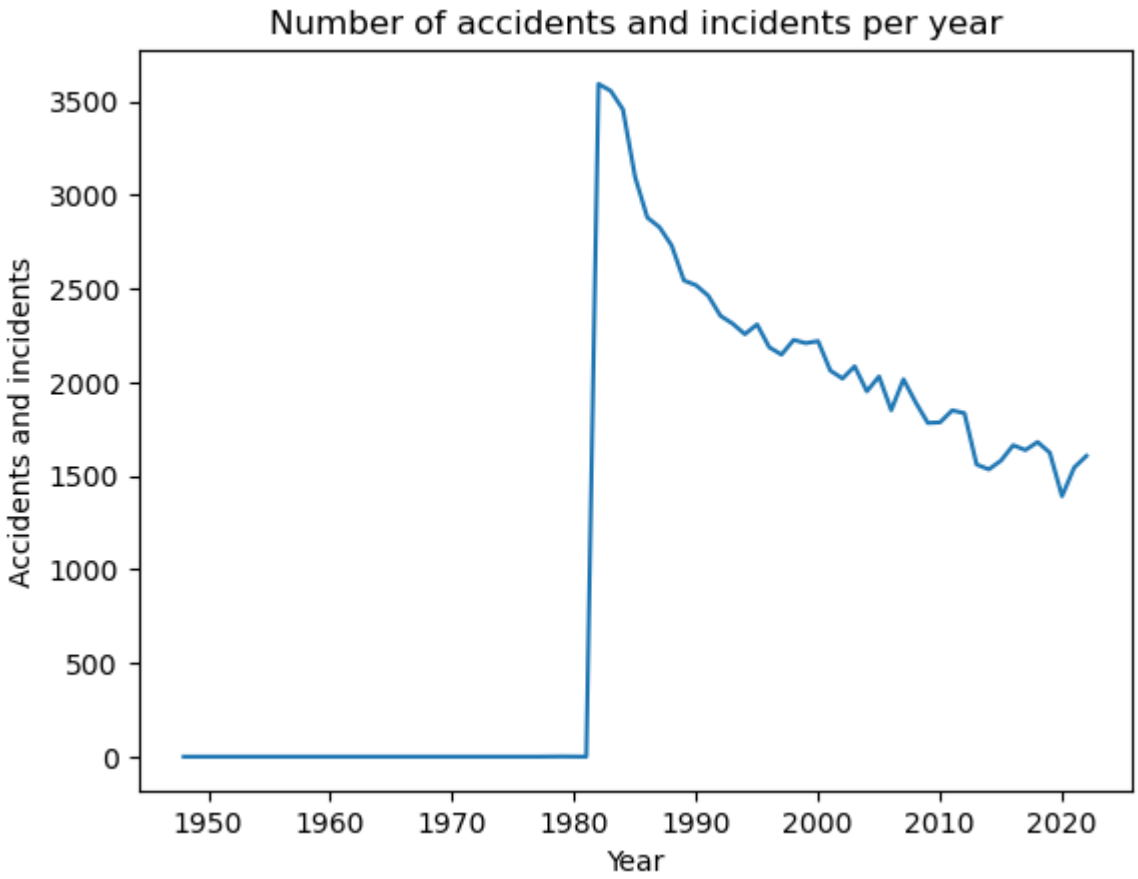
In [40]:
```
df['year'] = df['event_date'].map(lambda x:int(x[:4]))
df['year']
```

Out[40]:
```
0        1948
1        1962
2        1974
3        1977
4        1979
        ...
88884    2022
88885    2022
88886    2022
88887    2022
88888    2022
Name: year, Length: 88889, dtype: int64
```

In [41]:
```
df.groupby('year')['investigation_type'].count().plot(kind='line')

plt.title('Number of accidents and incidents per year')
plt.xlabel('Year')
plt.ylabel('Accidents and incidents')

plt.show()
```



In [42]:
```
df[df['year']<1982]
```

Out[42]:

	investigation_type	event_date	location	country	injury_severity	aircraft_damage	make
0	Accident	1948-10-24	MOOSE CREEK, ID	United States	Fatal(2)	Destroyed	Stinson
1	Accident	1962-07-19	BRIDGEPORT, CA	United States	Fatal(4)	Destroyed	Piper

	investigation_type	event_date	location	country	injury_severity	aircraft_damage	make
2	Accident	1974-08-30	Saltville, VA	United States	Fatal(3)	Destroyed	Cessna
3	Accident	1977-06-19	EUREKA, CA	United States	Fatal(2)	Destroyed	Rockwell
4	Accident	1979-08-02	Canton, OH	United States	Fatal(1)	Destroyed	Cessna
5	Accident	1979-09-17	BOSTON, MA	United States	Non-Fatal	Substantial	Mcdonnell Douglas
			COTTON	United			

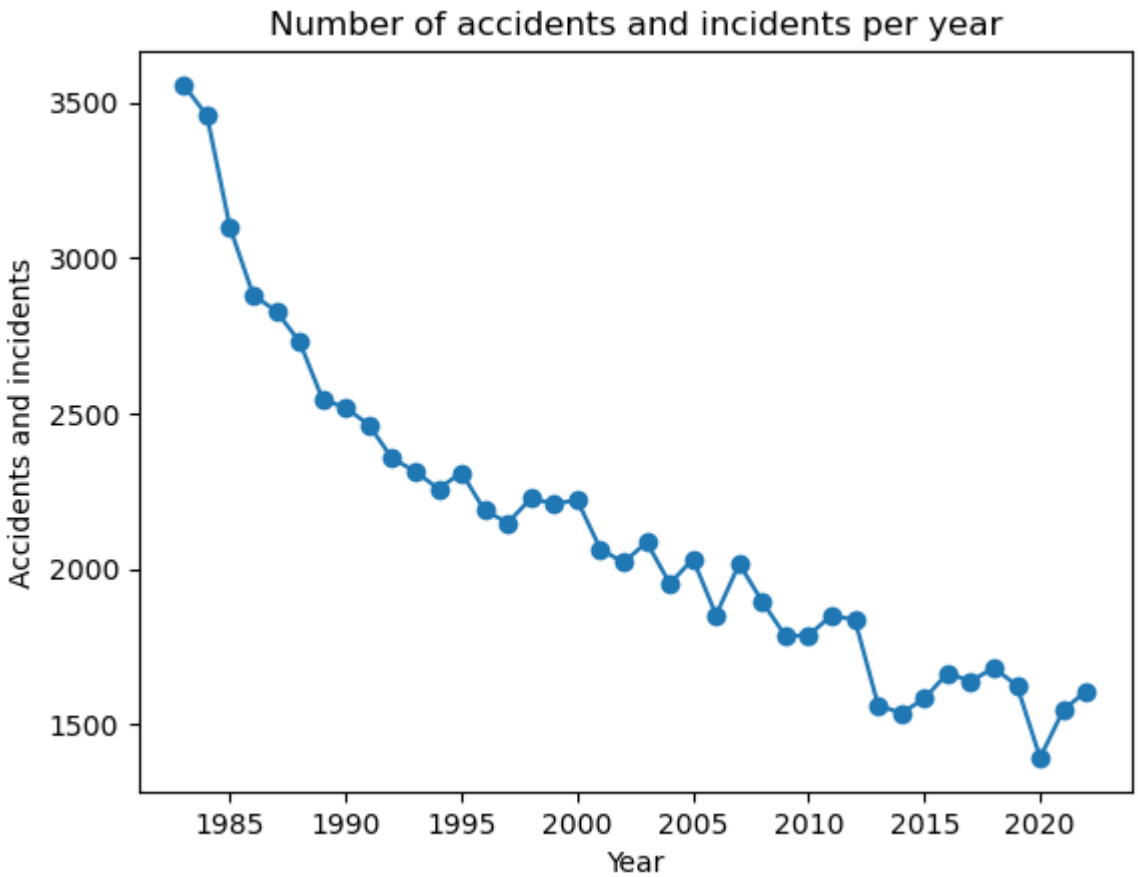
As can be seen there is only 7 rows of data before 1983. I will proceed to eliminate these rows

In [43]:
```
df = df[df['year']>1982]
```

In [44]:
```
df.groupby('year')['investigation_type'].count().plot(kind='line', marker='o')

plt.title('Number of accidents and incidents per year')
plt.xlabel('Year')
plt.ylabel('Accidents and incidents')

plt.show()
```



In the passing of time, it is visible that the number of accidents have reduced gradually. In 2020, there is a noticeable drop in the number of accidents, possible due to the Covid-19 restrictions period

I will now study the number of accidents per month

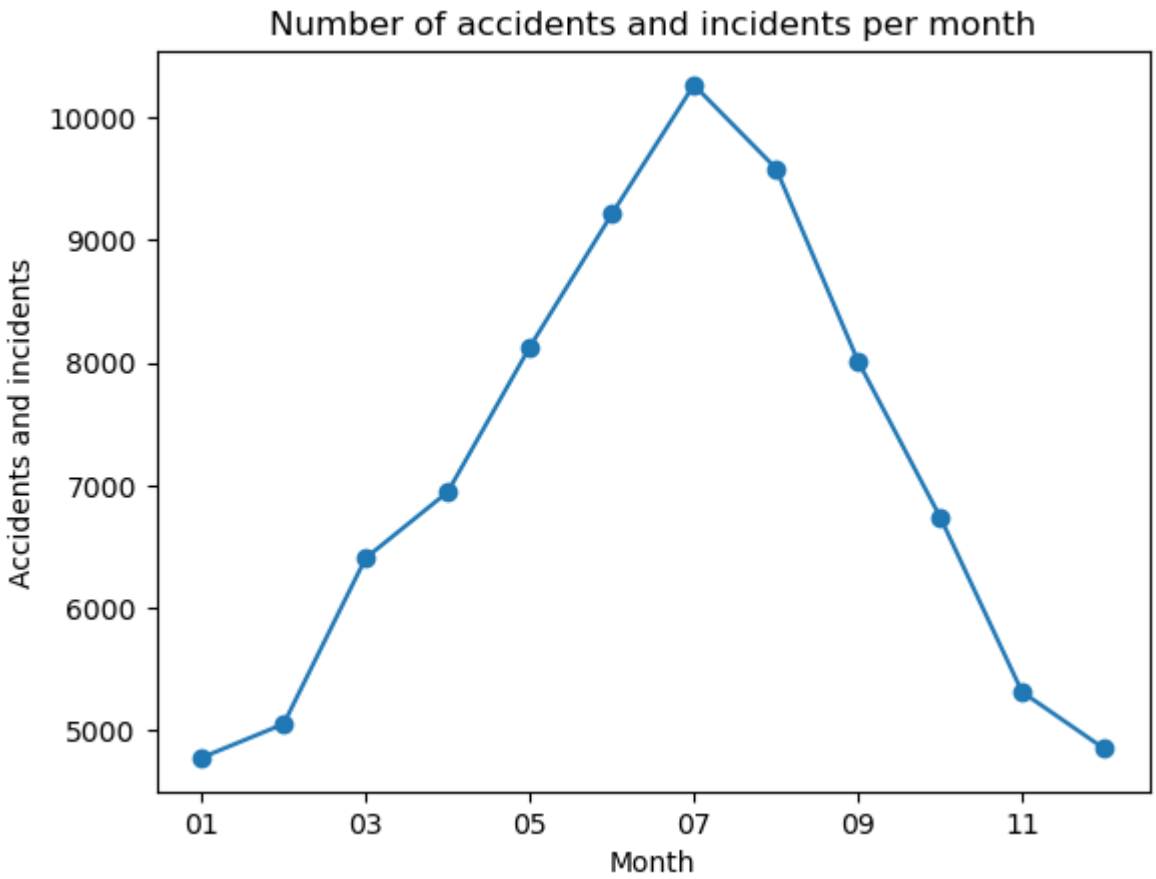
In [45]:
```
df['month'] = df['event_date'].map(lambda x:x[5:7])
df['month']
```

Out[45]:
```
3600     01
3601     01
3602     01
3603     01
3604     01
         ..
88884    12
88885    12
88886    12
88887    12
88888    12
Name: month, Length: 85289, dtype: object
```

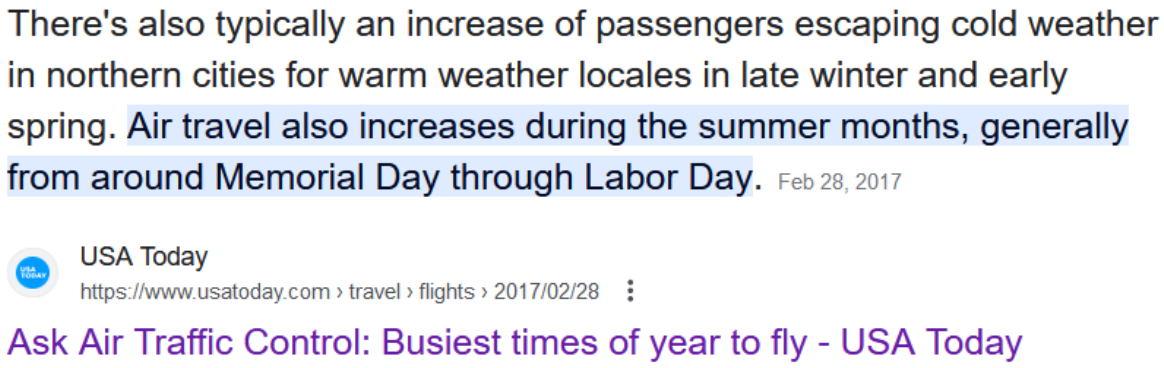
In [46]:
```
df.groupby('month')['investigation_type'].count().plot(kind='line', marker='o')

plt.title('Number of accidents and incidents per month')
plt.xlabel('Month')
plt.ylabel('Accidents and incidents')

plt.show()
```



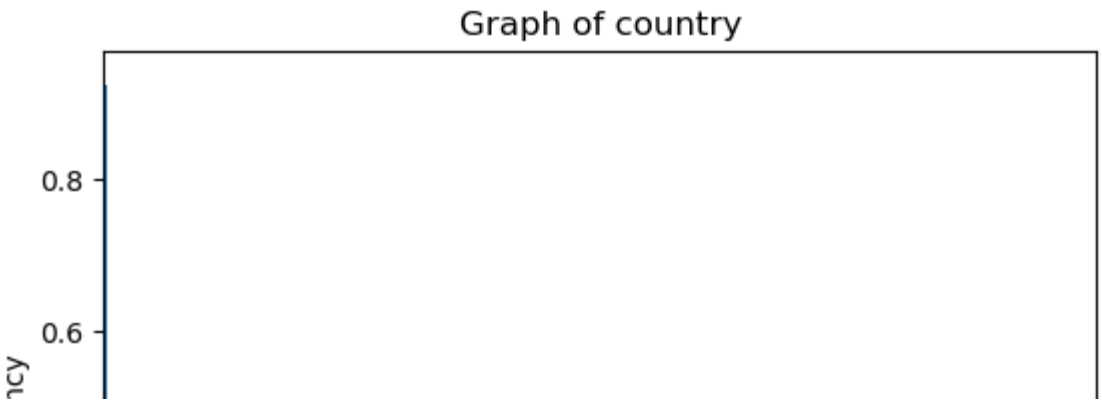
The information shows that there are more accidents and incidents during the summer period which is normal as there tends to be more flights during that period as can be seen in the following studies:



Country

In [47]:
```
plot_column_data(df,'country', 'bar')
```

```
country
United States                       0.922475
Brazil                              0.004385
Canada                              0.004209
Mexico                              0.004197
United Kingdom                      0.004033
                                      ...
Seychelles                          0.000012
Palau                               0.000012
Libya                               0.000012
Saint Vincent and the Grenadines    0.000012
Turks and Caicos Islands            0.000012
Name: proportion, Length: 220, dtype: float64
```



The majority of the events occur in USA. I will delete the rows where the country is not USA

In [48]:
```
df = df[df['country']=='United States']
```

Injury severity

In [49]:
```
df['injury_severity'].value_counts(normalize=True, dropna=False)
```

Out[49]:
```
injury_severity
Non-Fatal      0.788896
Fatal(1)       0.070656
Fatal          0.045197
Fatal(2)       0.041334
Incident       0.022294
Fatal(3)       0.012024
Fatal(4)       0.008262
Minor          0.002580
Fatal(5)       0.002110
Serious        0.001945
NaN            0.001373
Fatal(6)       0.001335
Fatal(7)       0.000432
Fatal(8)       0.000280
Fatal(10)      0.000216
Unavailable    0.000191
Fatal(9)       0.000102
Fatal(14)      0.000064
Fatal(11)      0.000064
Fatal(12)      0.000051
Fatal(17)      0.000038
Fatal(13)      0.000038
Fatal(18)      0.000038
Fatal(25)      0.000038
Fatal(82)      0.000025
Fatal(23)      0.000025
Fatal(20)      0.000025
Fatal(34)      0.000025
Fatal(31)      0.000013
Fatal(65)      0.000013
Fatal(19)      0.000013
Fatal(44)      0.000013
Fatal(64)      0.000013
Fatal(21)      0.000013
Fatal(92)      0.000013
Fatal(265)     0.000013
Fatal(228)     0.000013
Fatal(49)      0.000013
```

```
Fatal(70)      0.000013
Fatal(88)      0.000013
Fatal(15)      0.000013
Fatal(29)      0.000013
Fatal(230)     0.000013
Fatal(110)     0.000013
Fatal(68)      0.000013
Fatal(132)     0.000013
Fatal(37)      0.000013
Fatal(16)      0.000013
Fatal(135)     0.000013
Fatal(73)      0.000013
Fatal(111)     0.000013
Fatal(43)      0.000013
Fatal(28)      0.000013
Fatal(156)     0.000013
Fatal(27)      0.000013
```

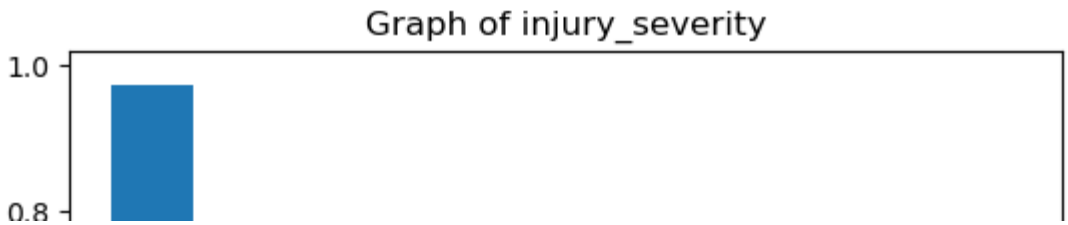
In [50]:
```
df['injury_severity'] = df['injury_severity'].astype('category')
```

I am going to group all the Fatal injuries. First I'll change the type of the column to categorical

In [51]:
```
df['injury_severity'] = df['injury_severity'].map(lambda x: 'Fatal' if isinstance(x,
```

In [52]:
```
plot_column_data(df,'injury_severity', 'bar')
```

```
injury_severity
Fatal          0.971618
Incident       0.022294
Minor          0.002580
Serious        0.001945
NaN            0.001373
Unavailable    0.000191
Name: proportion, dtype: float64
```



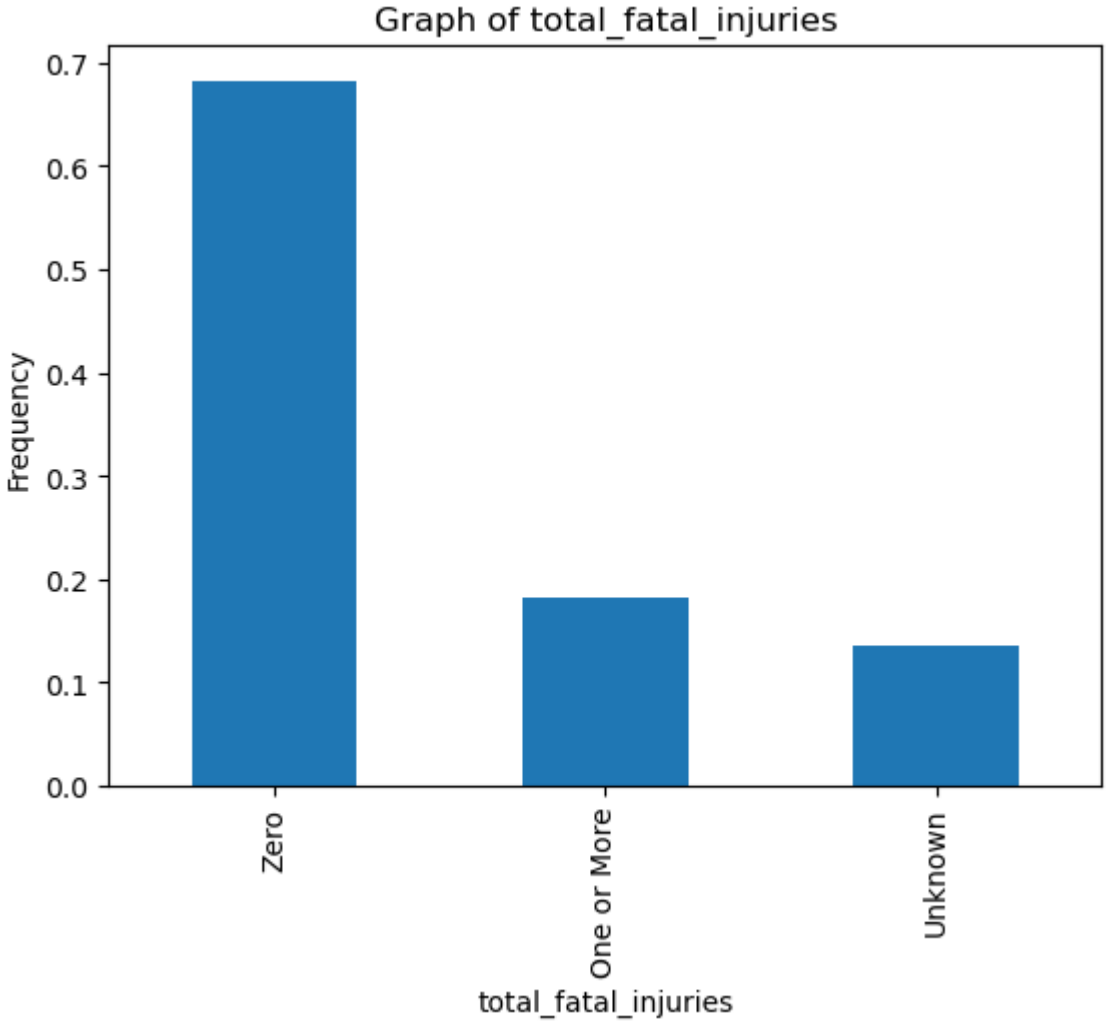
'total_fatal_injuries', 'total_serious_injuries', 'total_minor_injuries', 'total_uninjured' looking at their frequencies

In [53]:
```
columns_of_injuries = ['total_fatal_injuries', 'total_serious_injuries', 'total_minor

for columns in columns_of_injuries:
    # First, I am going to call categorize_data function to categorize the values in
    df[columns] = df[columns].map(categorize_data)

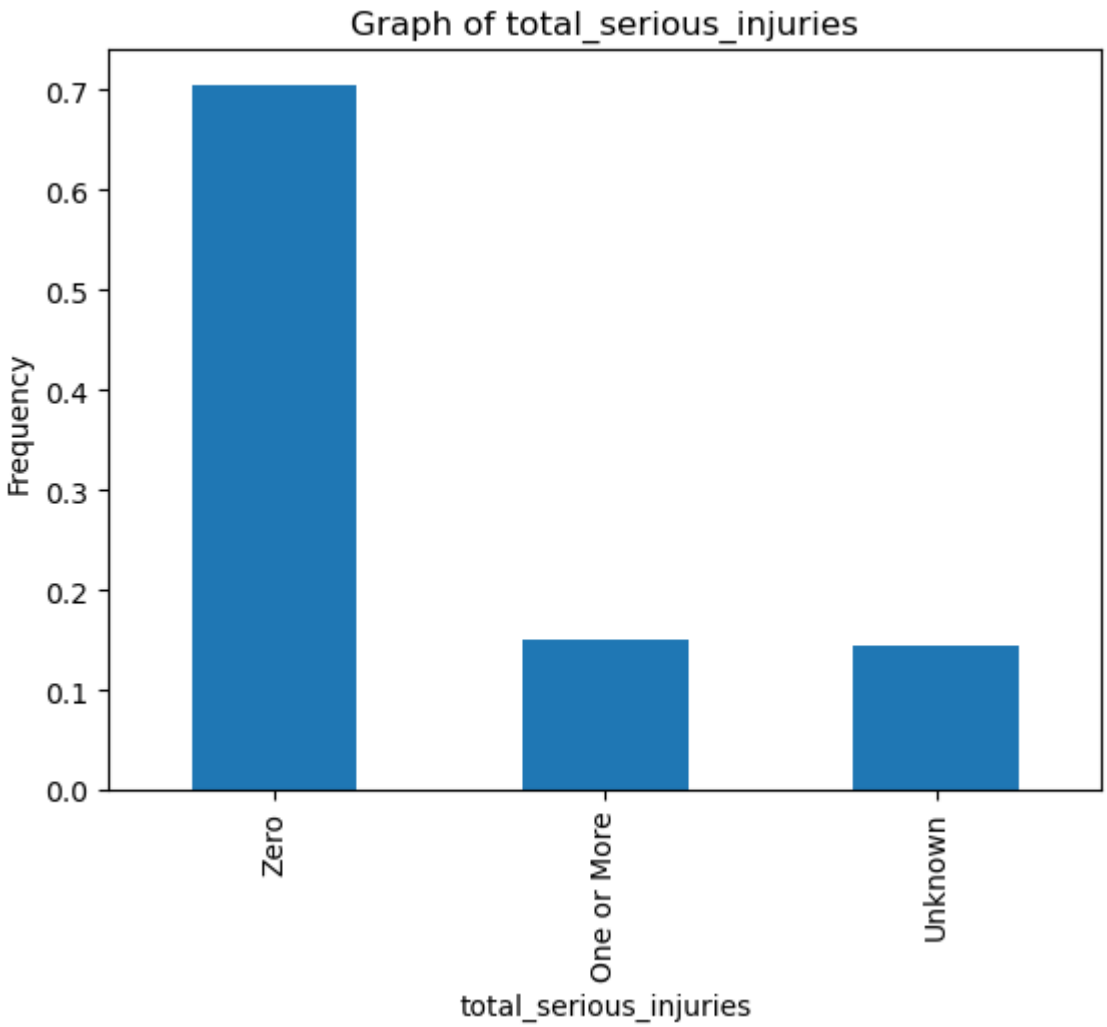
    # Second, I will represent the results of all the columns in bar graphs and their
    plot_column_data(df,columns, 'bar')
```

```
total_fatal_injuries
Zero           0.682220
One or More    0.182684
Unknown        0.135097
Name: proportion, dtype: float64
```

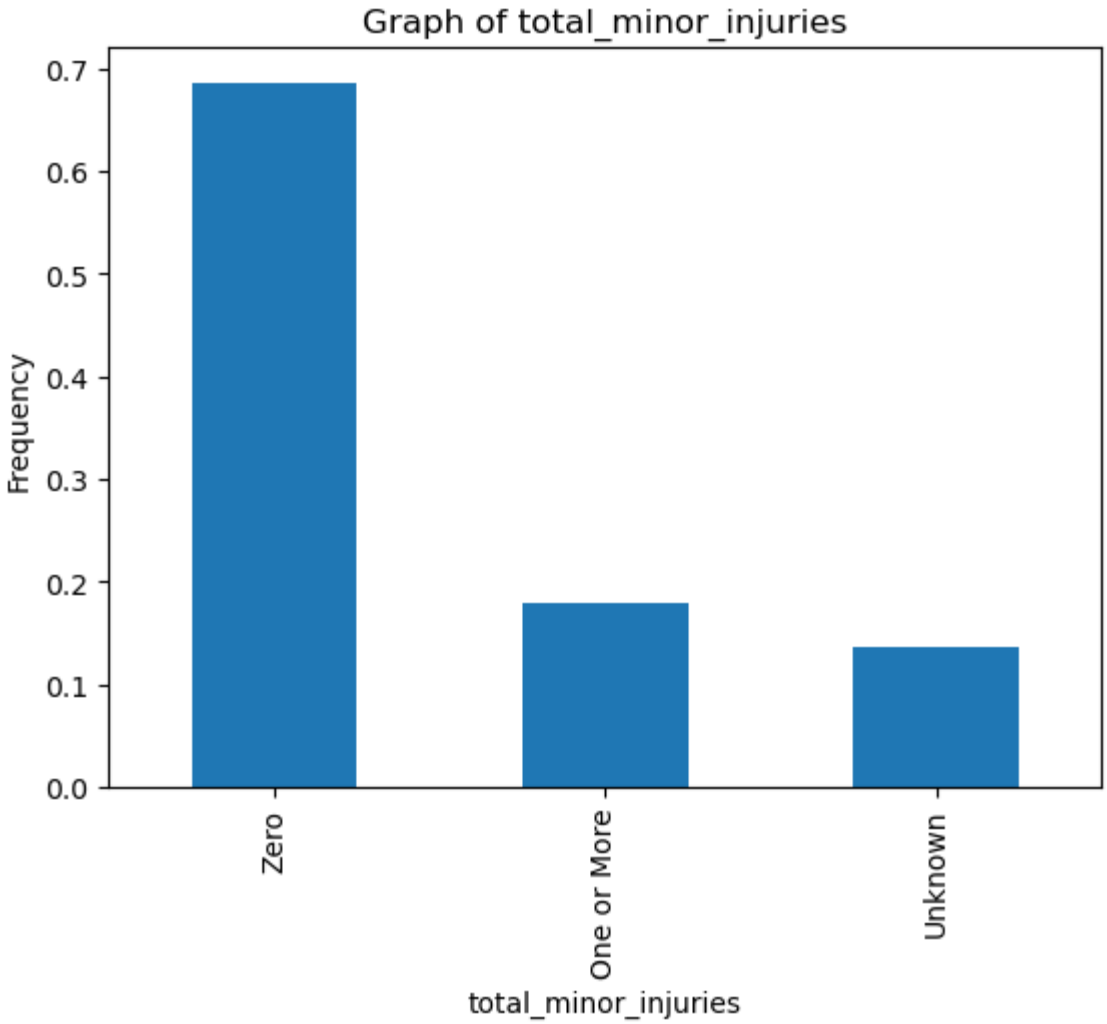



```
total_serious_injuries
```

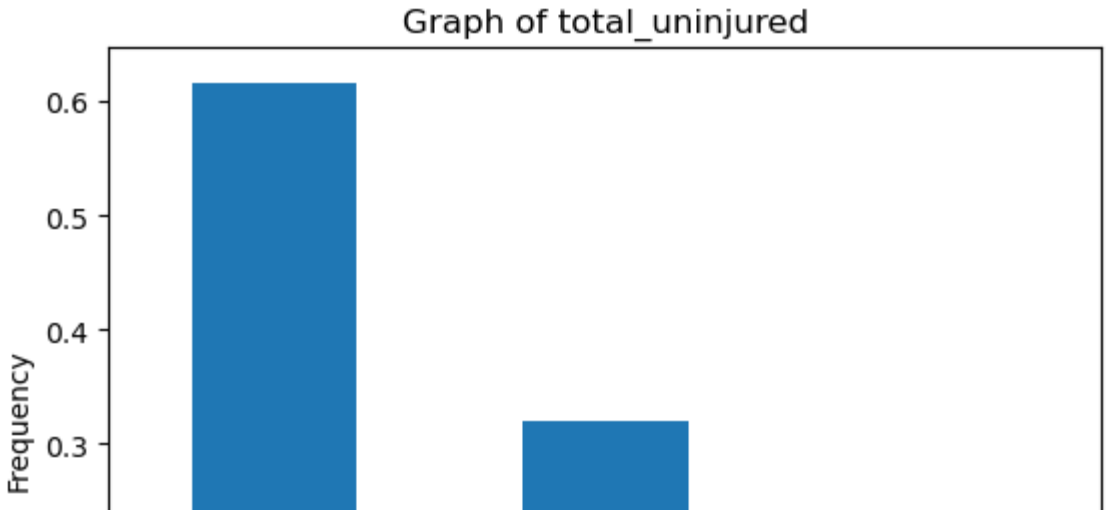
```
Zero           0.705009
One or More    0.150781
Unknown        0.144210
Name: proportion, dtype: float64
```




```
total_minor_injuries
Zero           0.685639
One or More    0.178349
Unknown        0.136012
Name: proportion, dtype: float64
```




```
total_uninjured
One or More    0.615707
Zero           0.320793
Unknown        0.063500
Name: proportion, dtype: float64
```



The graphs above give a view of the injuries. In particular, in the value counts one can see that around 30% of the accidents in the dataset have had injuries

I will eliminate the rows where injury_severity has 'Fatal' but don't have a number in the

corresponding value of total_fatal_injuries

In [54]:
```
df = df[~((df['injury_severity']=='Fatal') & (df['total_fatal_injuries']=='Zero'))]
```

I will eliminate the rows where injury_severity has 'Non-Fatal' but have a number in the corresponding value of total_fatal_injuries

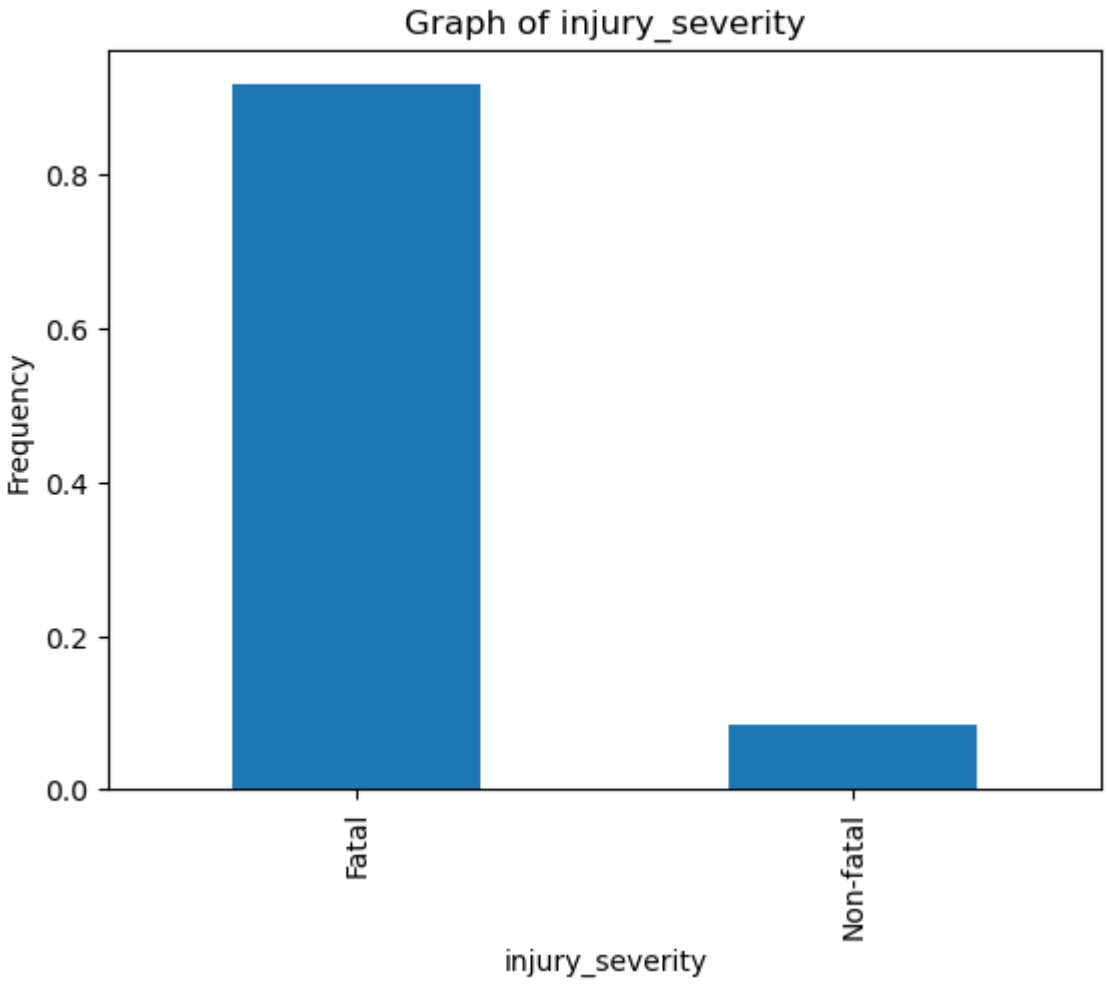
In [55]:
```
df = df[~((df['injury_severity']=='Non-Fatal') & (df['total_fatal_injuries']!='Zero'
```

Given that it is of my interest to study the fatal injuries above all, I will categorize injury_severity to either fatal or non-fatal.

In [56]:
```
df['injury_severity'] = df['injury_severity'].map(lambda x: 'Non-fatal' if x is not
plot_column_data(df,'injury_severity', 'bar')
```

```
injury_severity
Fatal        0.916747
Non-fatal    0.083253
Name: proportion, dtype: float64

<>:1: SyntaxWarning: "is not" with 'str' literal. Did you mean "!="?
<>:1: SyntaxWarning: "is not" with 'str' literal. Did you mean "!="?
C:\Users\Usuario\AppData\Local\Temp\ipykernel_22212\588282316.py:1: SyntaxWarning: "i
s not" with 'str' literal. Did you mean "!="?
  df['injury_severity'] = df['injury_severity'].map(lambda x: 'Non-fatal' if x is not
'Fatal' else x)
```



I decide to select the registrations of total fatal injuries and of total serious injuries that are 'One or More' and study those from now onwards. We don't consider minor injuries because they might be negligible

In [57]:
```
df = df[(df['total_fatal_injuries']=='One or More') | (df['total_serious_injuries']==
```

In [58]:
```
df = df.reset_index(drop=True)
df
```

Out[58]:

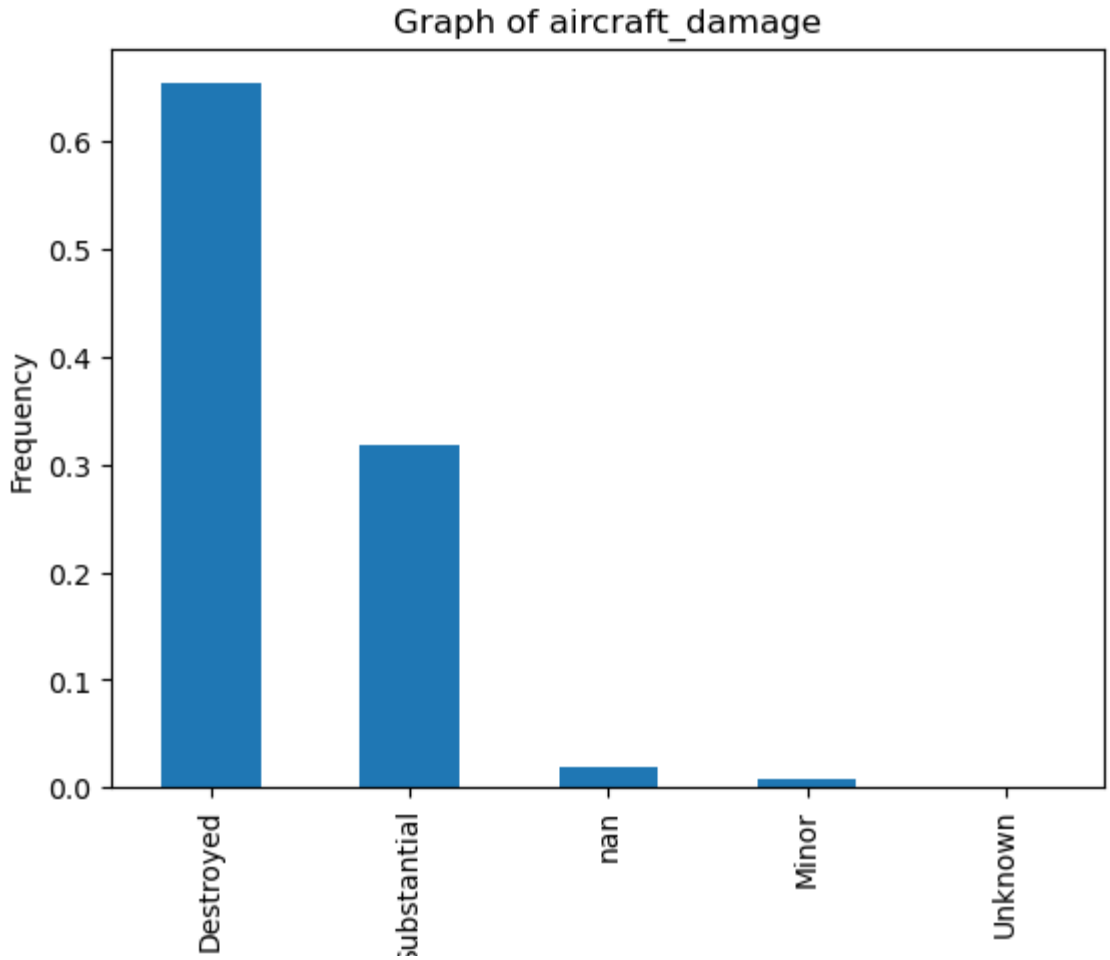
	investigation_type	event_date	location	country	injury_severity	aircraft_damage	m
0	Accident	1983-01-02	GENOA CITY, WI	United States	Fatal	Destroyed	N Amer
1	Accident	1983-01-02	BEAUFORT, SC	United States	Fatal	Destroyed	F
2	Accident	1983-01-02	HANCOCK, MD	United States	Fatal	Substantial	Ce
3	Accident	1983-01-03	WILLARD, WA	United States	Fatal	Destroyed	Ce
4	Accident	1983-01-03	AVALON, CA	United States	Fatal	Destroyed	F
...	...	...	...	...	...	...	
16048	Accident	2022-12-17	Cottonwood, CA	United States	Non-fatal	NaN	RC RAL
16049	Accident	2022-12-21	Auburn Hills, MI	United States	Non-fatal	NaN	CES
16050	Accident	2022-12-21	Reserve, LA	United States	Non-fatal	NaN	GRUMM AMERI AVN. C
16051	Accident	2022-12-26	Annapolis, MD	United States	Non-fatal	NaN	P
16052	Accident	2022-12-29	Athens, GA	United States	Non-fatal	NaN	P

16053 rows × 22 columns

Aircraft Damage

In [59]:
```
plot_column_data(df,'aircraft_damage', 'bar')
```

```
aircraft_damage
Destroyed      0.652900
Substantial    0.317635
NaN            0.019934
Minor          0.008846
Unknown        0.000685
Name: proportion, dtype: float64
```



In [60]:
```
df['aircraft_damage'].fillna('Unknown', inplace=True)
```

As we can see the majority of the damages are substantial and destroyed. I will proceed with further investigations

Make

In [61]:
```
df['make'].value_counts(normalize=True, dropna=False)
```

Out[61]:
```
make
Cessna                  0.211985
Piper                   0.148695
Beech                   0.073133
CESSNA                  0.040304
PIPER                   0.027970
                          ...
Bensen Aircraft Corp.   0.000062
Boykin B J              0.000062
Motley Vans             0.000062
Madsen                  0.000062
ROYSE RALPH L           0.000062
Name: proportion, Length: 2846, dtype: float64
```

In [62]:
```
df['make'].isna().sum()
```

Out[62]:
```
3
```

In [63]:
```
# Replace null values with 'Unknown'
df['make'].fillna('Unknown', inplace=True)
```

I will change the values of the make column to lower case letters and ensure they're all grouped correctly

In [64]:
```
df['make'] = df['make'].str.capitalize()
```

I am going to joint Douglas with Mcdonnell douglas because they're the same aircraft company

In [65]:
```
df['make'] = df['make'].map(lambda x: 'Douglas' if x in ['Mcdonnell douglas','Dougla
```

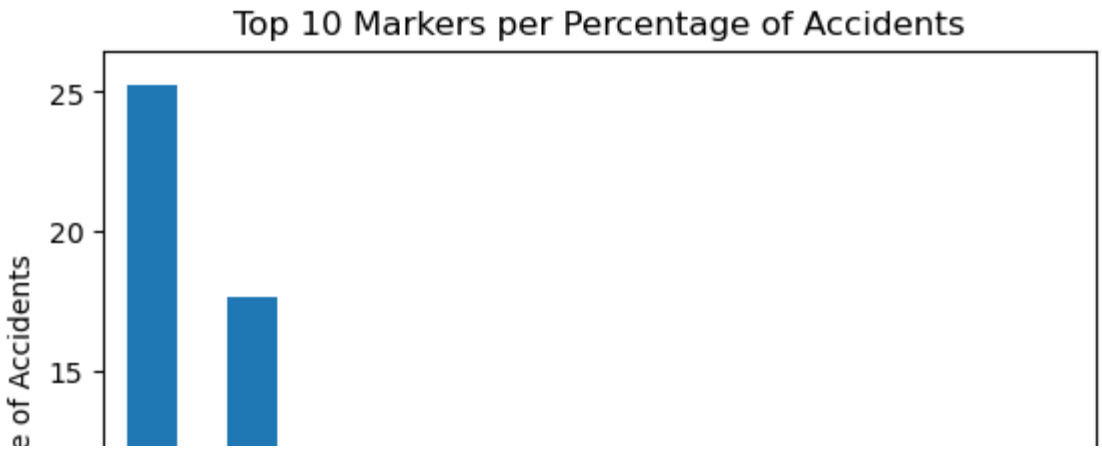
I will proceed to create a list of the top 10 makers with accidents

In [66]:
```
top_10_make = df['make'].value_counts(normalize=True, dropna=False).head(10)*100
top_10_make
```

Out[66]:
```
make
Cessna            25.228929
Piper             17.666480
Beech              8.851928
Bell               2.578957
Mooney             2.230113
Bellanca           1.345543
Robinson           1.002928
Boeing             0.822276
Hughes             0.797359
North american     0.735065
Name: proportion, dtype: float64
```

In [67]:
```
plt.figure()
top_10_make.plot(kind='bar')
plt.xlabel('Top 10 makers')
plt.ylabel('Percentage of Accidents')
plt.xticks(rotation=90)
plt.title('Top 10 Markers per Percentage of Accidents')
```

Out[67]:
```
Text(0.5, 1.0, 'Top 10 Markers per Percentage of Accidents')
```



The above makers are the ones with the highest number of accidents. It's noticeable that Cessna, Piper and Beech are the highest of all

Model

In [68]:
```
df['model'].value_counts(normalize=True, dropna=False)
```

Out[68]:
```
model
152          0.014764
172N         0.011774
PA-28-140    0.011026
A36          0.009095
172          0.008908
               ...
LJ-60        0.000062
172 F        0.000062
DN-1         0.000062
L-39CT       0.000062
EC 130 T2    0.000062
Name: proportion, Length: 4448, dtype: float64
```

In [69]:
```
df['model'].isna().sum()
```

Out[69]:
```
7
```

I don't believe to be able to extract much information from the model column

Amateur Built

In [70]:
```
df['amateur_built'].value_counts(normalize=True, dropna=False)
```

Out[70]:
```
amateur_built
No     0.846633
Yes    0.152869
NaN    0.000498
Name: proportion, dtype: float64
```

As can be seen most of the accident cases were commercial trips

Number of engines

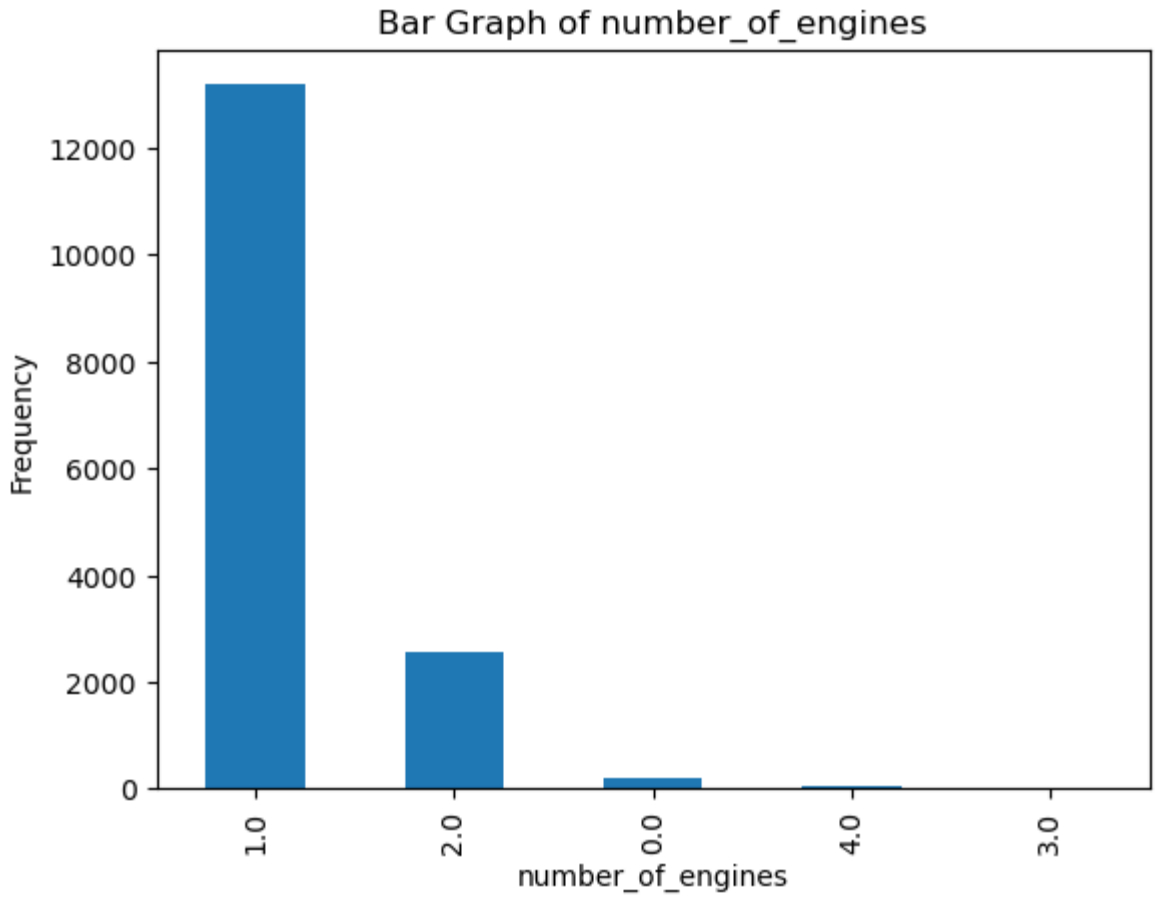
In [71]:
```
df['number_of_engines'].value_counts(normalize=True, dropna=False)
```

Out[71]:
```
number_of_engines
1.0    0.798854
```

```
2.0    0.160780
NaN    0.022488
0.0    0.013269
4.0    0.002990
3.0    0.001620
```

In [72]:
```
# I will proceed to replace the null values with the mode
df['number_of_engines'].fillna(df['number_of_engines'].mode()[0], inplace=True)
```

In [73]:
```
plot_bar_graph_for_columns('number_of_engines')
```

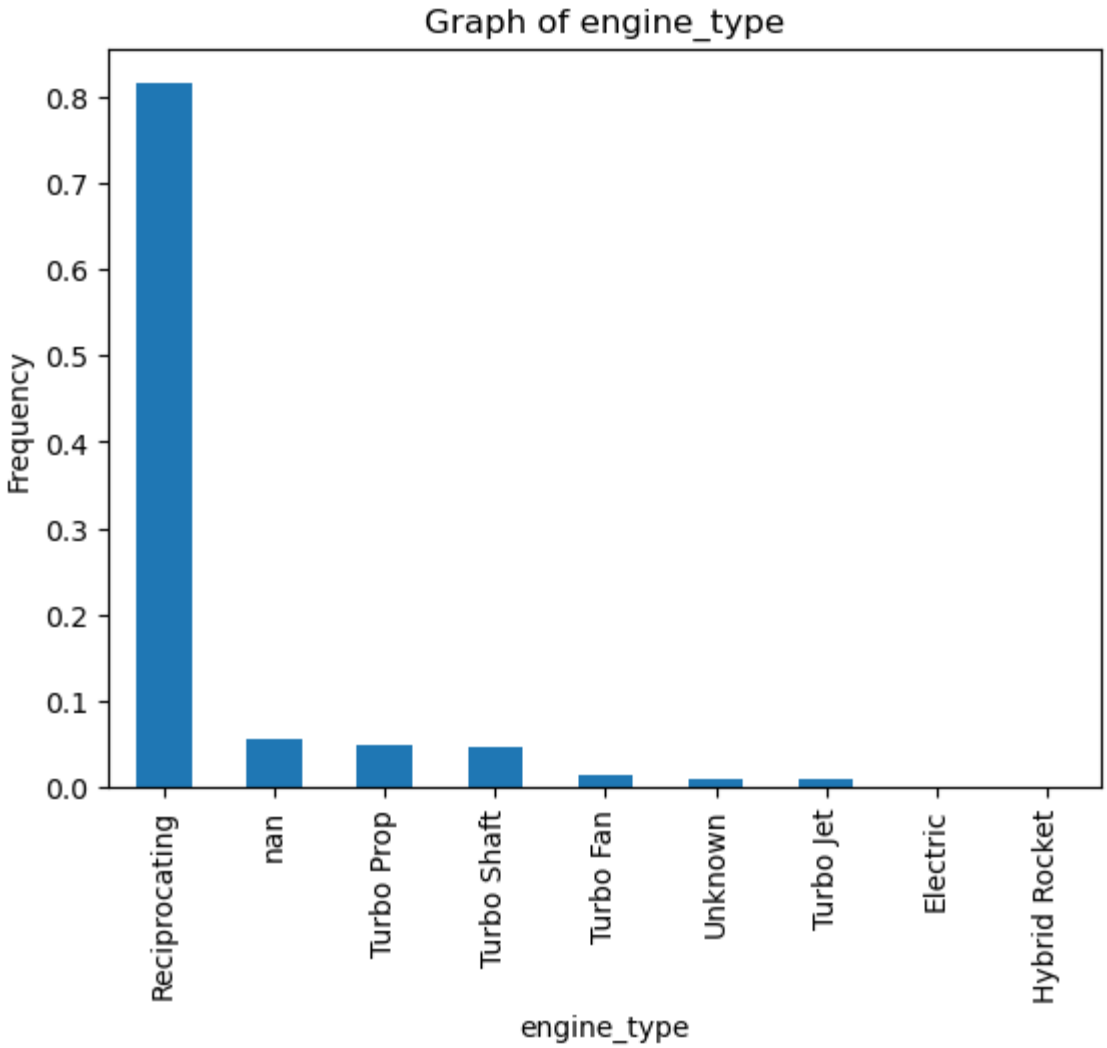


As is clearly visible, the majority of the accidents (in an 80% of the cases) happened with aircrafts that only had one engine

Engine type

In [74]:
```
plot_column_data(df,'engine_type', 'bar')
```

```
engine_type
Reciprocating    0.814365
NaN              0.056687
Turbo Prop       0.048278
Turbo Shaft      0.046596
Turbo Fan        0.015511
Unknown          0.009282
Turbo Jet        0.009095
Electric         0.000125
Hybrid Rocket    0.000062
Name: proportion, dtype: float64
```

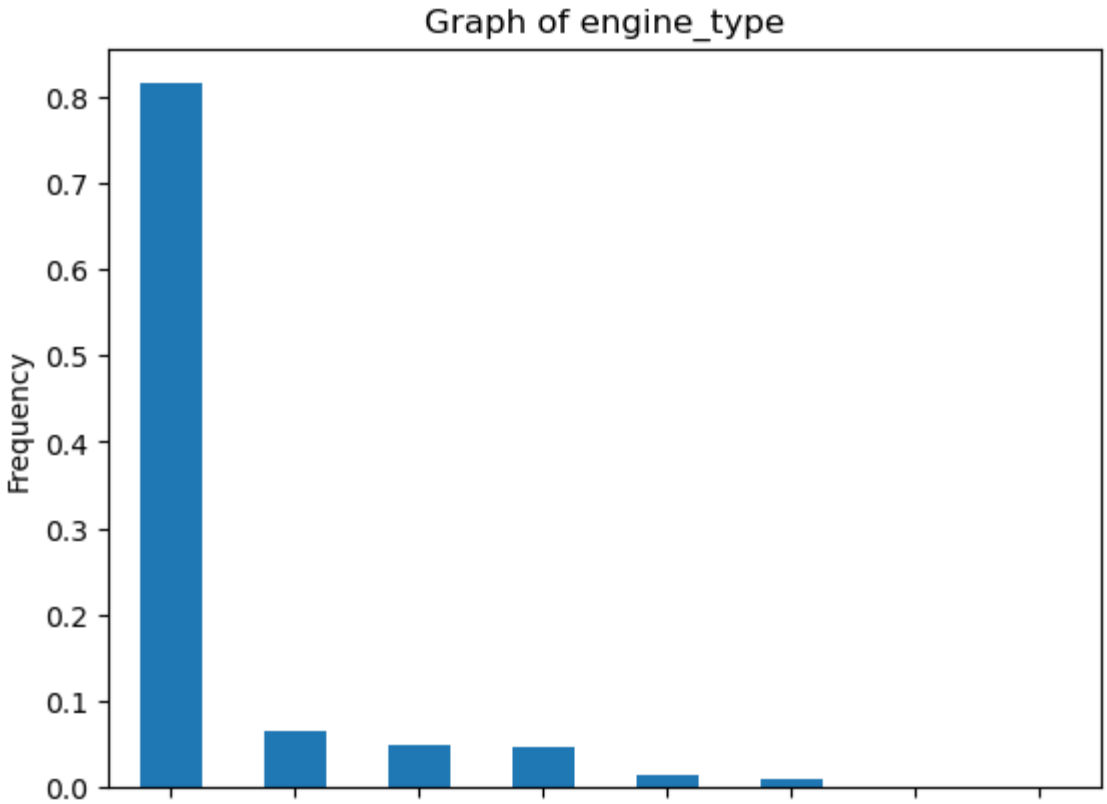


In [75]:
```
# Replace unknown values with 'Unknown' and replace na with 'Unknown'

df['engine_type'] = df['engine_type'].replace('UNK', 'Unknown')
df['engine_type'].fillna('Unknown', inplace=True)
```

In [76]:
```
plot_column_data(df,'engine_type', 'bar')
```

```
engine_type
Reciprocating    0.814365
Unknown          0.065969
Turbo Prop       0.048278
Turbo Shaft      0.046596
Turbo Fan        0.015511
Turbo Jet        0.009095
Electric         0.000125
Hybrid Rocket    0.000062
Name: proportion, dtype: float64
```



An overwhealming majority of the accidents (ie in 81% of the cases) the engine type of the aircraft was reciprocating

Purpose of Flight

In [77]:
```
df['purpose_of_flight'].value_counts(normalize=True, dropna=False)
```

Out[77]:
```
purpose_of_flight
Personal                  0.649100
Instructional             0.066343
Unknown                   0.063041
Business                  0.058556
Aerial Application        0.031770
NaN                       0.029029
Positioning               0.025042
Other Work Use            0.017068
Aerial Observation        0.011462
Public Aircraft           0.010901
Ferry                     0.007787
Executive/corporate       0.007413
Flight Test               0.006292
Skydiving                 0.003800
Air Race/show             0.002741
External Load             0.001931
Air Race show             0.001557
Banner Tow                0.001308
Public Aircraft - Federal 0.001308
Glider Tow                0.000997
Public Aircraft - State   0.000872
Public Aircraft - Local   0.000685
Firefighting              0.000623
ASHO                      0.000311
Air Drop                  0.000062
Name: proportion, dtype: float64
```

In [78]:
```
# Let's fill null values with unknown

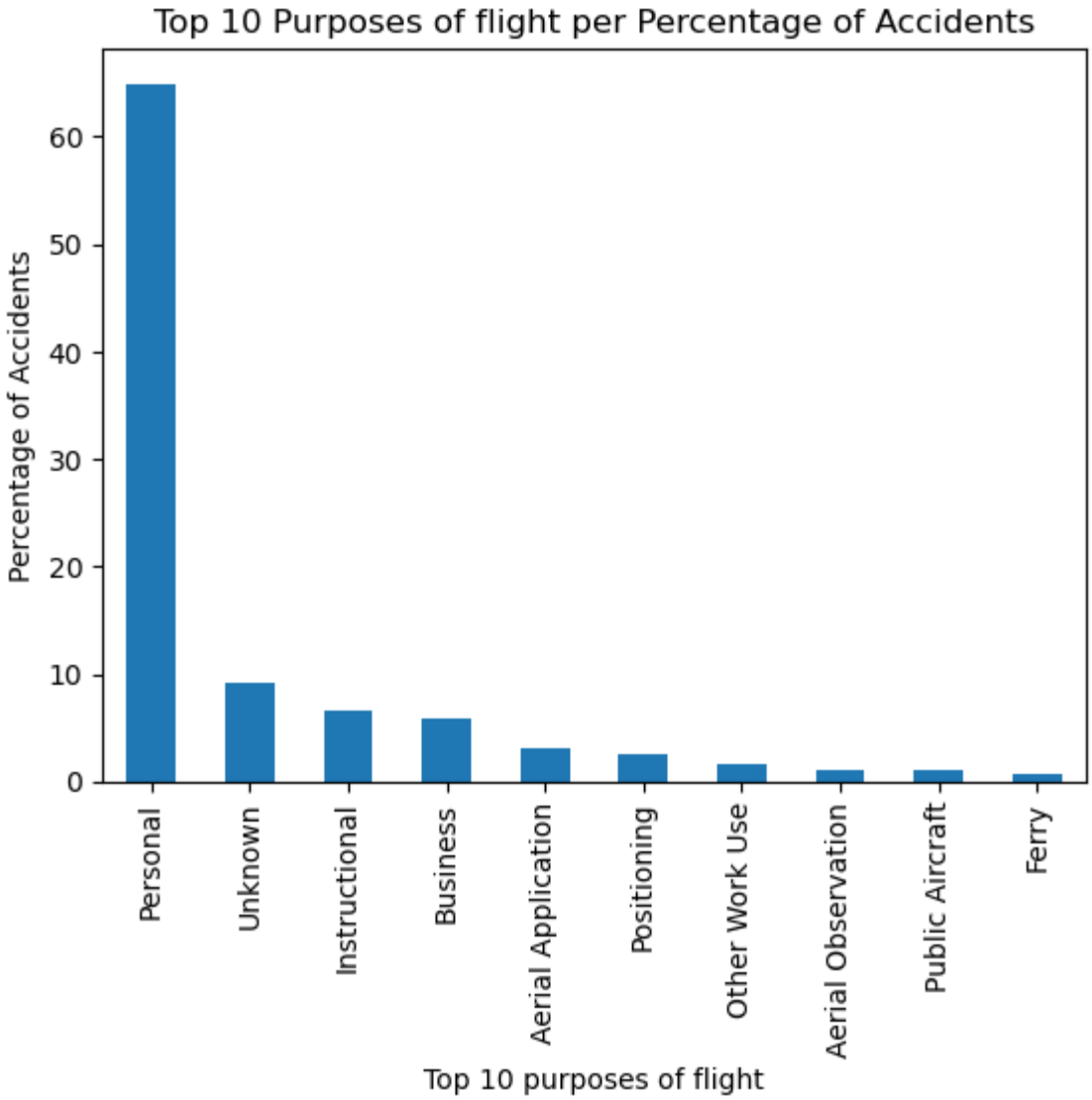
df['purpose_of_flight'].fillna('Unknown', inplace=True)
```

I am going to look at the top 10 of the instances

In [79]:
```
top_10_purpose_of_flight = df['purpose_of_flight'].value_counts(normalize=True, dropr
top_10_purpose_of_flight
```

Out[79]:
```
purpose_of_flight
Personal               64.909986
Unknown                 9.207002
Instructional           6.634274
Business                5.855603
Aerial Application      3.176976
Positioning             2.504205
Other Work Use          1.706846
Aerial Observation      1.146203
Public Aircraft         1.090139
Ferry                   0.778671
Name: proportion, dtype: float64
```

In [80]:
```
plt.figure()
top_10_purpose_of_flight.plot(kind='bar')
plt.xlabel('Top 10 purpose''s of flight')
plt.ylabel('Percentage of Accidents')
plt.xticks(rotation=90)
plt.title('Top 10 Purpose''s of flight per Percentage of Accidents');
```



The majority of the accidents happened under personal reasons apparently. This doesn't give much insight to our study

Weather condition

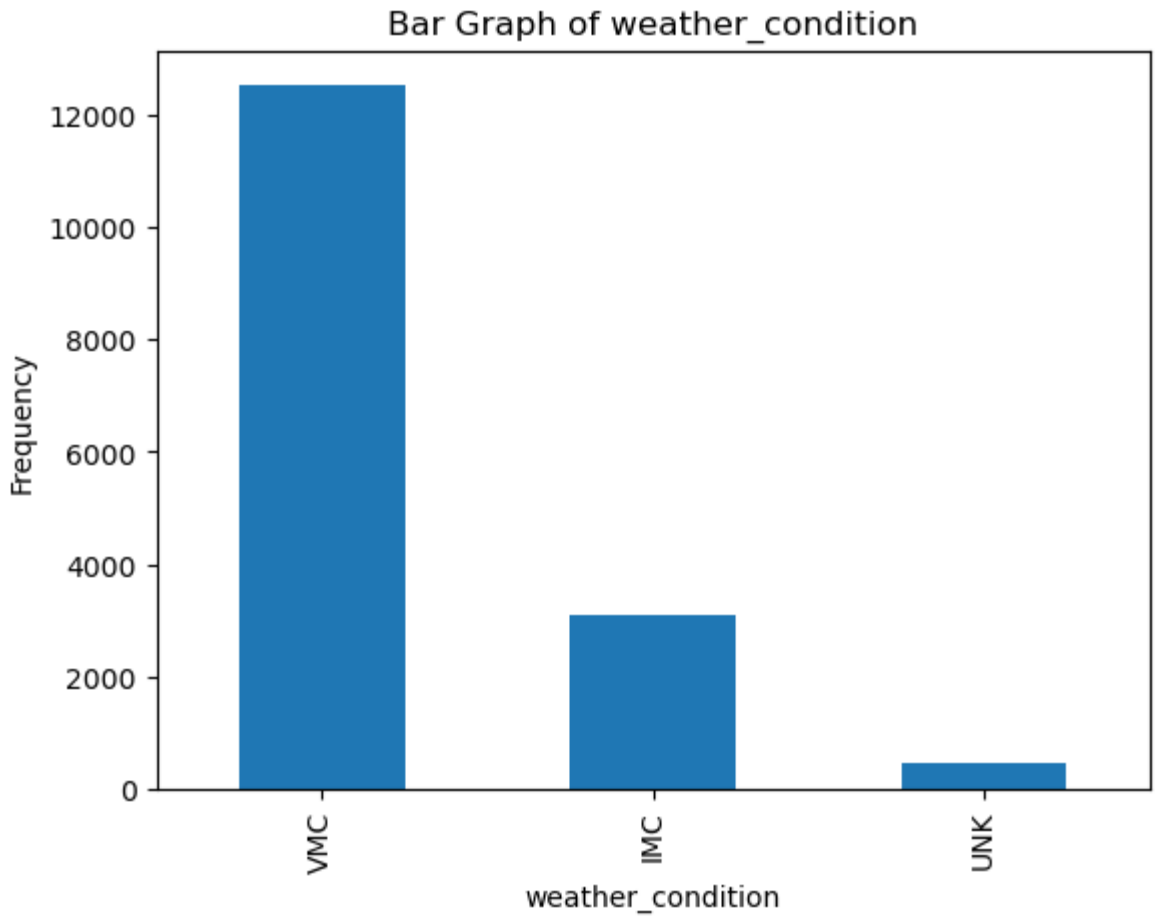
In [81]:
```
df['weather_condition'].value_counts(normalize=True, dropna=False)
```

Out[81]:
```
weather_condition
VMC    0.779044
IMC    0.192550
UNK    0.017006
NaN    0.008534
Unk    0.002866
Name: proportion, dtype: float64
```

In [82]:
```
# Let's replace Unk to UNK and all the null values let's call them: UNK (this means

df['weather_condition'] = df['weather_condition'].replace('Unk','UNK')
df['weather_condition'].fillna('UNK', inplace=True)
```

In [83]:
```
plot_bar_graph_for_columns('weather_condition')
```



The dataset contains in its majority VMC weather conditions (ie more than 91% of the data) which says that the flight conditions are good enough for pilots to fly using only visual cues. There is a remaining 7% of flights that were IMC and that are weather conditions that are so poor that pilots cannot safely fly using only visual cues.

Report Status

In [84]:
```
df['report_status'].value_counts(normalize=True, dropna=False)
```

Out[84]:
```
report_status
Probable Cause
0.764219
NaN
0.051019
Factual
0.000934
An in-flight loss of control for undetermined reasons.
0.000249
A loss of control for undetermined reasons.
0.000249

...
The pilots inadvertent pulling of the mixture control lever on takeoff, which shut do
wn the engine.
0.000062
The pilot's loss of airplane control during cruise flight.
0.000062
The pilots intentional low-altitude maneuvering and failure to maintain clearance fro
m terrain due to distraction.\r
```

```
0.000062
The pilot did not maintain adequate airspeed while maneuvering at low altitude, which
resulted in an aerodynamic stall.
0.000062
The pilots failure to secure the magneto switch before attempting to hand rotate the
engine which resulted in an inadvertent engine start, a runaway airplane, and subsequ
ent impact with parked airplanes. Contributing to the accident was the failure to pro
perly secure the airplane with chocks.    0.000062
Name: proportion, Length: 2916, dtype: float64
```

In [85]:
```
# df['report_status'].unique()
```

In [86]:
```
(df['report_status'].isnull().sum()/len(df['report_status']))*100
```

Out[86]:
```
5.101850121472622
```

I'm going to create a new category that groups pilot's faults

In [87]:
```
df['report_status'] = df['report_status'].map(lambda x: 'pilot failure' if isinstance
```

In [88]:
```
df['report_status'].unique()
```

Out[88]:
```
array(['Probable Cause', 'Factual', 'Preliminary', 'Foreign',
       'pilot failure',
       'An in-flight loss of control and an uncontrolled descent into terrain for und
etermined reasons.',
       "The flight instructor's failure to maintain control of the airplane, which re
sulted in an inadvertent stall while maneuvering.",
       'The loss of pitch control during cruise flight resulting from the separation
of the stabilator trim actuator due to inadequate maintenenace.',
       "The improper installation of the fuel pump, leading to a fatigue failure of t
he pump's lever arm and subsequent loss of engine power. Contributing to the accident
was the lack of suitable terrain for a forced landing.",
       'Airplane wing-structure damage sustained during impact with one or more large
birds (American white pelicans), which resulted in a loss of control of the airplan
e.',
       "The flight instructor's failure to maintain aircraft control while maneuverin
g during a simulated engine failure. Contributing to the accident was the flight inst
ructor's lack of total experience as a multiengine flight instructor.",
       'The in-flight failure of the left wing for undetermined reasons.',
       "An in-flight overtorque of the engine-to-transmission driveshaft resulting in
disconnection of the main transmission from the engine. The overtorque likely occurre
d due to an in-flight main rotor blade contact with snow-covered terrain, precluding
significant main rotor blade damage and ground scarring. Contributing to the severity
of the surviving occupant's injuries was the helicopter operator's failure to properl
y monitor their satellite flight-following system and to immediately institute a sear
ch once the system reported that the helicopter was overdue.",
       'A loss of engine power during initial climb for undetermined reasons.',
       "The certified flight instructor's failure to maintain airspeed during a steep
turn.",
       'Loss of control for undetermined reasons.',
       "A fuel system configuration that was not in accordance with the engine manufa
cturer's published guidance, which resulted in a complete loss of engine power due to
fuel starvation.",
       'A loss of control for undetermined reasons.',
       'Controlled flight into water for undetermined reasons.',
       'The loss of aircraft control due to an undetermined rudder malfunction.',
       'The partial loss of engine power for undetermined reasons.',
       'The loss of control during cruise flight in instrument conditions due to spat
ial disorientation.',
       "The flight instructor's failure to maintain airspeed which resulted in an ina
```

```
dvertent stall.",
       'An in-flight loss of control for undetermined reasons.',
       'Loss of engine power during approach for landing due to a fatigue fracture of
a power turbine blade.',
       'An in-flight collision with terrain for undetermined reasons.',
       'The in-flight collision with mountainous terrain for undetermined reasons.\r\
n\r\n*This report was modified on December 10, 2009.',
       'The improper installation of spark plugs during the annual inspection which r
esulted in a loss of engine power shortly after takeoff.  Contributing to the acciden
t was the lack of suitable terrain during the forced landing.',
       'A total loss of engine power due to a loss of engine oil as a result of the i
nstallation of the wrong oil adapter O-ring seal.',
       "The parachutist's failure to follow procedures/directives by not waiting to j
ump until the green jump light was illuminated, resulting in his collision with the a
irplane's tail.  Contributing to the accident was the parachutist's impairment by the
use of marijuana prior to performing a parachute jump.",
       'An inadvertent stall during the initial climb.',
       "The flight instructor's failure to initiate a go-around during a high approac
h, and his inadequate remedial action during an attempted touch-and-go.",
       'Undetermined.',
       'A partial loss of engine power for undetermined reasons which led to a forced
landing in unsuitable terrain.',
       'A loss of engine power for undetermined reasons.',
       'A loss of control in flight due to undetermined reasons.',
       "A partial loss of engine power during initial climb due to the detachment of
the engine supercharger drive belt.  The detachment resulted from the owner/builder's
inadequate installation of the supercharger system and belt-tensioning adjustment.",
       'A loss of engine power due to fuel exhaustion.',
       'Loss of control inflight for undetermined reason.',
       "The in-flight separation of a main rotor blade due to a fatigue failure of th
e blade spar, rendering the helicopter uncontrollable, and the manufacturer's product
ion of main rotor blades with latent manufacturing defects, which precipitated the fa
tigue failure of the blade spar.",
       'The improper (reverse) rigging of the elevator trim cables by company mainten
ance personnel, and their subsequent failure to discover the misrigging during requir
ed post-maintenance checks. Contributing to the accident was the captain\x92s inadequ
ate post-maintenance preflight check and the flight crew\x92s improper response to th
e trim problem.',
       "The failure of the flight crew to maintain airspeed above in-flight minimum c
ontrol speed (Vmca) after losing power in the left jet engine during initial climb af
ter takeoff. Contributing to the accident was the crew's inadequate cockpit resource
management procedures, the failure of the captain to assume command of the airplane d
uring the emergency, the flight crew's failure to carry out the jet engine fire emerg
ency procedure, and the failure of the crew to jettison the retardant load.",
       "The movement of the airplane\x92s modified horizontal stabilizer trim system
during an intentional high speed aerobatic maneuver that resulted in exceedence of th
e design stress limits of the airplane and an in-flight structural failure. Contrubut
ing to the accident was that the builder\x92s deviation from the airplane designer's
original trim system.",
       'The operator\x92s inadequate maintenance of the airplane\x92s tires, which re
sulted in multiple tire failures during takeoff roll due to severe underinflation, an
d the captain\x92s execution of a rejected takeoff (RTO) after V1, which was inconsis
tent with her training and standard operating procedures. \r\nContributing to the acc
ident were (1) deficiencies in Learjet\x92s design of and the Federal Aviation Admini
stration\x92s (FAA) certification of the Learjet Model 60\x92s thrust reverser syste
m, which permitted the failure of critical systems in the wheel well area to result i
n uncommanded forward thrust that increased the severity of the accident; (2) the ina
dequacy of Learjet\x92s safety analysis and the FAA\x92s review of it, which failed t
o detect and correct the thrust reverser and wheel well design deficiencies after a 2
001 uncommanded forward thrust accident; (3) inadequate industry training standards f
or flight crews in tire failure scenarios; and (4) the flight crew\x92s poor crew res
ource management (CRM).',
```

```
       'A loss of aircraft control for undetermined reasons.',
       'A loss of aircraft control due to spatial disorientation.',
       "The crews' failure to maintain adequate airspeed, which resulted in an aerody
namic stall close to the ground.",
       "The paramedic's failure to monitor and maintain clearance from the rotating m
ain rotor blades after exiting the helicopter.",
       'A loss of engine power due to a fractured crankshaft.',
       'The partial loss of engine power while maneuvering for undetermined reason
s.',
       "The flight's encounter with adverse tailwinds and downdrafts in mountainous t
errain that exceeded the airplane's climb capability.",
       'The loss of engine power while in climb to cruise flight for undetermined rea
sons.',
       '(1) the sudden loss of power to both engines that resulted from impact with a
bird (red-tailed hawk), which fractured the windshield and interfered with engine fue
l controls, and (2) the subsequent disorientation of the flight crewmembers, which le
ft them unable to recover from the loss of power. Contributing to the accident were
(1) the lack of Federal Aviation Administration regulations and guidance, at the time
the helicopter was certificated, requiring helicopter windshields to be resistant to
bird strikes; (2) the lack of protections that would prevent the T handles from inadv
ertently dislodging out of their detents; and (3) the lack of a master warning light
and audible system to alert the flight crew of a low-rotor-speed condition.',
       'A loss of control in flight for undetermined reasons.',
       'A loss of aircraft control during the landing approach for undetermined reaso
ns.',
       'An in-flight break-up while maneuvering as a result of the main rotor blades
diverging from the normal plane of rotation and severing the tailboom. The underlying
reason for the main rotor divergence could not be determined.',
       "The captain\x92s inappropriate response to the activation of the stick shake
r, which led to an aerodynamic stall from which the airplane did not recover. Contrib
uting to the accident were (1) the flight crew's failure to monitor airspeed in relat
ion to the rising position of the low-speed cue, (2) the flight crew failure to adher
e to sterile cockpit procedures, (3) the captain\x92s failure to effectively manage t
he flight, and (4) Colgan Air\x92s inadequate procedures for airspeed selection and m
anagement during approaches in icing conditions.",
       "The flight instructor's failure to verify that the helicopter's skid was clea
r of an obstruction while demonstrating a one-skid and toe-in landing maneuver. Contr
ibuting to the accident was the flight instructor's decision to practice this maneuve
r at an unauthorized landing site.",
       'The passenger\x92s inadvertent activation of the engine throttle.',
       'The in-flight failure of both wings due to aileron flutter. The aileron flutt
er was the result of inadequate wing stiffness and the lack of aileron counterbalance
s.',
       'A loss of engine power due to contamination and clogging of the fuel system b
y a post-assembly fuel tank sealant.',
       'Inflight collision with terrain for undetermined reasons.',
       'An in-flight loss of aircraft control for an undetermined reason.',
       'An in-flight fire for undetermined reasons.',
       'The in-flight separation of the elevator control torque tube rod end bearing
from the elevator torque tube as a result of incorrectly tightened rod end bearing lo
ck nuts.',
       "The flight crew's failure to maintain terrain clearance during low altitude f
light in low ceiling and visibility conditions. Contributing to the accident was the
flight crew's failure to adequately monitor their location with respect to the rising
terrain environment ahead, and, their lack of crew resource management communication
as a crew.",
       'The in-flight separation of the left wing due to failure of one of the inboar
d attachments to the fuselage.',
       'A total loss of engine power due to disengagement of the idler gear support p
in as a result of improper maintenance.',
       'The separation of the main rotor head during cruise flight as a result of cyc
lic fatigue of the main rotor head spindle. The fatigue crack was due to an inadequat
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e manufacturing process.',
       'The loss of aircraft control for undetermined reasons.',
       "A total loss of engine power due to fuel starvation as a result of the flight
crew's improper fuel management.",
       "A loss of engine power due to oil exhaustion from the fracture of the nipple
for the engine oil cooler return line. Contributing to the accident was the mechanic'
s signoff and release of the airplane without performing the required engine run-up f
ollowing an annual inspection.",
       "The flight instructor's failure to ensure that the airplane was properly conf
igured for a short field takeoff, and his decision to not abort the takeoff.",
       'A loss of airplane control for undetermined reasons.',
       'The cause of this accident is unknown; the airplane is missing.',
       'A loss of aircraft control for an undetermined reason.',
       'The glider departed controlled flight for undetermined reasons.',
       'The in-flight collision with terrain for undetermined reasons.',
       'Flight into terrain for undetermined reasons.',
       'The airplane\x92s impact with water for undetermined reasons.',
       "The rappeller's failure to properly latch the rappelling harness to the rappe
lling assembly before exiting the helicopter.",
       'A total loss of engine power during cruise flight due to the fatigue failure
of the number 4 cylinder connecting rod.',
       'The reason for this accident was not determined.',
       "The inadvertent deployment of the instructor's reserve parachute.",
       "A loss of torque to the gearbox engine-side coupling flange bolts, which resu
lted in separation of the gearbox and propeller from the engine and the subsequent se
vering of the airplane's tail structure.",
       'The improper assembly of both carburetors, resulting in an excessively rich f
uel to air ratio and subsequent partial loss of engine power.',
       'A loss of airplane control during approach for undetermined reasons.',
       "Structural failure of the right wing during the landing approach due to the s
eparation of the wing's fabric covering.",
       'The flight crew\x92s failure to maintain adequate main rotor speed while mane
uvering, which resulted in a main rotor blade stall and an uncontrolled descent into
terrain.',
       'An aerodynamic stall shortly after takeoff for undetermined reasons.',
       'A total loss of engine power during a night approach for undetermined reason
s.',
       'The loss of engine power for an undetermined reason.',
       'The in-flight separation of both wings due to aileron flutter. The aileron fl
utter was the result of inadequate wing stiffness and strength and the lack of ailero
n counterbalances.',
       "The flight's descent for undetermined reasons, resulting in the in-flight col
lision with terrain.",
       'Failure of the exhaust band V-clamp during cruise flight, which resulted in a
n in-flight fire and a subsequent forced landing.',
       'A total loss of engine power due to a delamination of the No. 3 connecting ro
d bearing. Contributing to the accident was the inadequate maintenance inspection of
the engine oil system.',
       'Airspeed was not maintained, which resulted in a loss of control and the airp
lane entering into a stall/spin to the ground. Contributing to the accident was a los
s of engine power due to carburetor icing.',
       "The loss of engine power due to the chaffing and grounding of the single magn
eto's ignition lead.",
       'An in-flight loss of control for an undetermined reason, which resulted in an
uncontrolled descent.',
       'A loss of aircraft control while maneuvering for undetermined reasons.',
       'The failure of both engines for undetermined reasons.',
       'The failure of maintenance personnel to properly secure a fitting cap on the
throttle and metering assembly inlet after conducting a fuel system pressure check, w
hich resulted in a loss of engine power due to fuel starvation. Contributing to the a
ccident was the decision by the Director of Maintenance to return the airplane to ser
vice without verifying with the assigned inspector that all annual inspection items h
```

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ad been completed.',
       'A malfunction of the flight controls for undetermined reasons.',
       'Impact with the runway pavement for unknown reasons.',
       'The complete loss of engine power due to fuel starvation.',
       'Pilot incapacitation due to the combined effect of multiple unreported medica
l conditions.',
       "The airplane's impact with terrain for undetermined reasons.",
       "The FAA inspector's rapid reduction of power which resulted in a loss of engi
ne power and his decision to initiate a turn during the autorotation without sufficie
nt altitude to clear obstacles. Contributing to the accident was the FAA\x92s lack of
comprehensive currency requirements in the make and model helicopter and the inspecto
r's specific limited recent flight experience related to this make and model helicopt
er.",
       'The loss of control for undetermined reasons.',
       'The opening of the cockpit canopy in-flight due to improper latching, which r
esulted in a loss of control and impact with terrain.',
       'The fracture of a swashplate drive pin as a result of hydrogen embrittlement
due to an unknown source, which resulted in an in-flight breakup of the main rotor sy
stem during cruise flight.',
       'The flight instructor\x92s initiation of a simulated single engine scenario a
t or below the airplane\x92s minimum single engine control speed, resulting in a loss
of airplane control. Contributing to the accident was the flight instructor\x92s fail
ure to set full engine power during the takeoff roll and the flight instructor\x92s l
ack of recent experience in the airplane make and model.',
       'The collision of two counter-rotating main rotor blades for undetermined reas
ons, which resulted in a loss of control.',
       "The total loss of engine power resulting from the fatigue failure of the engi
ne's number 2 cylinder exhaust valve. The fatigue failure was due to valve guide wear
that led to excessive clearance between the valve and valve guide. Contributing to th
e accident was the contract operator\x92s lack of compliance with its own maintenance
procedures, which, if followed, would have prevented the accident.",
       "The glider's encounter with insufficient atmospheric lift to maintain soaring
flight.",
       'The total loss of engine power due to fuel starvation as a result of accumula
ted debris in the fuel system from an undetermined source. Also causal was the inadeq
uate annual maintenance inspection that did not include inspection of the firewall fu
el strainer and the fuel inlet screen.',
       'The total loss of engine power due to a high-cycle fatigue fracture of a firs
t-stage compressor blade. The reason for the fracture could not be determined during
postaccident examination.\r\n\r',
       'A partial loss of engine power due to the owner\x92s inadequate fuel system m
aintenance, which resulted in a collision with trees and subsequent impact with the g
round.',
       "The manufacturer's inadequate quality control and improper manufacture of the
fuel servo diaphragm assembly, which resulted in fatigue cracking of the hub stud and
subsequent loss of engine power due to fuel starvation.",
       "The flight instructor's decision to exit the airplane on the taxiway with the
engine still operating, and his failure to avoid the rotating propeller.",
       "In-flight impact of a passenger's metal clipboard with the helicopter\x92s ta
il rotor, which resulted in destruction of the tail rotor and subsequent loss of cont
rol of the helicopter. The original location of the clipboard and how it became free
could not be determined.",
       'A loss of helicopter control for undetermined reasons.',
       'A partial loss of engine power during approach for reasons that could not be
determined because postaccident examination did not reveal any anomalies that would h
ave precluded normal operation.',
       'Inadequate maintenance performed on the airplane, which resulted in a loss of
engine power due to fuel starvation. Contributing to the accident was the corrosion w
ithin the carburetor.',
       'A loss of engine power during a low approach for undetermined reasons.',
       'The separation of the fuselage-mounted wing strut attachment fitting for an u
ndetermined reason, which resulted in the separation of the left wing of the airplan
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e.',
       'A total loss of engine power due to a cracked carburetor float and resulting
carburetor malfunction.',
       'A total loss of engine power due to the fatigue failure of the crankshaft, wh
ich resulted from improper tightening of the cylinder hold-down nuts.',
       'Controlled flight into terrain, while on an instrument approach in instrument
meteorological conditions, for undetermined reasons.',
       'A loss of engine power due to the magneto failure for undetermined reasons.',
       'The in-flight collision with a tree while returning to land for undetermined
reasons.',
       "The engine's loss of power during takeoff for reasons that could not be deter
mined because no engine anomalies were discovered during the postaccident examinatio
n.",
       'The magneto clamps were not securely fastened to the mount, which led to a pa
rtial loss of engine power and a subsequent forced landing on unsuitable terrain.',
       'The flight instructor did not maintain aircraft control while maneuvering at
low altitude. Contributing to the accident was the inadvertent application of the cho
ke, which resulted in a momentary interruption of engine power.',
       'A total loss of engine power for undetermined reasons.',
       'An inadvertent encounter with localized instrument meteorological conditions,
which resulted in spatial disorientation and a loss of control.',
       'The National Transportation Safety Board determines the probable cause(s) of
this accident as follows: \r\n\r\nan aerodynamic stall and subsequent uncommanded rol
l during a one engine-inoperative takeoff flight test, which were the result of (1) G
ulfstream\x92s failure to properly develop and validate takeoff speeds for the flight
tests and recognize and correct the takeoff safety speed (V2) error during previous G
650 flight tests, (2) the G650 flight test team\x92s persistent and increasingly aggr
essive attempts to achieve V2 speeds that were erroneously low, and (3) Gulfstream\x9
2s inadequate investigation of previous G650 uncommanded roll events, which indicated
that the company\x92s estimated stall angle of attack while the airplane was in groun
d effect was too high. Contributing to the accident was Gulfstream\x92s failure to ef
fectively manage the G650 flight test program by pursuing an aggressive program sched
ule without ensuring that the roles and responsibilities of team members had been app
ropriately defined and implemented, engineering processes had received sufficient tec
hnical planning and oversight, potential hazards had been fully identified, and appro
priate risk controls had been implemented and were functioning as intended.',
       'Pilot incapacitation shortly after takeoff for unknown reasons.',
       'The loss of aircraft control and subsequent impact with terrain for undetermi
ned reasons.',
       'An in-flight fire that mostly likely occurred in the right front cockpit area
behind the instrument panel and below the glare shield; the origin of the fire could
not be determined because of the extensive fire damage.',
       'A total loss of engine power during approach due to inadequate torque on the
No. 3 cylinder hold-down nuts.',
       'Collision with the ground while maneuvering at low altitude for reasons that
could not be determined because postaccident examination did not reveal any anomalies
that would have precluded normal operation. \r',
       "The total loss of engine power during the initial climb due to a cold seizure
as a result of a broken fan V-belt. Contributing to the accident was the passenger's
interference with the flight controls during the forced landing.",
       'The loss of engine power for reasons that could not be determined because pos
taccident examination of the airplane\x92s engine and ignition system did not reveal
any anomalies that would have precluded normal operation, and extensive postaccident
fire damage precluded evaluation of the airplane\x92s fuel system components.',
       'The total loss of engine power for reasons that could not be determined becau
se postimpact fire damage precluded a thorough examination of the engine.',
       'To be determined by the government of Burma.',
       'An in-flight loss of control for reasons that could not be determined during
postaccident examinations.',
       'A loss of airplane control for undetermined reasons as the autopsy was unable
to reveal any definitive conditions that would have led to the loss of control.',
       'The flight crew\x92s failure to maintain airplane control following a partial
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loss of engine thrust during cruise flight. Contributing to the accident was the fail
ed weld as a result of incomplete welding on the left propeller shaft, which led to t
he partial loss of engine thrust.',
       'A collision into water during initial climb after takeoff for undetermined re
asons.',
       "The passenger's accidental fall while turning the propeller by hand to start
the engine.",
       "The flight instructor's improper decision to attempt a visual descent into in
strument meteorological conditions while approaching the destination airport, which r
esulted in an in-flight collision with trees and terrain.",
       'The wing walker\x92s decision to release his grip of the airplane during an a
ttempted aerial transfer from airplane to helicopter before both aircraft achieved th
e proper relative positioning for the transfer.',
       'The failure of the propeller power speed reduction unit, which resulted in a
loss of engine power at low altitude.',
       'The in-flight separation of the main rotor mast following a mast bumping even
t. The reason for the mast bumping event could not be determined due to postaccident
damage.\r',
       'Maintenance personnel\x92s improper installation of the No. 2 cylinder\x92s c
onnecting rod, which resulted in the disconnection of the rod and a subsequent loss o
f engine power.',
       'The in-flight failure of the aircraft\x92s Y-tail attachment structure during
maneuvering flight due to overload. Contributing to the accident was, the kit manufac
turer\x92s use of 14 CFR Part 23, Appendix A design guidelines intended for a convent
ional tail airplane without a V- (or Y-) tail.',
       "The flight instructor's failure to maintain airspeed in changing wind conditi
ons during a steep climb after takeoff, which resulted in an aerodynamic stall. Contr
ibuting to the accident was the flight instructor\x92s ostentatious display close to
the ground.",
       'The loss of power to the rear engine due to fuel starvation during takeoff, w
hich resulted from the fuel selector valve being inadvertently moved to the \x93off\x
94 position, and resulted in the airplane\x92s inability to climb. \r',
       "The helicopter's sudden yaw and subsequent impact with the water for reasons
that could not be determined during postaccident examination of the helicopter and it
s systems.",
       'The failure of the No. 2 rod end cap bolt, which resulted in a total loss of
engine power.',
       'Sundance Helicopters\x92 inadequate maintenance of the helicopter, including
(1) the improper reuse of a degraded self-locking nut, (2) the improper or lack of in
stallation of a split pin, and (3) inadequate postmaintenance inspections, which resu
lted in the in-flight separation of the servo control input rod from the fore/aft ser
vo and rendered the helicopter uncontrollable. Contributing to the improper or lack o
f installation of the split pin was the mechanic\x92s fatigue and the lack of clearly
delineated maintenance task steps to follow. Contributing to the inadequate postmaint
enance inspection was the inspector\x92s fatigue and the lack of clearly delineated i
nspection steps to follow.',
       'The total loss of engine power for reasons that could not be determined becau
se postaccident examination of the airframe and engine did not reveal evidence of pre
accident mechanical malfunctions or failures that would have precluded normal operati
on.',
       'An electrical or engine electronic problem, which resulted in a loss of engin
e power, followed by a low-altitude stall.\r\n\r',
       'The flight crew\x92s loss of airplane control.',
       'An in-flight loss of control in instrument meteorological conditions.',
       'A loss of engine power due to fuel starvation for reasons that could not be d
etermined because the postaccident examination of the airframe and engine did not rev
eal any anomalies that would have precluded normal operation.',
       'A loss of airplane control for reasons that could not be determined because p
ostaccident examination of the airplane and engine did not reveal any anomalies that
would have precluded normal operation.',
       "the flight crew's failure to maintain adequate airspeed after shutting down t
he right engine due to an in-flight fire in one of the right augmentors. The failure
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to maintain airspeed resulted in either an aerodynamic stall or a loss of directional
control.",
       'An in-flight emergency followed by a collision with terrain for reasons that
could not be determined because postaccident examination of the airframe, engine, and
forward and aft canopies revealed no evidence of mechanical malfunctions or failures
that would have precluded normal operation.',
       nan,
       "The flight crew's misjudgment of terrain clearance while maneuvering for an a
erial application run, which resulted in controlled flight into terrain. Contributing
to the accident was the flight crew's failure to follow the lead airplane's track and
to effectively compensate for the tailwind condition while maneuvering.",
       'An inadvertent aerodynamic stall while maneuvering at a low altitude.',
       'Undetermined because the airplane was not found.',
       'The in-flight failure of the left wing spar, which resulted in the in-flight
separation of the left wing.',
       'A fatigue failure of the No. 3 piston skirt, which resulted in a total loss o
f engine power and the subsequent ditching in the ocean.',
       'The in-flight fire for a reason that could not be determined due to extensive
damage from the fire.',
       'Pilot incapacitation of unknown origin, which resulted in the airplane\x92s l
oss of control and an inadvertent aerodynamic stall/spin. \r',
       'The cause of the accident is undetermined as the airplane has not been locate
d and remains missing.',
       'A total loss of engine power for reasons that could not be determined during
the postaccident investigation and testing.',
       'The flight instructor\x92s delayed remedial action and inadequate supervision
during practice traffic pattern work.  Contributing to the accident was the flight in
structor\x92s use of sedating medication on the day of the accident and airplane\x92s
high angle of attack at a low altitude during the traffic pattern turn, which prevent
ed recovery during an aerodynamic stall.',
       'The loss of airplane control for reasons that could not be determined because
postaccident examination did not reveal any anomalies that would have precluded opera
tion.',
       'Disconnection of the upper rod end from the fore/aft servo due to severely wo
rn threads, which resulted in a loss of control and separation of a main rotor blade
during cruise flight. Contributing to the accident were incorrect maintenance procedu
res and inadequate maintenance inspections performed by the operator, and insufficien
t inspection criteria provided by the helicopter manufacturer.',
       "The loss of engine power during takeoff due to fuel contamination. Contributi
ng to the accident was maintenance personnel's failure to adequately correct the wate
r contamination effects. Contributing to the severity of the occupants' injuries was
the lack of shoulder restraints.",
       'The total loss of engine power as a result of a fractured compressor turbine
blade due to high-cycle fatigue.',
       'The total loss of engine power, the specific cause of which could not be iden
tified during the postaccident examination, and the airplane\x92s subsequent impact w
ith trees.',
       'Mast bumping for reasons that could not be determined because one main rotor
blade was not recovered.',
       'The descent and overstress of the airplane during the descent, which resulted
in the in-flight breakup of the airplane.',
       'An in-flight loss of control and impact with terrain for reasons that could n
ot be determined because postaccident examination did not reveal any anomalies that w
ould have precluded normal operation.',
       "The airplane's impact with terrain for reasons that could not be determined d
uring examination of the available evidence because of extensive impact damage and po
stimpact fire.",
       'An in-flight encounter with icing conditions during descent, which resulted i
n the airplane exceeding its critical angle-of-attack and experiencing an aerodynamic
stall followed by an in-flight breakup.\r',
       "The airplane's impact with a turkey vulture in cruise flight, which resulted
in the structural failure of the right wing and the subsequent loss of control.",
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'Fracture of the red tail rotor blade spar, which resulted in the separation a
nd departure of the red tail rotor blade from the helicopter and subsequent compromis
ed tail gearbox. The red tail rotor blade was not recovered, thus the cause of the in
itial fracture could not be determined.\r\n\r',
'The manufacture and installation of a nonstandard part by unknown maintenance
personnel to compensate for a bent, misaligned crankshaft propeller flange, which res
ulted in the improper clearance of the bearings on the crankshaft journal, a loss of
oil pressure, overheating of the bearings, and the failure of a connecting rod during
cruise flight.\r',
'A total loss of engine power due to oil starvation for reasons that could not
be determined due to extensive postcrash fire and heat damage to the engine component
s.\r\n\x0b\x0b\r',
"The flight instructor's inadequate preflight planning and his decision to tak
e off with the airplane at a high gross weight in high temperature conditions that de
graded the engine\x92s available power and his subsequent failure to maintain airspee
d while attempting to return to the departure airport, which resulted in the airplane
exceeding its critical angle-of-attack and experiencing an aerodynamic stall.",
'The loss of helicopter control for reasons that could not be determined becau
se an examination of the helicopter and its systems revealed no malfunctions or failu
res that would have precluded normal operation.\r\n\r',
'The premature release of the towline from the glider and the glider\x92s subs
equent right banking turn at low altitude for reasons that could not be determined be
cause postaccident airframe examination did not reveal any evidence of a mechanical m
alfunction or failure that would have precluded normal operation. \r',
"The operator's failure to determine the actual cargo weight, leading to the l
oading and operation of the airplane outside of the weight and center of gravity limi
ts contained in the airplane flight manual, which resulted in an aerodynamic stall. C
ontributing to the accident was the Federal Aviation Administration's failure to requ
ire weight and balance documentation for each flight in 14 Code of Federal Regulation
s Part 135 single-engine operations.",
"The airplane's unexpected encounter with a dust devil, which resulted in the
loss of airplane control.",
'The premature hoisting operation and the inadvertent disengagement of the hoi
st hook on the rescuer\x92s harness in dark night conditions. Contributing to the acc
ident was a lack of direct audio communication between the rescuer and the hoist oper
ator.\r',
'Slippage in the engine clutch and gear reduction module and a resultant uncom
manded movement of the propeller blades into reverse thrust.',
'The loss of engine power for reasons that could not be determined during post
accident examinations due to postcrash fire damage.\r',
"the flight crew's continuation of an unstabilized approach and their failure
to monitor the aircraft's altitude during the approach, which led to an inadvertent d
escent below the minimum approach altitude and subsequently into terrain. Contributin
g to the accident were (1) the flight crew's failure to properly configure and verify
the flight management computer for the profile approach; (2) the captain's failure to
communicate his intentions to the first officer once it became apparent the vertical
profile was not captured; (3) the flight crew's expectation that they would break out
of the clouds at 1,000 feet above ground level due to incomplete weather information;
(4) the first officer's failure to make the required minimums callouts; (5) the capt
ain's performance deficiencies likely due to factors including, but not limited to, f
atigue, distraction, or confusion, consistent with performance deficiencies exhibited
during training; and (6) the first officer's fatigue due to acute sleep loss resultin
g from her ineffective off-duty time management and circadian factors.",
'The improper routing of the seatbelt, which resulted in the inadvertent deplo
yment of the reserve parachute, and the open jump door, which allowed the passenger t
o be pulled from the airplane.',
'An impairing medical event of undetermined origin that led to a loss of contr
ol during takeoff.',
'The in-flight failure of the left elevator control torque tube. Contributing
to the accident was the improper assembly of the elevator control torque tubes. \r',
'The fatigue failure of the upper two tailboom attachment points, which result
ed in the tailboom separating from the fuselage during logging operations. Contributi

ng to the accident was poor maintenance throughout the helicopter\x92s operational li
fe. \r',
'Undetermined because the wreckage was not recovered.',
'A total loss of engine power due to the liberation of a second stage turbine
blade near the blade root due to a high-cycle fatigue crack and subsequent overload.
Although extensive testing and materials analysis was performed, the reason for crack
initiation could not be determined.\r\n\r',
'Controlled flight into terrain for reasons that could not be determined from
the available evidence.\r',
'The parachutist\x92s low altitude departure from the right wing before the pl
anned altitude and his delayed opening of his parachute canopy, which resulted in imp
act with a tree and then the ground before the parachute fully opened.',
"The flight instructor's failure to maintain airspeed following a partial loss
of engine power for reasons that could not be determined during postaccident examinat
ion, which resulted in an aerodynamic stall and subsequent loss of airplane contro
l.",
"The flight crew's excessive elevator input during a rapid descent under night
lighting conditions, which resulted in the overstress and breakup of the airplane. Co
ntributing to the accident was an initial loss of airplane control for reasons that c
ould not be determined because postaccident examination revealed no mechanical anomal
ies that would have precluded normal operation.",
'The loss of engine power due to the fracture of multiple blades on the compre
ssor turbine wheel, which resulted in a ditching. The reason for the blade failures c
ould not be determined due to secondary thermal damage to the blades.\r',
"The flight crew's failure to maintain airplane control during landing followi
ng an unstabilized approach. Contributing to the accident were the flight crew's deci
sion to land with a tailwind above the airplane's operating limitations and their fai
lure not to conduct a go-around when the approach became unstabilized.",
'The in-flight separation of a wing for reasons that could not be determined b
ecause the wreckage was not recovered from the ocean.\r',
'The loss of helicopter control due to a loss of hydraulic boost to the tail r
otor pedal controls at takeoff, followed by a loss of hydraulic boost to the main rot
or controls after takeoff. The reason for the loss of hydraulic boost to the main and
tail rotor controls could not be determined because of fire damage to hydraulic syste
m components and the lack of a flight recording device.',
"The check airman's delayed remedial action and initiation of a recovery proce
dure after a simulated pitch trim excursion, which resulted in a loss of airplane con
trol.",
'The flight instructor\x92s failure to arrest the airplane\x92s descent and ma
intain clearance from mountainous terrain while maneuvering at a low altitude.\r',
"The flight crewmembers' failure to perform the flight control check before ta
keoff, their attempt to take off with the gust lock system engaged, and their delayed
execution of a rejected takeoff after they became aware that the controls were locke
d. Contributing to the accident were the flight crew's habitual noncompliance with ch
ecklists, Gulfstream Aerospace Corporation's failure to ensure that the G-IV gust loc
k/throttle lever interlock system would prevent an attempted takeoff with the gust lo
ck engaged, and the Federal Aviation Administration's failure to detect this inadequa
cy during the G-IV's certification.",
'The loss of engine power during takeoff initial climb for reasons that could
not be determined during a postaccident examination of the airplane. \r',
"The flight crew's inability to maintain airplane control during initial climb
following deployment of the right thrust reverser for reasons that could not be deter
mined because postaccident examination of the airframe and engine thrust reverser sys
tem did not reveal any anomalies. Contributing to the accident was the excessive thru
st from the right engine with the thrust reverser deployed for reasons that could not
be determined during postaccident examinations and testing.",
'An in-flight fire of unknown origin for reasons that could not be determined
because of impact damage and postimpact fire damage. \r\n\r',
"Maintenance personnel's application of sealant to the engine case halves duri
ng engine overhaul, contrary to manufacturer's instructions, which resulted in intern
al failure of the engine due to the loss of case bolt torque.",
'An in-flight loss of airplane control for reasons that could not be determine

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d during postaccident examinations or based on the available evidence.\r',
       'The airplane\x92s vertical descent into water for reasons that could not be d
etermined because postaccident airplane examinations revealed no mechanical anomalie
s. \r',
       'A loss of engine power due to an inoperative magneto and possible carburetor
ice, which resulted in a forced landing into unsuitable terrain. Contributing to the
accident was an inadequate magneto overhaul by unknown personnel and the modification
to the carburetor heat system. \r',
       'An in-flight fire for reasons that could not be determined due to the extent
of impact and fire damage.\r',
       'The fatigue fracture of an engine connecting rod, which resulted in a catastr
ophic engine failure and a forced landing in unsuitable terrain.\r\n\r\n \r\n\r',
       'The partial loss of engine power for reasons that could not be determined bec
ause thermal damage to the engine prevented a complete examination. \r',
       'An inadvertent collision with a utility wire for reasons that could not be de
termined from recorded data and examination of the helicopter and accident site.',
       'The inadequate torque of the propeller mounting bolts and inspection of the p
ropeller, which resulted in the fatigue fracture of the bolts and a subsequent in-fli
ght separation of the propeller assembly.',
       'The failure of the right wing under normal race loads due to an improper repa
ir of the right wing spar that reduced its structural strength following a previous l
anding accident.\r',
       'A loss of engine power for reasons that could not be determined because posta
ccident examination of the airframe and engine did not reveal any anomalies that woul
d have precluded normal operation.\r\n\r\n \r\n\r',
       'An in-flight fire for reasons that could not be determined because the examin
ation of the airplane did not reveal the source of the fire.\r\n\r',
       'The failure of the flight control rod bearing due to an undetected preexistin
g corrosion-induced crack, which resulted in the main rotor blades going to full pitc
h and the rotor mast folding; this allowed the pusher propeller to strike and sever t
he tail. \r',
       'A total loss of engine power during cruise flight for reasons that could not
be determined due to the postaccident condition of the engine and its associated fuel
and ignition systems.',
       'The partial loss of engine power due to the undetected blockage of the inlet
and outlet ports of the manifold valve by an organic compound of an unknown source.\r
',
       'An in-flight loss of control for reasons that could not be determined based o
n the available evidence.\r',
       'The loss of engine power during cruise flight due to a fatigue fracture of th
e crankshaft, which resulted in a forced landing on unsuitable terrain.\r\n\r',
       'The loss of airplane control for reasons that could not be determined by the
postaccident examination, which was limited due to impact damage and postcrash fir
e.',
       'A total loss of engine power for reasons that could not be determined, becaus
e post accident examination did not reveal any mechanical malfunctions or anomalies t
hat would have precluded normal operation.',
       'The flight instructor\x92s decision to conduct a night training flight in mou
ntainous terrain without conducting or allowing the student to conduct appropriate pr
eflight planning and his lack of situational awareness of the surrounding terrain alt
itude, which resulted in controlled flight into terrain.',
       "The airplane's collision with water for reasons that could not be determined
because the wreckage was not located.",
       'A loss of engine power for reasons that could not be determined due to extens
ive damage sustained during the collision and postaccident water immersion. \r',
       'A loss of airplane control for reasons that could not be determined based on
available evidence.',
       'A main rotor stall due to low rotor rpm, which resulted in an uncontrolled de
scent into terrain. Contributing to the accident was the flight instructor\x92s delay
ed remedial action. \r',
       'The flight instructor\x92s failure to maintain airspeed during an approach wi
th a simulated engine failure, which resulted in an exceedance of the wing\x92s criti
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cal angle-of-attack and a subsequent aerodynamic stall/spin.\r',
       'An in-flight separation of the helicopter\x92s horizontal stabilizer due to u
ndetected fatigue cracking of the stabilizer spar, which resulted in a loss of contro
l.\r',
       'An in-flight loss of control for reasons that could not be determined based o
n available information.',
       'An in-flight loss of control for reasons that could not be determined during
postaccident investigation; the loss of control likely occurred during a simulated lo
ss of power in the right engine during an instructional flight.',
       "The flight instructor's decision to initiate flight into forecasted icing con
ditions in an airplane that was not certified or equipped for flight into icing condi
tions, which resulted in significant structural ice accumulation to the extent that t
he airplane was unable to maintain altitude.\r\n\r",
       'A loss of airplane control for reasons that could not be determined because t
he airplane impacted water, and the majority of the wreckage was not recovered. \r',
       "An in-flight failure of the helicopter's #2 main rotor spindle due to undetec
ted fatigue cracking, which resulted in an in-flight breakup. Contributing to failure
were the nonconforming thread root radius of the spindle and the manufacturer's failu
re to include a bending moment within the spindle threads when performing the fatigue
analysis during initial design of the spindle.",
       "A total loss of engine power after takeoff due to fuel starvation as a result
of excessive wear of the fuel selector valve. Also causal was the owner/operator and
maintenance personnel's inadequate maintenance, and inadequate postmaintenance inspec
tion.",
       "The left engine propeller's uncommanded travel to the feathered position duri
ng takeoff for reasons that could not be determined due to impact damage. Contributin
g to the accident was the flight crew's failure to establish a coordinated climb once
the left engine was shut down and the left propeller was in the feathered position. \
r\n\r",
       'The inadequate maintenance and inspection of the fuel system, which resulted
in partial blockage of a fuel filter, a partial loss of engine power, and subsequent
ditching.\x0b\x0b\x0b\r',
       'A partial loss of engine power for reasons that could not be determined based
on the available evidence. \r',
       'An in-flight loss of control for reasons that could not be determined based o
n the available evidence.',
       'An inflight loss of control due to the likely detachment of the forward left
servo control tube upper rod end attachment bolt.',
       'A loss of engine power for reasons that could not be determined due to postac
cident fire damage.\r\n\r',
       'A rapid onset of smoke and/or fire inflight for reasons that could not be det
ermined due to the postimpact fire and the condition of the wreckage.',
       'The helicopter rescue specialist was not properly attached to the hoist syste
m, which resulted in a fall during a night hoist operation.\r\n\r',
       'A partial loss of engine power due to contamination in the fuel manifold, whi
ch resulted in a collision with terrain shortly after takeoff.',
       'Undetermined because the airplane was not located.',
       'An in-flight impact with terrain for reasons that could not be determined bas
ed on available evidence. \r\n \r',
       'A loss of control for reasons that could not be determined, because examinati
on of the airframe and engine revealed no anomalies that would have precluded normal
operation.',
       'A loss of glider control for reasons that could not be determined based on th
e available evidence and the glider\x92s severe fragmentation.',
       'The partial loss of engine power during takeoff due to debris within the fuel
servo, which restricted fuel flow throughout the engine fuel system and resulted in a
partial loss of engine power.',
       "The powered-lift aircraft's departure from controlled flight for reasons that
could not be determined from the available information.",
       'The loss of translation/rotational power between the engine and the transmiss
ion due to the severe wear of the forward spline portion of the lower coupling drive
shaft. The reason for the severe wear of the forward spline could not be definitively
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determined due to fire damage and the loss of associated components, which were not l
ocated during the investigation.',
       'Undetermined because examination of the airplane wreckage did not reveal any
anomalies that would have precluded normal operation.',
       "A partial loss of engine power due to oil starvation. Contributing was the fl
ight instructor's failure to maintain control of the airplane during an aborted emerg
ency landing, and his delayed decision to deploy the airplane's parachute system.",
       'A loss of engine power due to three of the engine valve adjustment mechanisms
backing out, which resulted from improper maintenance.\r',
       'Oil starvation that led to the failure of the No. 5 connecting rod and a subs
equent loss of engine power.',
       'The loss of engine power for reasons that could not be determined because pos
taccident examination of the airframe and engine did not reveal any mechanical malfun
ctions or failures that would have precluded normal operation.',
       'A partial loss of engine power during takeoff. The reason for the partial los
s of power could not be determined due to the extensive fire and impact damage to the
engine.',
       'Failure of the No. 6 cylinder connecting rod, due to improper rotation of the
propeller during a previous hydraulic lock.  \r\n\r',
       "The flight instructor's loss of airplane control while departing in gusting w
ind conditions that were conducive to low-level wind shear.",
       'The total loss of engine power for reasons that could not be determined based
on postaccident examination and testing.\r\n\r',
       "The in-flight failure of the left wing lower forward attach point under norma
l loading conditions due to corrosion and fatigue cracking in the center section hing
e brackets. Contributing to the accident was the operator's inadequate maintenance an
d overweight operation of the airplane, and the manufacturer's inadequate guidance to
detect and prevent corrosion and fatigue cracking.",
       'An in-flight loss of airplane control for reasons that could not be determine
d because postaccident examination of the airframe and engine revealed no preimpact m
echanical malfunctions or failures that would have precluded normal operation.',
       'Separation of the vertical and horizontal stabilizers from the fuselage due t
o a fracture that initiated at the bond between the left horizontal stabilizer and th
e flange that attached the horizontal stabilizer to the fuselage skin. The failure wa
s likely caused by construction techniques that produced poor bond strength in a crit
ical area and the high loads on the horizontal stabilizer from a single or multiple a
erobatic maneuver(s).',
       'The partial loss of engine power for reasons that could not be determined bas
ed on the available evidence.\r\n\r\n\x0b\r',
       "Improper engine assembly by unknown maintenance personnel, which resulted in
the failure of the No. 6 connecting rod due to oil starvation from the shifting of th
e crankshaft's No. 4 main bearing.",
       'The separation of the attachment hardware connecting the elevator trim tab pu
shrod to the elevator trim actuator, which resulted in the elevator trim tab jamming
in a position outside the limits of normal travel and a subsequent loss of airplane c
ontrol.',
       'A loss of control for reasons that could not be determined based on the avail
able information.',
       'An in-flight structural failure due to a severely corroded wing strut, which
resulted in a loss of airplane control.',
       "The flight crew's mismanagement of the approach and multiple deviations from
company standard operating procedures, which placed the airplane in an unsafe situati
on and led to an unstabilized approach, a descent below minimum descent altitude with
out visual contact with the runway environment, and an aerodynamic stall. Contributin
g to the accident were Execuflight's casual attitude toward compliance with standard
s; its inadequate hiring, training, and operational oversight of the flight crew; the
company's lack of a formal safety program; and the Federal Aviation Administration's
insufficient oversight of the company's training program and flight operations.",
       "The airplane's impact with trees and terrain during an off-airport forced lan
ding in dark night conditions following a partial loss of engine power. The reason fo
r the partial loss of engine power could not be determined because postaccident exami
nation did not reveal any mechanical anomalies that would have precluded normal opera
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tion.",
       'A loss of airplane control for reasons that could not be determined because e
xamination of the wreckage revealed no mechanical deficiencies.  \r',
       'A total loss of engine power on takeoff, which resulted from a sudden over-te
mperature condition due to an improperly adjusted fuel control unit and the deteriora
ted condition of the fuel nozzles.',
       'A total loss of engine power for reasons that could not be determined because
the examination of the wreckage did not reveal any mechanical anomalies that would ha
ve precluded normal operation.',
       'Failure of the left wing in flight due to compression loading from wing loads
combined with preexisting damage.',
       "The failure of the prerotator belt, which impeded the engine's timing belt an
d resulted in a loss of engine power at low altitude.",
       'The in-flight failure of the engine-to-transmission drive shaft due to improp
er maintenance, which resulted in low main rotor rpm and a subsequent hard landing to
water.',
       "The flight instructor's inadequate preflight fuel planning, which resulted in
a total loss of engine power due to fuel exhaustion.",
       "The intentional low altitude maneuvering during takeoff in response to a near
-miss with an airplane departing from a converging runway, which resulted in an excee
dance of the airplane's critical angle of attack and a subsequent aerodynamic stal
l.",
       "The flight instructor's failure to ensure that her seat was properly secured
before initiating the takeoff, which resulted in a subsequent loss of control. Contri
buting was the lack of an installed secondary seat stop.",
       'An inflight loss of engine power due to a failure of the engine fuel pump, wh
ich resulted in a collision with trees and terrain during the subsequent autorotatio
n. The failure of the engine fuel pump resulted from the absence of adequate grease l
eading to accelerated spline wear within the fuel pump.',
       "The flight instructor's inability to move the control stick after takeoff for
undetermined reasons, which resulted in an exceedance of the airplane's critical angl
e of attack and inadvertent aerodynamic stall. The reason for the inability to move t
he control stick could not be determined, because postaccident examination revealed n
o evidence of flight control malfunctions or anomalies that would have precluded norm
al operation.",
       'A loss of control while maneuvering for reasons that could not be determined
because postaccident examination did not reveal any mechanical malfunctions or anomal
ies with the airplane.',
       'The in-flight collision with one or more large birds (Bald Eagle), which resu
lted in a loss of airplane control.',
       'An in-flight collision with trees and terrain for reasons that could not be d
etermined because no anomalies consistent with a preimpact failure or malfunction wer
e observed during the examination.',
       "The failure of the power turbine governor's dual-spool bearing due to a lack
of lubrication, which resulted in a complete loss of engine power and subsequent impa
ct with terrain.",
       "The mechanic's failure to properly secure the bolt connecting the throttle ca
ble to the carburetor during the installation of the carburetor, which resulted in a
loss of engine power.",
       'A preexisting stress rupture that initiated at a spot weld in the turbocharge
r v-band exhaust clamp, which resulted in the failure of the clamp and separation of
the exhaust tailpipe, an in-flight fire, and subsequent impact with terrain.',
       'A total loss of engine power due to fatigue failure of the camshaft drive gea
r teeth.',
       'The steep descent to ground impact for reasons that could not be determined b
ased on the available evidence.',
       'A loss of engine power during cruise flight for reasons that could not be det
ermined because a test run of the engine did not reveal any mechanical malfunctions o
r anomalies that would have precluded normal operation. Contributing to the accident
were the tree stumps at the forced landing site.',
       "\r\nThe failure of the right wing due to a fatigue fracture of the right outb
oard wing forward spar lower fitting. Contributing to the accident was the routine op
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eration of the airplane over its certificated maximum gross weight and the operator's
improper or inadequate maintenance practices, which failed to apply a service life fa
ctor to the airplane to account for its overweight operation and also failed to detec
t the extensive corrosion throughout the airplane.",
       'An encounter with turbulence due to updrafts and/or dust devils that resulted
in mast bumping and an in-flight break-up.',
       "A severe vibration of the helicopter that led to the crew's inability to main
tain sufficient rotor rotation speed (Nr), leading to excessive main rotor blade flap
ping, subsequent main rotor blade contact with the tail boom, and the resultant in-fl
ight breakup. Contributing to the severity and sustainment of the vibration, which wa
s not predicted during development, were (1) the collective biomechanical feedback an
d (2) the attitude and heading reference system response, both of which occurred due
to the lack of protections in the flight control laws against the sustainment and gro
wth of adverse feedback loops when the 6-hertz airframe vibration initiated. Contribu
ting to the crew's inability to maintain sufficient Nr in the severe vibration enviro
nment were (1) the lack of an automated safeguard in the modified one-engine-inoperat
ive software used during flight testing to exit at a critical Nr threshold and (2) th
e lack of distinct and unambiguous cues for low Nr.",
       "The emergency response team's failure to ensure that the system operator was
secured to the helicopter, which resulted in his fall during the recurrent rescue hoi
st training operation.",
       "Company maintenance personnel's inappropriate removal without replacement of
the safety wires on the collective lever pin screws during a recent maintenance inspe
ction, which resulted in the screws backing out and led to a loss of collective contr
ol in flight.",
       'The loss of aircraft control for reasons that could not be determined because
postaccident examination did not reveal any anomalies that would have precluded norma
l operation.',
       'Improper installation of a fuel line by unknown personnel, which resulted in
a total loss of engine power during initial climb due to fuel starvation.',
       'An inflight fire in the floor area near the main bus tie circuit breaker pane
l that resulted from chafing between an electrical wire and a hydraulic line and/or a
irplane structure.',
       'A departure flight path that consisted of several unexplained turns during th
e initial climbout, and terminated in a high-speed descent and ground impact. The rea
son(s) for the turns and descent could not be determined due to lack of definitive ev
idence.',
       'Impact with terrain for reasons that could not be determined based on the ava
ilable information.',
       "The improper execution of an autorotation following the loss of engine power,
which resulted in an uncontrolled descent into terrain. Contributing to the accident
was the flight instructor's lack of remedial action during the autorotation.",
       'The sudden right turn on approach to landing for reasons that could not be de
termined because postaccident examination did not reveal any anomalies that would hav
e precluded normal operation.',
       "The airplane's departure from cruise flight for reasons that could not be det
ermined based on the available information.",
       "The flight crew's decision to continue the visual flight rules flight into de
teriorating visibility and their failure to perform an immediate escape maneuver afte
r entry into instrument meteorological conditions, which resulted in controlled fligh
t into terrain (CFIT). Contributing to the accident were (1) Hageland's allowance of
routine use of the terrain inhibit switch for inhibiting the terrain awareness and wa
rning system alerts and inadequate guidance for uninhibiting the alerts, which reduce
d the margin of safety, particularly in deteriorating visibility; (2) Hageland's inad
equate crew resource management (CRM) training; (3) the Federal Aviation Administrati
on's failure to ensure that Hageland's approved CRM training contained all the requir
ed elements of Title 14 Code of Federal Regulations 135.330; and (4) Hageland's CFIT
avoidance ground training, which was not tailored to the company's operations and did
not address current CFIT-avoidance technologies.",
       "The flight instructor's loss of control during an aerodynamic stall demonstra
tion, which resulted in an inadvertent spin from which he was unable to recover. Cont
ributing to the accident was the flight instructor's lack of familiarity with the air
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plane's stall characteristics.",
       'The separation of the main rotor assembly due to mast bumping.',
       'The NTSB did not determine the probable cause of this event and does not plan
to issue a report or open a public docket. The investigation of this event is being c
onducted under the jurisdiction of the Federal Bureau of Investigation.',
       "The jumpmaster's failure to guard the reserve parachute ripcord, which caused
an inadvertent deployment of his reserve parachute.",
       'A loss of airplane control for reasons that could not be determined due to th
e extensive impact and fire damage to the airplane.',
       'An abrupt pitch-up maneuver following a descent, which resulted in the in-fli
ght separation of the right wing due to the overload failure of both the forward and
aft right wing attachment brackets.',
       'The in-flight failure of the propeller due to excessive engine vibration load
s and the use of an incorrectly-sized propeller, which resulted in a fatigue crack of
the leading edge strip. Contributing to the accident was the inadequate repair of the
propeller following a previous crack.',
       'A loss of engine power to the left engine for reasons that could not be deter
mined due to the extensive fire and impact damage to the airplane.',
       'The loose fuel fitting on the combustion heater that leaked a lean fuel-air m
ixture into the nose baggage compartment. The mixture was most likely ignited by the
combustion heater, blowing off the nose baggage compartment doors and starting an in-
flight fire.',
       'Undetermined due to a lack of physical evidence.',
       'A loss of control in flight for reasons that could not be determined because
no anomalies consistent with a preimpact failure or malfunction were identified durin
g the investigation.',
       'A total loss of engine power during takeoff due to fuel starvation as a resul
t of a failure of internal components of the fuel servo.',
       "The flight instructor's failure to ensure that adequate clearance from terrai
n was maintained after performance of a simulated engine failure maneuver, which resu
lted in controlled flight into terrain.",
       'The failure of maintenance personnel to ensure that the throttle and fuel met
ering unit AN "B" nut was secured, which resulted in a total loss of engine power in
flight and a subsequent collision with trees while attempting to land after sunset.',
       "The flight instructor's inadequate preflight planning and operation of the ai
rplane outside its center of gravity envelope, which resulted in a loss of control wh
ile maneuvering.",
       "The failure of the fuel selector valve in a position that restricted fuel flo
w to the engine, resulting in a total loss of engine power during initial climb due t
o fuel starvation. Also causal was the operator's failure to effectively detect and r
esolve the wear and progressive binding of the fuel selector valve before it failed d
ue to excessive rotational force being applied. Contributing was the flight instructo
r's exceedance of the airplane's critical angle of attack during an emergency return
to the airport, which resulted in an aerodynamic stall/spin.",
       "The flight instructor's exceedance of the critical angle of attack during a g
o-around, which resulted in an aerodynamic stall/spin. Contributing to the accident w
as the flight instructor's failure to familiarize himself with the flight characteris
tics of the unfamiliar airplane before conducting the flight review.",
       'The failure of unknown personnel to properly safety an elevator control cable
turnbuckle, which disconnected in flight resulting in loss of pitch control. Contribu
ting to the accident was the inadequate design of the experimental airplane, which di
d not provide a mechanism for accessing the entire flight control system during routi
ne inspections.',
       'An impact with terrain during final approach for reasons that could not be de
termined because no evidence of an in-flight failure or malfunction was observed.',
       "The flight instructor's decision to continue the takeoff in gusting tailwind
and high density altitude conditions, which significantly reduced airplane performanc
e, and his subsequent exceedance of the airplane's critical angle of attack during th
e initial climb, which resulted in an aerodynamic stall at low altitude.",
       "The in-flight failure of the left wing due to the owner's use of improper har
dware and his improper assembly of the airplane, which reduced the strength of the le
ft wing and resulted in its subsequent failure following a sharp pullup maneuver.",
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       'A partial loss of engine power during initial climb for reasons that could no
t be determined because extensive fire damage precluded thorough examination of the e
ngine and its associated systems.',
       'A loss of control and subsequent in-flight breakup for reasons that could not
be determined based on the available information.',
       "The flight instructor's failure to maintain control of the aircraft while dem
onstrating a spiral dive, which resulted in a loss of control. Contributing to the ac
cident was the instructor's decision to demonstrate a spiral dive maneuver at an alti
tude that was too low for recovery.",
       'Controlled descent into terrain due to engine issues, the reason for which co
uld not be determined because examination of the engine revealed no evidence of malfu
nctions or failures that would have precluded normal operation.',
       "The flight instructor's decision to conduct a low-altitude flight into a box
canyon in high density altitude conditions and his failure to maintain airspeed while
maneuvering to escape the canyon, which resulted in an exceedance of the airplane's c
ritical angle of attack and an aerodynamic stall.",
       'A loss of control in flight for reasons that could not be determined based on
the available information, which resulted in an in-flight breakup.',
       'The loss of airplane control while maneuvering at low altitude for reasons th
at could not be determined.',
       'A loss of control during takeoff for reasons that could not be determined.',
       'A loss of engine power for reasons that could not be determined based on avai
lable evidence.',
       "The flight instructor's failure to ensure that the wing flaps were properly c
onfigured for takeoff, which resulted in an aerodynamic stall and loss of control dur
ing the initial climb.",
       'A loss of control for reasons that could not be determined because of the ext
ensive thermal damage from the postcrash fire.',
       "The total loss of engine power due to oil starvation to the No. 1 connecting
rod, which resulted from the improper torque of the No. 1 cylinder hold-down bolts an
d through-studs at the time of the cylinder's installation, which resulted in the fai
lure of the connecting rod due to oil starvation. Contributing to the accident was th
e omission, from the air traffic control display map data, of a closer alternate airp
ort for the emergency landing.\r",
       'An in-flight loss of control and collision with terrain for reasons that coul
d not be determined based on the available information.',
       'The  loss of directional control during takeoff and impact with a steel culve
rt.',
       'Controlled flight into terrain in dark night conditions.',
       'A descent and subsequent impact with open ocean waters for reasons that could
not be determined based on the available information.',
       'An in-flight loss of control due to a bird strike.',
       'Failure of the left aileron control cable that resulted in a loss of aircraft
control during takeoff. Contributing to the accident was inadequate maintenance inspe
ctions to the aileron cable connections.',
       "The loss of engine power due to fuel starvation, which resulted from the unpo
rting of the fuel during a right turn due to the auxiliary fuel tanks' improper confi
guration.",
       'An in-flight loss of control due to bird strikes.',
       'Impact with trees and terrain for reasons that could not be determined based
on available evidence.',
       'A total loss of engine power for reasons that could not be determined based o
n the available information.',
       'A loss of engine power due to snow or ice ingestion at an altitude that was i
nsufficient to allow for engine re-ignition. Contributing to the accident were condit
ions, including altitude and flat light conditions, that precluded a successful autor
otation to the field.',
       "A loss of control following the gunner's failure to ensure that the net maint
ained clearance from the tail rotor.",
       'A loss of control for reasons that could not be determined based on the avail
able information.\r\n\r',
       'The driveshaft fracture due to overstress loading and rotational bending as a
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result of the under-torqued nuts on the elastomeric couplings backing off and the sub
sequent in-flight separation of the horizontal fairing due to contact with the separa
ted end of the driveshaft, which led to a loss of control. Contributing to the accide
nt was inadequate maintenance.   \r\n\r\n \r\n\r\n \r\n\r\n \r\n\r',
       'An inflight loss of control and collision with terrain for reasons that could
not be determined.',
       "Liberty Helicopters Inc.'s use of a NYONair-provided passenger harness/tether
system, which caught on and activated the floor-mounted engine fuel shutoff lever and
resulted in the in-flight loss of engine power and the subsequent ditching. Contribut
ing to this accident were (1) Liberty's and NYONair's deficient safety management, wh
ich did not adequately mitigate foreseeable risks associated with the harness/tether
system interfering with the floor-mounted controls and hindering passenger egress;
(2) Liberty allowing NYONair to influence the operational control of Liberty's FlyNYO
N flights; and (3) the Federal Aviation Administration's inadequate oversight of Titl
e 14 Code of Federal Regulations Part 91 revenue passenger-carrying operations. Contr
ibuting to the severity of the accident were (1) the rapid capsizing of the helicopte
r due to partial inflation of the emergency flotation system and (2) Liberty and NYON
air's use of the harness/tether system that hindered passenger egress.",
       'Descent and impact with terrain for reasons that could not be determined.',
       'Extensive fatigue cracking in the left-wing main spar lower cap and doublers,
which resulted in the in-flight separation of the left wing. The fatigue cracks initi
ated and grew to a critical size due to flight and ground loads associated with fligh
t-training involving flight-training maneuvers, significant operation at low altitude
s and frequent landing cycles. Previously established inspection criteria were insuff
icient to detect the fatigue crack before it grew to a critical size.',
       "The flight instructor's failure to maintain airplane control during the initi
al climb as a result of the airplane being loaded above its maximum gross weight and
beyond its aft center of gravity limits. Contributing to the accident was a degraded
engine power output due to a preexisting engine cylinder intake valve spring failure,
which further reduced the airplane's climb capability.\r\n\r\n \r\n\r\n \r\n\r\n \r\
n\r\n \r\n\r",
       'An in-flight fire and subsequent total loss of engine power for reasons that
could not be determined due to extensive impact and fire damage, followed by a loss o
f airplane control.',
       'An in-flight impact with terrain for reasons that could not be determined due
to a lack of evidence.',
       'A low-cycle fatigue crack in the dovetail of fan blade No. 13, which resulted
in the fan blade separating in flight and impacting the engine fan case at a location
that was critical to the structural integrity and performance of the fan cowl structu
re. This impact led to the in-flight separation of fan cowl components, including the
inboard fan cowl aft latch keeper, which struck the fuselage near a cabin window and
caused the window to depart from the airplane, the cabin to rapidly depressurize, and
the passenger fatality.',
       'A partial loss of engine power due to inadequate thru-bolt and stud preload t
ension by undetermined maintenance personnel, which resulted in fretting between the
engine crankcase halves, and the subsequent separation of the No. 2 cylinder due to t
he fatigue failure of the No. 2 cylinder stud/thru bolts.',
       'An in-flight fire and total loss of engine power after takeoff due to a loose
fuel line. Contributing to the accident was the installation of an unapproved fuel li
ne by unknown personnel.',
       'An inadvertent stall, resulting in an uncontrollable descent and impact with
terrain. Contributing to the accident was the high density altitude.',
       'A loss of engine power for reasons that could not be determined based on the
available information.',
       'Undetermined based on the available evidence.',
       'A loss of control due to the banner tow rope becoming entangled with the left
horizontal stabilizer in crosswind conditions.',
       'A loss of control during the landing approach for reasons that could not be d
etermined based on the available information.',
       'A total loss of engine power due to oil exhaustion, which resulted in an unco
ntrolled descent and hard landing.',
       'The inflight separation of the upper transmission due to the thread failure o
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f transmission housing attachment bolts, which were installed on the helicopter with
thread damage from a prior installation.',
       'An in-flight breakup as a result of the airplane exceeding the structural str
ength of the airplane during a rapid descent that the flight instructor was unable to
recover from following a collision with a large bird.\r',
       'A loss of engine power for reasons that could not be determined.',
       'An in-flight separation of the right wing due to upward and rearward bending
that led to an overstress fracture. The reason for the upward and rearward bending co
uld not be determined based on the available information.',
       "The airplane's encounter with wake turbulence from the lead airplane in the f
ormation flight, which resulted in a compressor stall and the airplane's subsequent i
nability to climb.\r\n\r\n\r\n\r\n\r\n\r\n\r",
       'The undetected wear of the ignition switch and key, which allowed removal of
the key from an intermediate position and subsequently led to an unintended engine st
art-up. Contributing to the undetected wear of the 42-year-old ignition switch was th
e lack of guidance by the switch manufacturer and airframe manufacturer for procedure
s to detect lack of integrity between the ignition key and switch.\r',
       'The passengers\x92 fall from the basket after landing when the basket tipped
over.  \r',
       'Impact with terrain for reasons that could not be determined because the airp
lane was not recovered due to the inaccessible nature of the accident site.',
       'The NTSB did not determine the probable cause of this event and does not plan
to issue an investigative report or open a public docket. The investigation of this e
vent is being conducted under the jurisdiction of the Federal Bureau of Investigatio
n.\r\n\r\n \r\n\r',
       "The in-flight fracture of a stainless steel bolt that was used to secure the
upper and lower wing cables to the outer attach point at the leading edge spar of the
right wing due to stress corrosion cracking, which caused the right wing to fail and
precluded controlled flight. Contributing to the bolt failure was the installation of
a bolt that did not conform with the company's specification.",
       'Loss of control for reasons that could not be determined because postaccident
examination of the airframe and engine revealed no mechanical anomalies that would ha
ve precluded normal operation.\r',
       "An exceedance of the airplane's critical angle of attack while maneuvering fo
r landing, which resulted in an aerodynamic stall/spin at an altitude too low for rec
overy.\r\n\r\n\r\n\r\n \r\n\r\n \r\n\r",
       'The total loss of engine power for reasons that could not be determined based
on available information.',
       'The improper manufacture of the left wing, which resulted in a left wing flut
ter event and failure at low altitude and high speed.',
       "A loss of engine power shortly after takeoff due to fuel exhaustion, and the
exceedance of the airplane's critical angle of attack when the flight instructor made
an abrupt turn back toward the runway, which resulted in an aerodynamic stall/spin at
an altitude too low for recovery.  Contributing to the accident was an inadequate pre
flight inspection.",
       'An impact with terrain for reasons that could not be determined based on the
available information.',
       "The operator's decision to allow a flight in an airplane with known, unresolv
ed maintenance discrepancies, and the flight crew's failure to properly configure the
airplane in a way that would have allowed the emergency or parking brake systems to s
top the airplane during landing.",
       "The instructor's decision to conduct and continue a visual flight rules fligh
t into instrument meteorological conditions with a known flight instrument anomaly, w
hich resulted in spatial disorientation, causing a loss of airplane control and subse
quent in-flight breakup. Contributing to the accident were the instructor's lack of r
ecent instrument flight experience and degraded airplane control and decision-making
due to hypoxia.",
       'An in-flight loss of control, which resulted in an impact with water, for rea
sons that could not be determined because the airplane was not recovered.',
       'An in-flight fire of undetermined origin. Contributing to the accident were t
he severe icing conditions encountered during the final minutes of the flight, which
led to a loss of airplane control.',
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       'Pilot incapacitation due to carbon monoxide poisoning as a result of an undet
ected crack in an engine exhaust muffler, which permitted entry of exhaust gasses int
o the cabin via the cabin heat system. \r',
       'The loss of engine power due to fatigue failure of the crankshaft.',
       'The loss of airplane control after an engine flameout and auto-feather system
interruption during the takeoff climb, which resulted in an impact with terrain.',
       'A loss of control for reasons that could not be determined based on the avail
able information.\r',
       "A total loss of left engine power for reasons that could not be determined, a
nd the instructor's failure to maintain airspeed while maneuvering for a forced landi
ng, which resulted in a loss of control. Contributing to the accident was the instruc
tor's decision to conduct a simulated engine failure at low altitude.",
       "The flight instructor's failure to maintain airplane control during initial c
limb after a touch-and-go landing, which resulted in an exceedance of the airplane's
critical angle of attack and an aerodynamic stall.",
       "A partial loss of engine power for reasons that could not be determined, and
the flight instructor's exceedance of the airplane's critical angle of attack while m
aneuvering for a forced landing, which resulted in an aerodynamic stall and subsequen
t loss of control.",
       'The airplane\x92s unairworthy thrust reverser (T/R) system due to inadequate
maintenance that resulted in an asymmetric T/R deployment during an approach to the a
irport and the subsequent loss of airplane control.\r',
       "The flight instructor\x92s failure to maintain adequate airspeed during the i
nitial climb after takeoff, which resulted in an exceedance of the airplane's critica
l angle of attack, an aerodynamic stall, and loss of control. \r",
       "The exceedance of the airplane's critical angle of attack during a steep clim
b after takeoff, which resulted in an aerodynamic stall and spin into terrain.\r",
       'A loss of control and impact with terrain while maneuvering.\r',
       'The helicopter\x92s encounter with a strong downdraft or outflow boundary whi
le operating at a higher than recommended airspeed in turbulence which resulted in a
low-G condition, excessive main rotor flapping, and an in-flight breakup when the mai
n rotor contacted the cabin area.   \r',
       "A partial loss of engine power due to a stuck exhaust valve and the flight in
structor's exceedance of the airplane's critical angle of attack following the loss o
f power, which resulted in an aerodynamic stall at low altitude.",
       'A loss of control due to an inflight right engine fire due to the loose fuel
hose between the engine-driven fuel pump and the flow transducer.',
       'Impact with water for reasons that could not be determined based on the avail
able information.',
       'A loss of control while conducting low-altitude, high-speed maneuvers. \r',
       'Impact with the ocean for reasons that could not be determined because the ai
rplane was not located.',
       'A total loss of engine power due to fuel starvation.\r',
       "The airplane's floats impact with an ocean wave or swell, which exceeded the
design load specifications of the flying wire assemblies and resulted in a partial se
paration of the float assemblies.\r",
       'The improper installation of the engine\x92s metal intake screen, which allow
ed the filter element to become displaced and subsequently lodge in the intake, block
ing intake air and causing the total loss of engine power, at low altitude and low ai
rspeed resulting in the airplane impacting terrain.\r',
       'Impact with terrain for reasons that could not be determined based on the ava
ilable information.\r\n\r\n\r',
       'A total loss of engine power due to the failure of the engine\x92s Nos. 3 and
4 bearings and the power turbine pinion gear, and subsequent loss of main rotor rpm,
which resulted in a loss of control and impact with the water.\r',
       'The loss of engine power due to fuel starvation.\r',
       'The mechanic\x92s failure to clean the oil suction screen during the most rec
ent maintenance, which resulted in oil starvation and subsequent total loss of engine
power. \r',
       'A loss of control during landing due to the loose and uneven landing surface.
\r',
       'The flight instructor\x92s failure to maintain directional control with a qua
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rtering tailwind.\r',
       'The flight instructor\x92s delayed remedial action during an unstabilized app
roach, which resulted in an impact with powerlines and a subsequent loss of control\r
',
       'A collision with water following a loss of visual reference to the water surf
ace due to sun glare.\r',
       'A loss of engine power for reasons that could not be determined due to a lack
```

I'm going to create a new category that groups collisions

In [89]:
```
df['report_status'] = df['report_status'].map(lambda x: 'Collision' if isinstance(x,s
```

In [90]:
```
df['report_status'].nunique()
```

Out[90]: 418

There are still 4358 unique cases in the report_status column and the majority of the explanations are not very clear

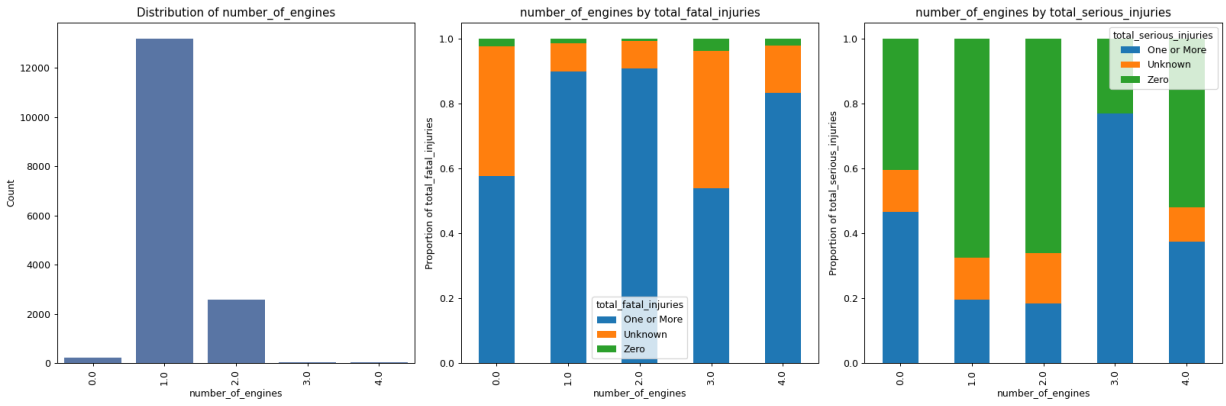
3.7 Results

First business recommendation: Invest in aircrafts with more than one engine. The dataset shows that 82% of the accidents happened with aircrafts that had only 1 engine.

This implies that aircraft with more than one engine may have a better safety record and could represent a safer investment.

In [91]:
```
plot_feature(df, 'number_of_engines', 'bar', 'total_fatal_injuries', 'total_serious_i
```

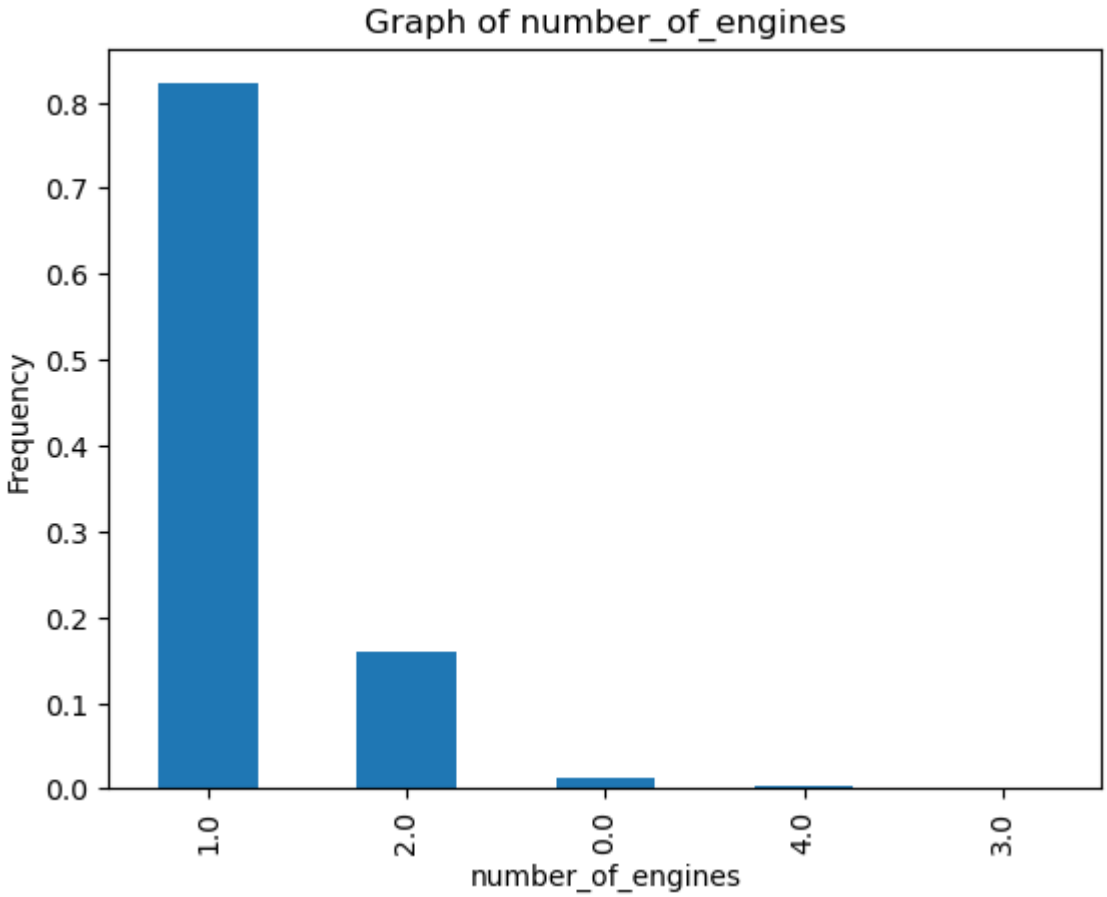
```
C:\Users\Usuario\anaconda3\envs\aircraft_env\Lib\site-packages\seaborn\_oldcore.py:14
98: FutureWarning: is_categorical_dtype is deprecated and will be removed in a future
version. Use isinstance(dtype, CategoricalDtype) instead
  if pd.api.types.is_categorical_dtype(vector):
C:\Users\Usuario\anaconda3\envs\aircraft_env\Lib\site-packages\seaborn\_oldcore.py:14
98: FutureWarning: is_categorical_dtype is deprecated and will be removed in a future
version. Use isinstance(dtype, CategoricalDtype) instead
  if pd.api.types.is_categorical_dtype(vector):
```



In [92]:
```
plot_column_data(df,'number_of_engines', 'bar')
```

```
number_of_engines
1.0    0.821342
2.0    0.160780
0.0    0.013269
4.0    0.002990
```

```
3.0    0.001620
Name: proportion, dtype: float64
```

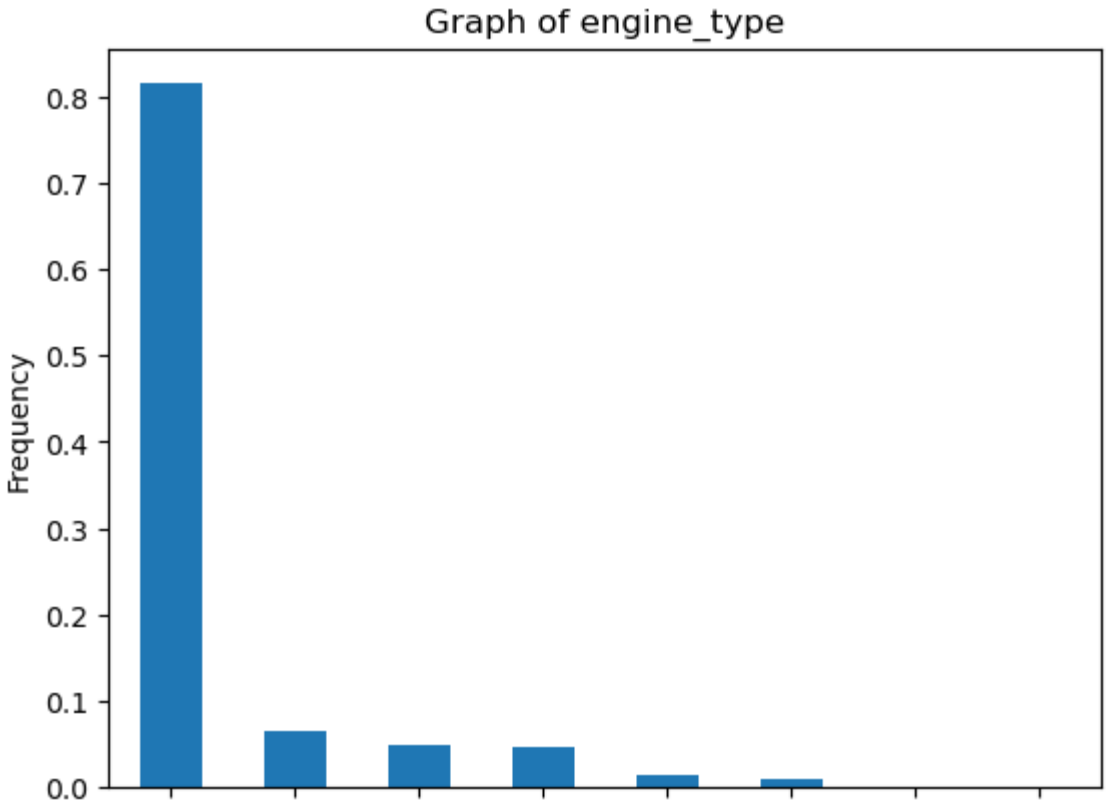


Second business recommendation: Do not invest in aircrafts with a reciprocating engine type. The dataset shows that 81.4% of the accidents happened with aircrafts that had this type of engine.

Investing in aircraft with alternative engine types might reduce risk exposure.

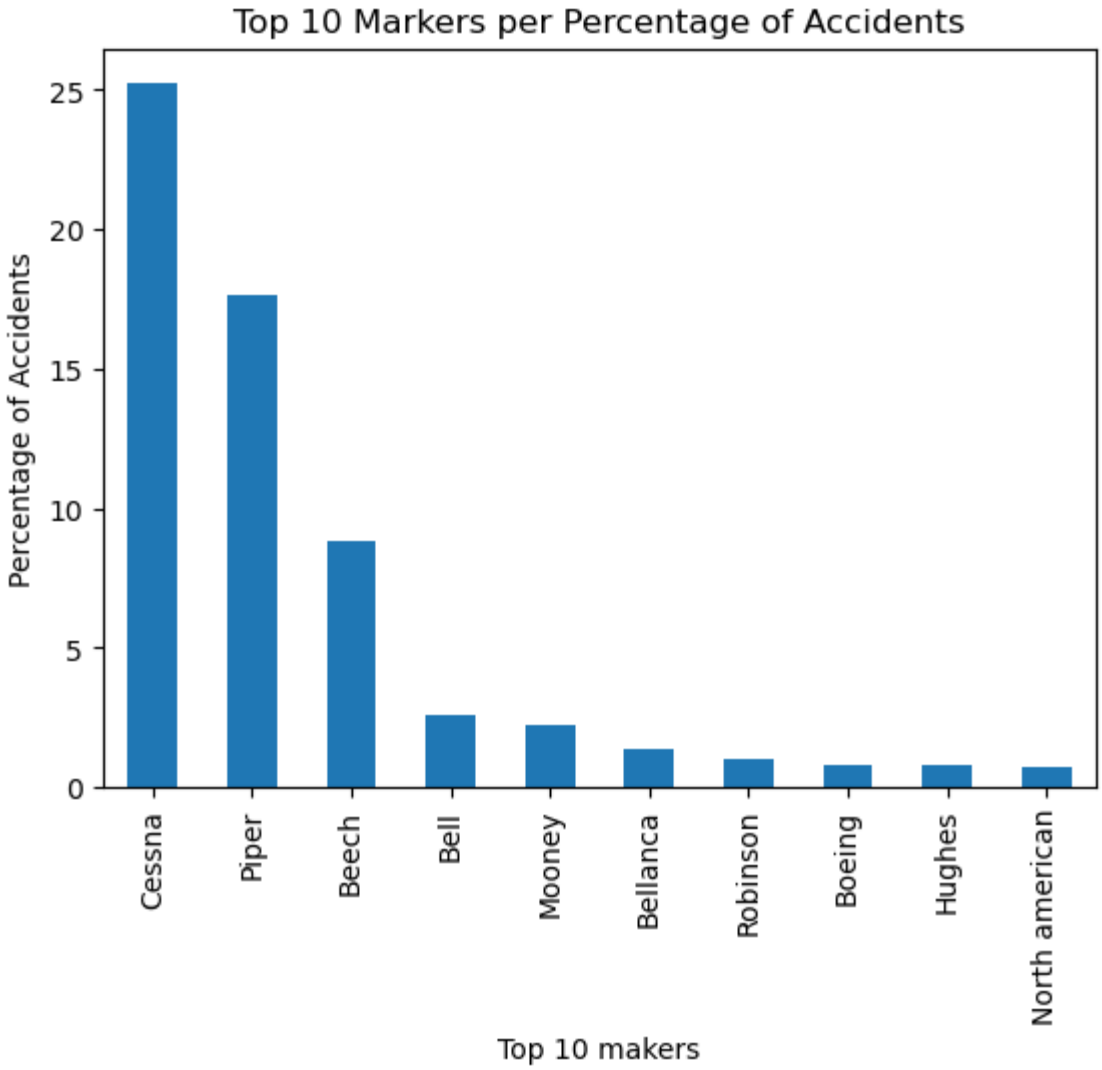
In [93]:
```
plot_column_data(df,'engine_type', 'bar')
```

```
engine_type
Reciprocating    0.814365
Unknown          0.065969
Turbo Prop       0.048278
Turbo Shaft      0.046596
Turbo Fan        0.015511
Turbo Jet        0.009095
Electric         0.000125
Hybrid Rocket    0.000062
Name: proportion, dtype: float64
```



Third business recommendation: Be weary of investing in certain aircraft makers. Be very carefull in investing on 'Cessna', 'Piper' and 'Beech' as their aircrafts combined have had around 50% of the fatal and serious accidents. In particular, 'Cessna' has 25%, 'Piper' 17.7%, and 'Beech' 8.8%. The rest of the makers are involved in less than 2.6% of the fatal and serious accidents.

In [94]:
```
plt.figure()
top_10_make.plot(kind='bar')
plt.xlabel('Top 10 makers')
plt.ylabel('Percentage of Accidents')
plt.xticks(rotation=90)
plt.title('Top 10 Markers per Percentage of Accidents');
```



A prudent investment strategy might be to diversify into manufacturers with lower accident rates or to further scrutinize the causes of these accidents to determine if they are related to maintenance practices, specific models, or flight circumstances that could be mitigated.

Considering the above recommendations, this would be the resulting dataset to consider for aircraft investment

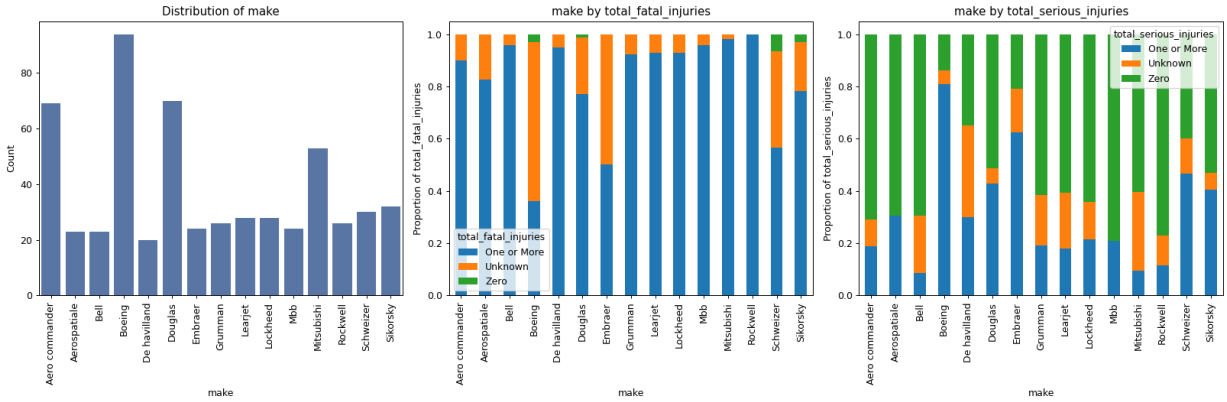
In [95]:
```
df_filtered = df[(df['number_of_engines']!=1) & (df['engine_type']!='Recriprocating')
df_filtered.reset_index(drop=True, inplace=True)
```

In [96]:
```
df_filtered.columns
```

Out[96]:
```
Index(['investigation_type', 'event_date', 'location', 'country',
       'injury_severity', 'aircraft_damage', 'make', 'model', 'amateur_built',
       'number_of_engines', 'engine_type', 'purpose_of_flight',
       'total_fatal_injuries', 'total_serious_injuries',
       'total_minor_injuries', 'total_uninjured', 'weather_condition',
       'broad_phase_of_flight', 'report_status', 'primary_key', 'year',
       'month'],
      dtype='object')
```

In [97]:
```
plot_feature(df_filtered,'make', 'categorical', 'total_fatal_injuries', 'total_seriou
```

```
C:\Users\Usuario\anaconda3\envs\aircraft_env\Lib\site-packages\seaborn\_oldcore.py:14
98: FutureWarning: is_categorical_dtype is deprecated and will be removed in a future
version. Use isinstance(dtype, CategoricalDtype) instead
  if pd.api.types.is_categorical_dtype(vector):
C:\Users\Usuario\anaconda3\envs\aircraft_env\Lib\site-packages\seaborn\_oldcore.py:14
98: FutureWarning: is_categorical_dtype is deprecated and will be removed in a future
version. Use isinstance(dtype, CategoricalDtype) instead
  if pd.api.types.is_categorical_dtype(vector):
```



Looking at the results, I would recommend to invest in aircrafts made by Schweizer because they're the ones with the lowest numbers of total fatal injuries and are thus, a priori, more reliable

3.8 Write the Results

I will export the dataframe to an excel

In [98]:
```
df_filtered.to_csv("../results_data/aircraft_safety_final_dataset.csv", index=False)
```