Elements Of Data Science - F2024

Week 3: Pandas, Data Exploration and Visualization

9/23/2024

TODOs

- Practical Statistics for Data Scientists, Chapter 3 EBSCO
- An introduction to seaborn https://seaborn.pydata.org/tutorial/introduction.html
- (Optional) Data Science From Scratch, Chapter 5,6,7 EBSCO

- Complete Week 3 Quiz

- HW1 out this week, includes questions on Hypothesis Testing

TODAY

- Pandas
- Data Exploration
- Visualization

Questions?

Environment Setup

Environment Setup

In [1]:
```
1 import numpy as np
```

Intro to Pandas

Intro to Pandas

Pandas is an open source, BSD-licensed* library providing:

- **high-performance, easy-to-use data structures** and
- **data analysis tools**

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- **high-performance, easy-to-use data structures** and
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Berkeley Source Distribution (BSD) licenses are used for the distribution of many freeware, shareware and open source software.

In [2]:

```
# usually imported using the alias 'pd'
import pandas as pd
```

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```
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import pandas as pd
```

- Primary datastructures:
  - **Series**: 1D array with a flexible index
  - **Dataframe**: 2D matrix with flexible index and column names

Pandas Series

Pandas Series

- 1D array of data (any numpy datatype) plus an associated **index** array

Pandas Series

- 1D array of data (any numpy datatype) plus an associated **index** array

In [3]:
```
1 s = pd.Series(np.random.rand(4))
2 s
```

Out[3]:
```
0    0.841416
1    0.537238
2    0.277649
3    0.663616
dtype: float64
```

Pandas Series

- 1D array of data (any numpy datatype) plus an associated **index** array

In [3]:
```
1 s = pd.Series(np.random.rand(4))
2 s
```

Out[3]:
```
0    0.841416
1    0.537238
2    0.277649
3    0.663616
dtype: float64
```

In [4]:
```
1 # return the values of the series
2 s.values
```

Out[4]:
```
array([0.84141624, 0.53723786, 0.27764907, 0.66361562])
```

Pandas Series

- 1D array of data (any numpy datatype) plus an associated **index** array

In [3]:
```
s = pd.Series(np.random.rand(4))
s
```

Out[3]:
```
0    0.841416
1    0.537238
2    0.277649
3    0.663616
dtype: float64
```

In [4]:
```
# return the values of the series
s.values
```

Out[4]:
```
array([0.84141624, 0.53723786, 0.27764907, 0.66361562])
```

In [5]:
```
# return the index of the series
s.index
```

Out[5]:
```
RangeIndex(start=0, stop=4, step=1)
```

Pandas Series Cont.

Pandas Series Cont.

- index is flexible, can be anything hashable (integers, strings, ...)

Pandas Series Cont.

- index is flexible, can be anything hashable (integers, strings, ...)

In [6]:
```
# create Series from array and set index
s1 = pd.Series([1,2,3],index=['house_a','2','house c'],name='NumRooms',dtype=float)
s1
```

Out[6]:
```
house_a    1.0
2          2.0
house c    3.0
Name: NumRooms, dtype: float64
```

Pandas Series Cont.

- index is flexible, can be anything hashable (integers, strings, ...)

In [6]:
```
# create Series from array and set index
s1 = pd.Series([1,2,3],index=['house_a','2','house c'],name='NumRooms',dtype=float)
s1
```

Out[6]:
```
house_a    1.0
2          2.0
house c    3.0
Name: NumRooms, dtype: float64
```

In [7]:
```
s1['house_a'] # access a single value via index label
```

Out[7]:
```
1.0
```

Pandas Series Cont.

- index is flexible, can be anything hashable (integers, strings, ...)

In [6]:
```
# create Series from array and set index
s1 = pd.Series([1,2,3],index=['house_a','2','house c'],name='NumRooms',dtype=float)
s1
```

Out[6]:
```
house_a    1.0
2          2.0
house c    3.0
Name: NumRooms, dtype: float64
```

In [7]:
```
s1['house_a'] # access a single value via index label
```

Out[7]:
```
1.0
```

In [8]:
```
s1['house c'] # dot notation (How do we get "house c"?)
```

Out[8]:
```
3.0
```

Pandas Series Cont.

Pandas Series Cont.

- accessing other Series attributes

In [9]:
```
1 s1
```

Out[9]:
```
house_a    1.0
2          2.0
house c    3.0
Name: NumRooms, dtype: float64
```

Pandas Series Cont.

- accessing other Series attributes

In [9]:
```
s1
```

Out[9]:
```
house_a    1.0
2          2.0
house c    3.0
Name: NumRooms, dtype: float64
```

In [10]:
```
#print(f'{s.index  = :}')
#print(f'{s.values = :}')
print(f'{s1.name   = :}')
print(f'{s1.dtype  = :}')
print(f'{s1.shape  = :}')
```

```
s1.name   = NumRooms
s1.dtype  = float64
s1.shape  = (3,)
```

Pandas Series Cont.

Pandas Series Cont.

In [11]:
```
# Can create series with index from a dictionary
s2 = pd.Series({'a':1,'b':2,'c':3,'d':4})
s2
```

Out[11]:
```
a    1
b    2
c    3
d    4
dtype: int64
```

Pandas Series Cont.

In [11]:
```
# Can create series with index from a dictionary
s2 = pd.Series({'a':1,'b':2,'c':3,'d':4})
s2
```

Out[11]:
```
a    1
b    2
c    3
d    4
dtype: int64
```

In [12]:
```
print(f'{s2.index  = :}')
print(f'{s2.values = :}')
```

```
s2.index  = Index(['a', 'b', 'c', 'd'], dtype='object')
s2.values = [1 2 3 4]
```

Pandas DataFrame

Pandas DataFrame

- tabular datastructure
- each column a single datatype
- contains both row and column indices
- single column == Series

Pandas DataFrame Cont.

Pandas DataFrame Cont.

In [13]:

```
df = pd.DataFrame({'Year':[2017,2018,2018,2019],
                   'Semester':['Fall','Fall','Spring','Fall'],
                   'Measure_1':[2.1,3.0,2.4,1.9]
                  })
```

Pandas DataFrame Cont.

In [13]:
```
df = pd.DataFrame({'Year':[2017,2018,2018,2019],
                   'Semester':['Fall','Fall','Spring','Fall'],
                   'Measure_1':[2.1,3.0,2.4,1.9]
                  })
```

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

Out[14]:

	Year	Semester	Measure_1
0	2017	Fall	2.1
1	2018	Fall	3.0
2	2018	Spring	2.4
3	2019	Fall	1.9

Pandas DataFrame Cont.

In [13]:
```
df = pd.DataFrame({'Year':[2017,2018,2018,2019],
                   'Semester':['Fall','Fall','Spring','Fall'],
                   'Measure_1':[2.1,3.0,2.4,1.9]
                  })
```

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

Out[14]:

	Year	Semester	Measure_1
0	2017	Fall	2.1
1	2018	Fall	3.0
2	2018	Spring	2.4
3	2019	Fall	1.9

In [15]:
```
print(df)
```

```
   Year Semester  Measure_1
0  2017     Fall        2.1
1  2018     Fall        3.0
2  2018   Spring        2.4
3  2019     Fall        1.9
```

Pandas DataFrame Cont.

In [13]:
```
df = pd.DataFrame({'Year':[2017,2018,2018,2019],
                   'Semester':['Fall','Fall','Spring','Fall'],
                   'Measure_1':[2.1,3.0,2.4,1.9]
                  })
```

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

Out[14]:

	Year	Semester	Measure_1
0	2017	Fall	2.1
1	2018	Fall	3.0
2	2018	Spring	2.4
3	2019	Fall	1.9

In [15]:
```
print(df)
```

```
   Year Semester  Measure_1
0  2017     Fall        2.1
1  2018     Fall        3.0
2  2018   Spring        2.4
3  2019     Fall        1.9
```

In [16]:
```
display(df)
```

	Year	Semester	Measure_1
0	2017	Fall	2.1
1	2018	Fall	3.0
2	2018	Spring	2.4
3	2019	Fall	1.9

Pandas DataFrame Cont.

Pandas DataFrame Cont.

In [17]:

```
data = [[2017,'Fall',2.1],
        [2018,'Fall',3.0],
        [2018,'Spring',2.4],
        [2019,'Fall',1.9]]
```

Pandas DataFrame Cont.

In [17]:
```
data = [[2017,'Fall',2.1],
        [2018,'Fall',3.0],
        [2018,'Spring',2.4],
        [2019,'Fall',1.9]]
```

In [18]:
```
df = pd.DataFrame(data,
                  columns=['Year','Semester','Measure_1'],
                  index=['001','002','003','004'])
df.shape
```

Out[18]:
```
(4, 3)
```

Pandas DataFrame Cont.

In [17]:
```
data = [[2017,'Fall',2.1],
        [2018,'Fall',3.0],
        [2018,'Spring',2.4],
        [2019,'Fall',1.9]]
```

In [18]:
```
df = pd.DataFrame(data,
                  columns=['Year','Semester','Measure_1'],
                  index=['001','002','003','004'])
df.shape
```

Out[18]: (4, 3)

In [19]:
```
df
```

Out[19]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Attributes

Pandas Attributes

- Get shape of DataFrame : `shape`

Pandas Attributes

- Get shape of DataFrame : `shape`

In [20]:
```
1 df.shape # rows, columns
```

Out[20]:
```
(4, 3)
```

Pandas Attributes

- Get shape of DataFrame : `shape`

```
In [20]: 1 df.shape # rows, columns

Out[20]: (4, 3)
```

- Get index values : `index`

Pandas Attributes

- Get shape of DataFrame : `shape`

```
In [20]:
1 df.shape # rows, columns
```

```
Out[20]: (4, 3)
```

- Get index values : `index`

```
In [21]:
1 df.index
```

```
Out[21]: Index(['001', '002', '003', '004'], dtype='object')
```

Pandas Attributes

- Get shape of DataFrame : `shape`

```
In [20]:
1 df.shape # rows, columns
```

```
Out[20]: (4, 3)
```

- Get index values : `index`

```
In [21]:
1 df.index
```

```
Out[21]: Index(['001', '002', '003', '004'], dtype='object')
```

- Get column values : `columns`

Pandas Attributes

- Get shape of DataFrame : `shape`

In [20]:
```
1 df.shape # rows, columns
```

Out[20]:
```
(4, 3)
```

- Get index values : `index`

In [21]:
```
1 df.index
```

Out[21]:
```
Index(['001', '002', '003', '004'], dtype='object')
```

- Get column values : `columns`

In [22]:
```
1 df.columns
```

Out[22]:
```
Index(['Year', 'Semester', 'Measure_1'], dtype='object')
```

Pandas Indexing/Selection

In [23]:
```
1 df
```

Out[23]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Indexing/Selection

In [23]:
```
1 df
```

Out[23]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Select by label:

- `.loc[]`

Pandas Indexing/Selection

In [23]:
```
1 df
```

Out[23]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Select by label:

- `.loc[]`

In [24]:
```
1 df.loc['001']
```

Out[24]:
```
Year          2017
Semester      Fall
Measure_1      2.1
Name: 001, dtype: object
```

Pandas Indexing/Selection

In [23]:
```
1 df
```

Out[23]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Select by label:

- `.loc[]`

In [24]:
```
1 df.loc['001']
```

Out[24]:
```
Year          2017
Semester      Fall
Measure_1      2.1
Name: 001, dtype: object
```

In [25]:
```
1 df.loc['001','Measure_1']
```

Out[25]:
```
2.1
```

Pandas Indexing/Selection Cont.

Pandas Indexing/Selection Cont.

Select by position:

- `.iloc[]`

Pandas Indexing/Selection Cont.

Select by position:

- `.iloc[]`

In [26]:
```
1 df.iloc[0]
```

Out[26]:
```
Year         2017
Semester     Fall
Measure_1     2.1
Name: 001, dtype: object
```

Pandas Indexing/Selection Cont.

Select by position:

- `.iloc[]`

In [26]:
```
1 df.iloc[0]
```

Out[26]:
```
Year         2017
Semester     Fall
Measure_1     2.1
Name: 001, dtype: object
```

In [27]:
```
1 df.iloc[0,2]
```

Out[27]:
```
2.1
```

Pandas Indexing/Selection Cont.

Pandas Indexing/Selection Cont.

Selecting multiple rows/columns: use list (fancy indexing)

In [28]:
```
1 df
```

Out[28]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Indexing/Selection Cont.

Selecting multiple rows/columns: use list (fancy indexing)

In [28]:
```
1 df
```

Out[28]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

In [29]:
```
1 df.loc[['002','004']]
```

Out[29]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
004	2019	Fall	1.9

Pandas Indexing/Selection Cont.

Selecting multiple rows/columns: use list (fancy indexing)

In [28]:
```
1 df
```

Out[28]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

In [29]:
```
1 df.loc[['002','004']]
```

Out[29]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
004	2019	Fall	1.9

In [30]:
```
1 df.loc[['002','004'],['Year','Measure_1']]
```

Out[30]:

	Year	Measure_1
002	2018	3.0
004	2019	1.9

Pandas Slicing

Pandas Slicing

In [31]:
```
# Get last two rows
df.iloc[-2:]
```

Out[31]:

	Year	Semester	Measure_1
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Slicing

In [31]:
```
# Get last two rows
df.iloc[-2:]
```

Out[31]:

	Year	Semester	Measure_1
003	2018	Spring	2.4
004	2019	Fall	1.9

In [32]:
```
# Get first two rows and first two columns
df.iloc[:2,:2]
```

Out[32]:

	Year	Semester
001	2017	Fall
002	2018	Fall

Pandas Slicing

In [31]:
```
# Get last two rows
df.iloc[-2:]
```

Out[31]:

	Year	Semester	Measure_1
003	2018	Spring	2.4
004	2019	Fall	1.9

In [32]:
```
# Get first two rows and first two columns
df.iloc[:2,:2]
```

Out[32]:

	Year	Semester
001	2017	Fall
002	2018	Fall

NOTE: `.iloc` is **exclusive** (start:end+1)

Pandas Slicing Cont.

Pandas Slicing Cont.

Can also slice using labels:

Pandas Slicing Cont.

Can also slice using labels:

In [33]:
```
1 df.loc['002':'004']
```

Out[33]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Slicing Cont.

Can also slice using labels:

In [33]:
```
1 df.loc['002':'004']
```

Out[33]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

In [34]:
```
1 df.loc['002':'004',:'Measure_1']
```

Out[34]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Slicing Cont.

Can also slice using labels:

In [33]:
```
1 df.loc['002':'004']
```

Out[33]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

In [34]:
```
1 df.loc['002':'004',:'Measure_1']
```

Out[34]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

NOTE: `.loc` is **inclusive**

Pandas Slicing Cont.

Pandas Slicing Cont.

How to indicate all rows or all columns? `:`

Pandas Slicing Cont.

How to indicate all rows or all columns? `:`

In [35]:
```
1 df.loc[:,'Measure_1']
```

Out[35]:
```
001    2.1
002    3.0
003    2.4
004    1.9
Name: Measure_1, dtype: float64
```

Pandas Slicing Cont.

How to indicate all rows or all columns? `:`

In [35]:
```
1 df.loc[:,'Measure_1']
```

Out[35]:
```
001    2.1
002    3.0
003    2.4
004    1.9
Name: Measure_1, dtype: float64
```

In [36]:
```
1 df.iloc[2:,:]
```

Out[36]:

	Year	Semester	Measure_1
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Indexing Cont.

Pandas Indexing Cont.

Shortcut for indexing:

Pandas Indexing Cont.

Shortcut for indexing:

In [37]:
```
1 df['Semester']
```

Out[37]:
```
001      Fall
002      Fall
003    Spring
004      Fall
Name: Semester, dtype: object
```

Pandas Indexing Cont.

Shortcut for indexing:

In [37]:
```
df['Semester']
```

Out[37]:
```
001      Fall
002      Fall
003    Spring
004      Fall
Name: Semester, dtype: object
```

In [38]:
```
# can use dot notation if there is no space in label
df.Semester
```

Out[38]:
```
001      Fall
002      Fall
003    Spring
004      Fall
Name: Semester, dtype: object
```

Panda Selection Chaining

Panda Selection Chaining

Get 'Year' and 'Measure_1' for first 3 rows:

Panda Selection Chaining

Get 'Year' and 'Measure_1' for first 3 rows:

In [39]:
```
1 df.iloc[:3].loc[:,['Year','Measure_1']]
```

Out[39]:

	Year	Measure_1
001	2017	2.1
002	2018	3.0
003	2018	2.4

Panda Selection Chaining

Get 'Year' and 'Measure_1' for first 3 rows:

In [39]:
```
1 df.iloc[:3].loc[:,['Year','Measure_1']]
```

Out[39]:

	Year	Measure_1
001	2017	2.1
002	2018	3.0
003	2018	2.4

For records '001' and '003' get last two columns

Panda Selection Chaining

Get 'Year' and 'Measure_1' for first 3 rows:

In [39]:
```
df.iloc[:3].loc[:,['Year','Measure_1']]
```

Out[39]:

	Year	Measure_1
001	2017	2.1
002	2018	3.0
003	2018	2.4

For records '001' and '003' get last two columns

In [40]:
```
df.loc[['001','003']].iloc[:,-2:]
```

Out[40]:

	Semester	Measure_1
001	Fall	2.1
003	Spring	2.4

Pandas Selection Chaining Cont.

Pandas Selection Chaining Cont.

For record '002' get last two columns?:

Pandas Selection Chaining Cont.

For record '002' get last two columns?:

In [41]:
```
# reduce the amount of error information printed
%xmode Minimal
```

```
Exception reporting mode: Minimal
```

Pandas Selection Chaining Cont.

For record '002' get last two columns?:

In [41]:
```
# reduce the amount of error information printed
%xmode Minimal
```

```
Exception reporting mode: Minimal
```

In [42]:
```
# Note: add 'raises-exception' tag to cell to continue running after exception

df.loc['002'].iloc[:,-2:] # row with label '002', then all rows, last two columns?
```

```
IndexingError: Too many indexers
```

Pandas Selection Chaining Cont.

For record '002' get last two columns?:

In [41]:
```
# reduce the amount of error information printed
%xmode Minimal
```

```
Exception reporting mode: Minimal
```

In [42]:
```
# Note: add 'raises-exception' tag to cell to continue running after exception

df.loc['002'].iloc[:,-2:] # row with label '002', then all rows, last two columns?
```

```
IndexingError: Too many indexers
```

In [43]:
```
df.loc['002'].iloc[:-1] # row with label '002', last two elements of Series
```

Out[43]:
```
Year        2018
Semester    Fall
Name: 002, dtype: object
```

Pandas `head` and `tail`

Pandas `head` and `tail`

Get a quick view of the first or last rows in a DataFrame

Pandas `head` and `tail`

Get a quick view of the first or last rows in a DataFrame

In [44]:
```
1 df.head() # first 5 rows by default
```

Out[44]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas `head` and `tail`

Get a quick view of the first or last rows in a DataFrame

In [44]:
```
1 df.head() # first 5 rows by default
```

Out[44]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
003	2018	Spring	2.4
004	2019	Fall	1.9

In [45]:
```
1 df.tail(2) # only print last 2 rows
```

Out[45]:

	Year	Semester	Measure_1
003	2018	Spring	2.4
004	2019	Fall	1.9

Pandas Boolean Mask

Pandas Boolean Mask

In [46]:
```
# Which rows have Semester of 'Fall'?
df.loc[:,'Semester'] == 'Fall'
```

Out[46]:
```
001     True
002     True
003    False
004     True
Name: Semester, dtype: bool
```

Pandas Boolean Mask

In [46]:
```
# Which rows have Semester of 'Fall'?
df.loc[:,'Semester'] == 'Fall'
```

Out[46]:
```
001     True
002     True
003    False
004     True
Name: Semester, dtype: bool
```

In [47]:
```
# Get all data for rows with with Semester 'Fall'
df[df['Semester'] == 'Fall']
```

Out[47]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
004	2019	Fall	1.9

Pandas Boolean Mask

In [46]:
```
# Which rows have Semester of 'Fall'?
df.loc[:,'Semester'] == 'Fall'
```

Out[46]:
```
001     True
002     True
003    False
004     True
Name: Semester, dtype: bool
```

In [47]:
```
# Get all data for rows with with Semester 'Fall'
df[df['Semester'] == 'Fall']
```

Out[47]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0
004	2019	Fall	1.9

In [48]:
```
# Get Measure_1 for all records for Semester 'Fall'
df.loc[df.Semester == 'Fall','Measure_1']
```

Out[48]:
```
001    2.1
002    3.0
004    1.9
Name: Measure_1, dtype: float64
```

Pandas Boolean Mask Cont.

Pandas Boolean Mask Cont.

Get all records Fall Semester prior to 2019

In [49]:
```
1 df.loc[df.Semester =='Fall'].loc[df.Year<2019]
```

Out[49]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0

Pandas Boolean Mask Cont.

Get all records Fall Semester prior to 2019

In [49]:
```
df.loc[df.Semester =='Fall'].loc[df.Year<2019]
```

Out[49]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0

In [50]:
```
# make sure to use parentheses with comparisons!
df.loc[(df.Semester == 'Fall') & (df.Year < 2019) ]
```

Out[50]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0

Pandas Boolean Mask Cont.

Get all records Fall Semester prior to 2019

In [49]:
```
df.loc[df.Semester =='Fall'].loc[df.Year<2019]
```

Out[49]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0

In [50]:
```
# make sure to use parentheses with comparisons!
df.loc[(df.Semester == 'Fall') & (df.Year < 2019) ]
```

Out[50]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0

In [51]:
```
# or use comparison functions: .eq, .ne, .gt, .ge, .lt, .le
df.loc[df.Semester.eq('Fall') & df.Year.lt(2019)]
```

Out[51]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
002	2018	Fall	3.0

Pandas Boolean Mask Cont.

Pandas Boolean Mask Cont.

Get all records belonging to a set with `.isin`:

Pandas Boolean Mask Cont.

Get all records belonging to a set with `.isin`:

In [52]:
```
1 df.loc[df.Year.isin([2017,2019])]
```

Out[52]:

	Year	Semester	Measure_1
001	2017	Fall	2.1
004	2019	Fall	1.9

Pandas Selection Review

Pandas Selection Review

- `.loc[]`
- `.iloc[]`
- Fancy Indexing
- Slicing
- Chaining
- `head` and `tail`
- Boolean Mask
- `.isin`

Pandas Sorting

Pandas Sorting

In [53]:
```
1 df.sort_values(by=['Measure_1']).head(3)
```

Out[53]:

	Year	Semester	Measure_1
004	2019	Fall	1.9
001	2017	Fall	2.1
003	2018	Spring	2.4

Pandas Sorting

In [53]:
```
1 df.sort_values(by=['Measure_1']).head(3)
```

Out[53]:

	Year	Semester	Measure_1
004	2019	Fall	1.9
001	2017	Fall	2.1
003	2018	Spring	2.4

In [54]:
```
1 df.sort_values(by=['Measure_1'],ascending=False).head(3)
```

Out[54]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
001	2017	Fall	2.1

Pandas Sorting

In [53]:
```
1 df.sort_values(by=['Measure_1']).head(3)
```

Out[53]:

	Year	Semester	Measure_1
004	2019	Fall	1.9
001	2017	Fall	2.1
003	2018	Spring	2.4

In [54]:
```
1 df.sort_values(by=['Measure_1'],ascending=False).head(3)
```

Out[54]:

	Year	Semester	Measure_1
002	2018	Fall	3.0
003	2018	Spring	2.4
001	2017	Fall	2.1

In [55]:
```
1 df.sort_values(by=['Semester','Measure_1'], ascending=False).head(3)
```

Out[55]:

	Year	Semester	Measure_1
003	2018	Spring	2.4
002	2018	Fall	3.0
001	2017	Fall	2.1

Questions?

Exploratory Data Analysis

Exploratory Data Analysis

For a new set of data, would like to know:

- amount of data (rows, columns)
- range (min, max)
- counts of discrete values
- central tendencies (mean, median)
- dispersion or spread (variance, IQR)
- skew
- covariance and correlation ...

Yellowcab Dataset

- Records of Yellowcab Taxi trips from January 2017
- more info: https://www1.nyc.gov/site/tlc/about/tlc-trip-record-data.page

Loading Datasets from CSV (Comma Separated Values)

- columns separated by delimiter, eg. comma, tab (\t), pipe (|)
- one row per record, observation
- often, strings quoted
- often, first row contains column headings
- often, comment rows starting with #

Loading Datasets from CSV (Comma Separated Values)

- columns separated by delimiter, eg. comma, tab (\t), pipe (|)
- one row per record, observation
- often, strings quoted
- often, first row contains column headings
- often, comment rows starting with #

In [56]:
```
!head ../data/yellowcab_demo_withdaycategories.csv
```

```
# A sample of yellocab taxi trip data from Jan 2017
pickup_datetime,dropoff_datetime,trip_distance,fare_amount,tip_amount,payment_type,day_of_week,is_weekend
2017-01-05 14:49:04,2017-01-05 14:53:53,0.89,5.5,1.26,Credit card,3,False
2017-01-15 01:07:22,2017-01-15 01:26:47,2.7,14.0,0.0,Cash,6,True
2017-01-29 09:55:00,2017-01-29 10:04:43,1.41,8.0,0.0,Cash,6,True
2017-01-10 05:40:12,2017-01-10 05:42:22,0.4,4.0,0.0,Cash,1,False
2017-01-06 17:02:48,2017-01-06 17:16:10,2.3,11.0,0.0,Cash,4,False
2017-01-14 19:03:14,2017-01-14 19:08:41,0.8,5.5,,Credit card,5,False
2017-01-06 18:51:52,2017-01-06 18:55:45,0.2,4.5,0.0,Cash,4,False
2017-01-04 20:47:30,2017-01-04 21:01:24,2.68,11.5,,Credit card,2,False
```

Loading Datasets with Pandas

Loading Datasets with Pandas

In [57]:

```
import pandas as pd
df_taxi = (
    pd.read_csv('../data/yellowcab_demo_withdaycategories.csv',
                sep=',',
                header=1,
                parse_dates= ['pickup_datetime','dropoff_datetime'],
               )
)
```

Loading Datasets with Pandas

In [57]:
```
import pandas as pd
df_taxi = (
    pd.read_csv('../data/yellowcab_demo_withdaycategories.csv',
                sep=',',
                header=1,
                parse_dates= ['pickup_datetime','dropoff_datetime'],
               )
)
```

In [58]:
```
# display first 5 rows
df_taxi.head(5)
```

Out[58]:

	pickup_datetime	dropoff_datetime	trip_distance	fare_amount	tip_amount	payment_type	day_of_week	is_weekend
0	2017-01-05 14:49:04	2017-01-05 14:53:53	0.89	5.5	1.26	Credit card	3	False
1	2017-01-15 01:07:22	2017-01-15 01:26:47	2.70	14.0	0.00	Cash	6	True
2	2017-01-29 09:55:00	2017-01-29 10:04:43	1.41	8.0	0.00	Cash	6	True
3	2017-01-10 05:40:12	2017-01-10 05:42:22	0.40	4.0	0.00	Cash	1	False
4	2017-01-06 17:02:48	2017-01-06 17:16:10	2.30	11.0	0.00	Cash	4	False

Get Size of Dataset

Get Size of Dataset

In [59]:
```
1 df_taxi.shape
```

Out[59]: (1000, 8)

Get Size of Dataset

In [59]:
```
1 df_taxi.shape
```

Out[59]: (1000, 8)

In [60]:
```
1 # number of rows
2 f'{df_taxi.shape[0]} rows'
```

Out[60]: '1000 rows'

Get Size of Dataset

In [59]:
```
df_taxi.shape
```

Out[59]:
```
(1000, 8)
```

In [60]:
```
# number of rows
f'{df_taxi.shape[0]} rows'
```

Out[60]:
```
'1000 rows'
```

In [61]:
```
# number of columns
f'{df_taxi.shape[1]} columns'
```

Out[61]:
```
'8 columns'
```

Get Size of Dataset

In [59]:
```
df_taxi.shape
```

Out[59]:
```
(1000, 8)
```

In [60]:
```
# number of rows
f'{df_taxi.shape[0]} rows'
```

Out[60]:
```
'1000 rows'
```

In [61]:
```
# number of columns
f'{df_taxi.shape[1]} columns'
```

Out[61]:
```
'8 columns'
```

In [62]:
```
'number of rows: {}, number of columns: {}'.format(*df_taxi.shape)
```

Out[62]:
```
'number of rows: 1000, number of columns: 8'
```

Aside: Argument Unpacking with `*`

Aside: Argument Unpacking with `*`

- `*` in when calling a function unpacks an iterable, passing each value as an argument
- want `format(2,8)` instead of the `format((2,8))`

Aside: Argument Unpacking with `*`

- `*` in when calling a function unpacks an iterable, passing each value as an argument
- want `format(2,8)` instead of the `format((2,8))`

In [63]:
```
print(*df_taxi.shape)
```

```
1000 8
```

Aside: Argument Unpacking with `*`

- `*` in when calling a function unpacks an iterable, passing each value as an argument
- want `format(2,8)` instead of the `format((2,8))`

In [63]:
```
print(*df_taxi.shape)
```

```
1000 8
```

In [64]:
```
# call .format( (2,8) )
'number of rows: {}, number of columns: {}'.format(df_taxi.shape)
```

```
IndexError: Replacement index 1 out of range for positional args tuple
```

Aside: Argument Unpacking with `*`

- `*` in when calling a function unpacks an iterable, passing each value as an argument
- want `format(2,8)` instead of the `format((2,8))`

In [63]:
```
print(*df_taxi.shape)
```

```
1000 8
```

In [64]:
```
# call .format( (2,8) )
'number of rows: {}, number of columns: {}'.format(df_taxi.shape)
```

```
IndexError: Replacement index 1 out of range for positional args tuple
```

In [65]:
```
# call .format(2,8)
'number of rows: {}, number of columns: {}'.format(*df_taxi.shape)
```

Out[65]:
```
'number of rows: 1000, number of columns: 8'
```

What are the column names?

What are the column names?

In [66]:
```
1 df_taxi.columns
```

Out[66]:
```
Index(['pickup_datetime', 'dropoff_datetime', 'trip_distance', 'fare_amount',
       'tip_amount', 'payment_type', 'day_of_week', 'is_weekend'],
      dtype='object')
```

What are the column names?

In [66]:
```
1 df_taxi.columns
```

Out[66]:
```
Index(['pickup_datetime', 'dropoff_datetime', 'trip_distance', 'fare_amount',
       'tip_amount', 'payment_type', 'day_of_week', 'is_weekend'],
      dtype='object')
```

In [67]:
```
1 # columns as numpy array
2 df_taxi.columns.values
```

Out[67]:
```
array(['pickup_datetime', 'dropoff_datetime', 'trip_distance',
       'fare_amount', 'tip_amount', 'payment_type', 'day_of_week',
       'is_weekend'], dtype=object)
```

What are the column names?

In [66]:
```
1 df_taxi.columns
```

Out[66]:
```
Index(['pickup_datetime', 'dropoff_datetime', 'trip_distance', 'fare_amount',
       'tip_amount', 'payment_type', 'day_of_week', 'is_weekend'],
      dtype='object')
```

In [67]:
```
1 # columns as numpy array
2 df_taxi.columns.values
```

Out[67]:
```
array(['pickup_datetime', 'dropoff_datetime', 'trip_distance',
       'fare_amount', 'tip_amount', 'payment_type', 'day_of_week',
       'is_weekend'], dtype=object)
```

In [68]:
```
1 # columns as list
2 df_taxi.columns.tolist()
```

Out[68]:
```
['pickup_datetime',
 'dropoff_datetime',
 'trip_distance',
 'fare_amount',
 'tip_amount',
 'payment_type',
 'day_of_week',
 'is_weekend']
```

What are the column datatypes?

What are the column datatypes?

In [69]:
```
1 df_taxi.dtypes
```

Out[69]:
```
pickup_datetime     datetime64[ns]
dropoff_datetime    datetime64[ns]
trip_distance              float64
fare_amount                float64
tip_amount                 float64
payment_type                object
day_of_week                  int64
is_weekend                    bool
dtype: object
```

What are the column datatypes?

In [69]:
```
1 df_taxi.dtypes
```

Out[69]:
```
pickup_datetime     datetime64[ns]
dropoff_datetime    datetime64[ns]
trip_distance              float64
fare_amount                float64
tip_amount                 float64
payment_type                object
day_of_week                  int64
is_weekend                    bool
dtype: object
```

In [70]:
```
1 type(df_taxi.dtypes)
```

Out[70]:
```
pandas.core.series.Series
```

Get Summary Info for DataFrame

Get Summary Info for DataFrame

In [71]:
```
1 df_taxi.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   pickup_datetime   1000 non-null   datetime64[ns]
 1   dropoff_datetime  1000 non-null   datetime64[ns]
 2   trip_distance     1000 non-null   float64
 3   fare_amount       1000 non-null   float64
 4   tip_amount        910 non-null    float64
 5   payment_type      1000 non-null   object
 6   day_of_week       1000 non-null   int64
 7   is_weekend        1000 non-null   bool
dtypes: bool(1), datetime64[ns](2), float64(3), int64(1), object(1)
memory usage: 55.8+ KB
```

Get Summary Info for DataFrame

In [71]:
```
1 df_taxi.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000 entries, 0 to 999
Data columns (total 8 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   pickup_datetime   1000 non-null   datetime64[ns]
 1   dropoff_datetime  1000 non-null   datetime64[ns]
 2   trip_distance     1000 non-null   float64
 3   fare_amount       1000 non-null   float64
 4   tip_amount        910 non-null    float64
 5   payment_type      1000 non-null   object
 6   day_of_week       1000 non-null   int64
 7   is_weekend        1000 non-null   bool
dtypes: bool(1), datetime64[ns](2), float64(3), int64(1), object(1)
memory usage: 55.8+ KB
```

- number of rows
- number of columns
- column names, number of filled values, datatypes
- number of each datatype seen
- size of dataset in memory

Variable (Observation) Types

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- **Numeric** (eg. weight, temperature)
    - usually has a zero value
    - describes magnitude

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- **Numeric** (eg. weight, temperature)
    - usually has a zero value
    - describes magnitude

- **Categorical** (eg. class, variety)
    - usually a finite set
    - no order

Variable (Observation) Types

- **Numeric** (eg. weight, temperature)
    - usually has a zero value
    - describes magnitude

- **Categorical** (eg. class, variety)
    - usually a finite set
    - no order

- **Ordinal** (eg. Like scale, education level, etc.)
    - usually a finite set
    - has order
    - usually missing zero
    - difference between levels may not be the same

Numeric: Data Ranges

Numeric: Data Ranges

In [72]:
```
1 df_taxi.trip_distance.min()
```

Out[72]:
```
0.0
```

Numeric: Data Ranges

In [72]:
```
1 df_taxi.trip_distance.min()
```

Out[72]: 0.0

In [73]:
```
1 df_taxi.trip_distance.max()
```

Out[73]: 32.77

Numeric: Data Ranges

In [72]:
```
1 df_taxi.trip_distance.min()
```

Out[72]:
```
0.0
```

In [73]:
```
1 df_taxi.trip_distance.max()
```

Out[73]:
```
32.77
```

In [74]:
```
1 df_taxi.min(numeric_only=True)
```

Out[74]:
```
trip_distance      0.0
fare_amount        2.5
tip_amount         0.0
day_of_week          0
is_weekend       False
dtype: object
```

Numeric: Central Tendency with Mean

Numeric: Central Tendency with Mean

- Sample Mean

$$\bar{x} = \frac{1}{n} \sum x_i$$

Numeric: Central Tendency with Mean

- Sample Mean

$$\bar{x} = \frac{1}{n} \sum x_i$$

```
In [75]: 1 df_taxi.fare_amount.mean()

Out[75]: 12.4426
```

Numeric: Central Tendency with Mean

- Sample Mean

$$\bar{x} = \frac{1}{n} \sum x_i$$

In [75]:
```
1 df_taxi.fare_amount.mean()
```

Out[75]:
```
12.4426
```

In [76]:
```
1 print(f'{df_taxi.fare_amount.mean() = :0.2f}')
```

```
df_taxi.fare_amount.mean() = 12.44
```

Numeric: Central Tendency with Mean

- Sample Mean

$$\bar{x} = \frac{1}{n} \sum x_i$$

```
In [75]: 1 df_taxi.fare_amount.mean()

Out[75]: 12.4426
```

```
In [76]: 1 print(f'{df_taxi.fare_amount.mean() = :0.2f}')

         df_taxi.fare_amount.mean() = 12.44
```

- Mean is sensitive to *outliers*
- **Outlier:** a data point that differs significantly from other observations
  - data error
  - effect of heavy tailed distribution?

Numeric: Central Tendency with Median

Numeric: Central Tendency with Median

- Median
    - Divides sorted dataset into two equal sizes
    - 50% of the data is less than or equal to the median

Numeric: Central Tendency with Median

- Median
  - Divides sorted dataset into two equal sizes
  - 50% of the data is less than or equal to the median

```
In [77]: 1 df_taxi.fare_amount.median()

Out[77]: 9.0
```

Numeric: Central Tendency with Median

- Median
    - Divides sorted dataset into two equal sizes
    - 50% of the data is less than or equal to the median

```
In [77]: 1 df_taxi.fare_amount.median()

Out[77]: 9.0
```

- Median is *robust* to outliers
- **Robust:** Not affected by outliers

Numeric: Quantiles/Percentiles

Numeric: Quantiles/Percentiles

- **Quantile:** cut point for splitting distribution
- **Percentile:** $x\%$ of data is less than or equal to the xth percentile

Numeric: Quantiles/Percentiles

- **Quantile:** cut point for splitting distribution
- **Percentile:** $x\%$ of data is less than or equal to the xth percentile

In [78]:
```
1 df_taxi['fare_amount'].quantile(.95, interpolation='linear') # 95% of the data is less than or equal to x
```

Out[78]: 33.5

Numeric: Quantiles/Percentiles

- **Quantile:** cut point for splitting distribution
- **Percentile:** $x\%$ of data is less than or equal to the xth percentile

In [78]:
```
1 df_taxi['fare_amount'].quantile(.95, interpolation='linear') # 95% of the data is less than or equal to x
```

Out[78]:
```
33.5
```

In [79]:
```
1 df_taxi.fare_amount.quantile([.05,.95], interpolation='linear') # 90% of the data is between 4 and 33.5
```

Out[79]:
```
0.05     4.0
0.95    33.5
Name: fare_amount, dtype: float64
```

Numeric: Quantiles/Percentiles

- **Quantile:** cut point for splitting distribution
- **Percentile:** $x\%$ of data is less than or equal to the xth percentile

In [78]:
```
df_taxi['fare_amount'].quantile(.95, interpolation='linear') # 95% of the data is less than or equal to x
```

Out[78]:
```
33.5
```

In [79]:
```
df_taxi.fare_amount.quantile([.05,.95], interpolation='linear') # 90% of the data is between 4 and 33.5
```

Out[79]:
```
0.05     4.0
0.95    33.5
Name: fare_amount, dtype: float64
```

In [80]:
```
df_taxi.fare_amount.quantile([0,.25,.5,.75,1]) # Quartiles: 25% of data is between each pair
```

Out[80]:
```
0.00     2.5
0.25     6.5
0.50     9.0
0.75    14.0
1.00    88.0
Name: fare_amount, dtype: float64
```

Numeric: Spread with Variance

Numeric: Spread with Variance

- Sample Variance

$$s^2 = \frac{\sum(x-\bar{x})^2}{n-1}$$

Numeric: Spread with Variance

- Sample Variance

$$s^2 = \frac{\sum(x-\bar{x})^2}{n-1}$$

```
In [81]: 1 round(df_taxi.fare_amount.var(),3)

Out[81]: 116.809
```

Numeric: Spread with Variance

- Sample Variance

$$s^2 = \frac{\sum(x-\bar{x})^2}{n-1}$$

```
In [81]: 1 round(df_taxi.fare_amount.var(),3)

Out[81]: 116.809
```

but this is in dollars^2!

Numeric: Spread with Standard Deviation

Numeric: Spread with Standard Deviation

- Sample Standard Deviation

$$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

Numeric: Spread with Standard Deviation

- Sample Standard Deviation

$$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

```
In [82]: 1 round(df_taxi.fare_amount.std(),3)

Out[82]: 10.808
```

Numeric: Spread with Standard Deviation

- Sample Standard Deviation

$$s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

```
In [82]: 1 round(df_taxi.fare_amount.std(),3)

Out[82]: 10.808
```

- Back in original scale of dollars
- Sensitive to outliers

Numeric: Exploring Spread with IQR

Numeric: Exploring Spread with IQR

- Quartiles
    - ~25% of data is ≤ first quartile, 25th percentile
    - ~50% of data is ≤ second quartile, 50th percentile (Median)
    - ~75% of data is ≤ third quartile, 75th percentile

Numeric: Exploring Spread with IQR

- Quartiles
    - ~25% of data is ≤ first quartile, 25th percentile
    - ~50% of data is ≤ second quartile, 50th percentile (Median)
    - ~75% of data is ≤ third quartile, 75th percentile

- Can find quartiles with: pandas quantile or numpy percentile

Numeric: Exploring Spread with IQR

- Quartiles
    - ~25% of data is ≤ first quartile, 25th percentile
    - ~50% of data is ≤ second quartile, 50th percentile (Median)
    - ~75% of data is ≤ third quartile, 75th percentile

- Can find quartiles with: pandas quantile or numpy percentile

- **Interquartile Range (IQR)**
    - (third quartile - first quartile) or (75th percentile - 25th percentile)

Numeric: Exploring Spread with IQR

- Quartiles
    - ~25% of data is ≤ first quartile, 25th percentile
    - ~50% of data is ≤ second quartile, 50th percentile (Median)
    - ~75% of data is ≤ third quartile, 75th percentile

- Can find quartiles with: pandas quantile or numpy percentile

- **Interquartile Range (IQR)**
    - (third quartile - first quartile) or (75th percentile - 25th percentile)

```
In [83]: 1 df_taxi.fare_amount.quantile(.75) - df_taxi.fare_amount.quantile(.25)

Out[83]: 7.5
```

Numeric: Exploring Spread with IQR

- Quartiles
    - ~25% of data is ≤ first quartile, 25th percentile
    - ~50% of data is ≤ second quartile, 50th percentile (Median)
    - ~75% of data is ≤ third quartile, 75th percentile

- Can find quartiles with: pandas quantile or numpy percentile

- **Interquartile Range (IQR)**
    - (third quartile - first quartile) or (75th percentile - 25th percentile)

```
In [83]: 1 df_taxi.fare_amount.quantile(.75) - df_taxi.fare_amount.quantile(.25)

Out[83]: 7.5
```

- IQR is robust to outliers

Numeric: Exploring Distribution with Skew

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- **Skewness**
  - measures assymetry of distribution around mean
  - indicates tail to left (neg) or right (pos)
  - skew will lead to difference between median and mean

Numeric: Exploring Distribution with Skew

- **Skewness**
  - measures assymetry of distribution around mean
  - indicates tail to left (neg) or right (pos)
  - skew will lead to difference between median and mean

In [84]:
```
1 df_taxi.fare_amount.skew()
```

Out[84]:
```
2.882730031010152
```

Numeric: Exploring Distribution with Skew

- **Skewness**
  - measures assymetry of distribution around mean
  - indicates tail to left (neg) or right (pos)
  - skew will lead to difference between median and mean

```
In [84]: 1 df_taxi.fare_amount.skew()

Out[84]: 2.882730031010152
```

Easier to understand with a plot (histogram/boxplot)...

Numeric Summary Stats with `.describe`

Numeric Summary Stats with `.describe`

In [85]:
```
1 df_taxi.describe()
```

Out[85]:

	trip_distance	fare_amount	tip_amount	day_of_week
count	1000.000000	1000.000000	910.000000	1000.000000
mean	2.880010	12.442600	1.766275	2.987000
std	3.678534	10.807802	2.315507	2.043773
min	0.000000	2.500000	0.000000	0.000000
25%	0.950000	6.500000	0.000000	1.000000
50%	1.565000	9.000000	1.350000	3.000000
75%	3.100000	14.000000	2.460000	5.000000
max	32.770000	88.000000	22.700000	6.000000

Numeric Summary Stats with `.describe`

In [85]:
```
1 df_taxi.describe()
```

Out[85]:

	trip_distance	fare_amount	tip_amount	day_of_week
count	1000.000000	1000.000000	910.000000	1000.000000
mean	2.880010	12.442600	1.766275	2.987000
std	3.678534	10.807802	2.315507	2.043773
min	0.000000	2.500000	0.000000	0.000000
25%	0.950000	6.500000	0.000000	1.000000
50%	1.565000	9.000000	1.350000	3.000000
75%	3.100000	14.000000	2.460000	5.000000
max	32.770000	88.000000	22.700000	6.000000

In [86]:
```
1 df_taxi.describe().round(2) # reduce precision with round
```

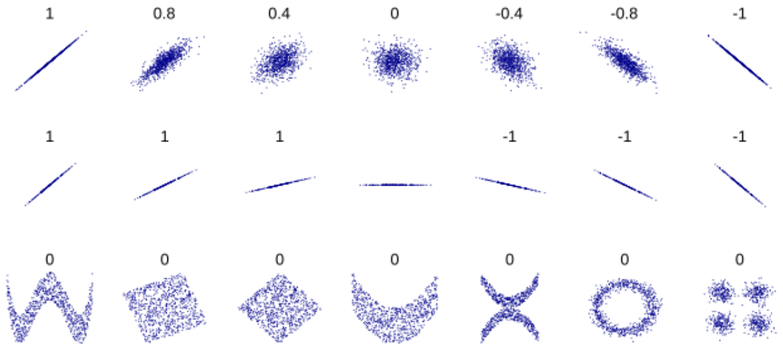
Out[86]:

	trip_distance	fare_amount	tip_amount	day_of_week
count	1000.00	1000.00	910.00	1000.00
mean	2.88	12.44	1.77	2.99
std	3.68	10.81	2.32	2.04
min	0.00	2.50	0.00	0.00
25%	0.95	6.50	0.00	1.00
50%	1.56	9.00	1.35	3.00
75%	3.10	14.00	2.46	5.00
max	32.77	88.00	22.70	6.00

Bivariate: Evaluating Correlation

Bivariate: Evaluating Correlation

- **Correlation:** the degree to which two variables are linearly related
- Pearson Correlation Coefficient: $\rho_{XY} = \frac{cov(X,Y)}{\sigma_X \sigma_Y}$
- Sample Correlation: $r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y}$
- Takes values between:
    - -1 (highly negatively correlated)
    - 0 (not correlated)
    - 1 (highly positively correlated)



Calculating Correlation

Calculating Correlation

In [87]:
```
1 df_taxi.trip_distance.corr(df_taxi.fare_amount).round(2)
```

Out[87]: 0.95

Calculating Correlation

In [87]:
```
1 df_taxi.trip_distance.corr(df_taxi.fare_amount).round(2)
```

Out[87]:
```
0.95
```

In [88]:
```
1 from scipy.stats import pearsonr
2 r,p = pearsonr(df_taxi.trip_distance, df_taxi.fare_amount)
3 print(f"{r = :.2f}, {p = :.2f}")
```

```
r = 0.95, p = 0.00
```

Counting Categorical Values with `.value_counts()`

Counting Categorical Values with `.value_counts()`

In [89]:
```
1 df_taxi.payment_type.value_counts()
```

Out[89]:
```
Credit card    663
Cash           335
No charge        2
Name: payment_type, dtype: int64
```

Counting Categorical Values with `.value_counts()`

In [89]:
```
1 df_taxi.payment_type.value_counts()
```

Out[89]:
```
Credit card    663
Cash           335
No charge        2
Name: payment_type, dtype: int64
```

In [90]:
```
1 df_taxi.payment_type.value_counts(normalize=True)
```

Out[90]:
```
Credit card    0.663
Cash           0.335
No charge      0.002
Name: payment_type, dtype: float64
```

Counting Categorical Values with `.value_counts()`

In [89]:
```
1 df_taxi.payment_type.value_counts()
```

Out[89]:
```
Credit card    663
Cash           335
No charge        2
Name: payment_type, dtype: int64
```

In [90]:
```
1 df_taxi.payment_type.value_counts(normalize=True)
```

Out[90]:
```
Credit card    0.663
Cash           0.335
No charge      0.002
Name: payment_type, dtype: float64
```

In [91]:
```
1 tmp = pd.DataFrame()
2 tmp['count'] = df_taxi.payment_type.value_counts()
3 tmp['prop'] = df_taxi.payment_type.value_counts(normalize=True)
4 tmp.round(2)
```

Out[91]:

	count	prop
Credit card	663	0.66
Cash	335	0.34
No charge	2	0.00

Applying Functions to Groups of Data

Applying Functions to Groups of Data

In [92]:
```
1 df_taxi.groupby('payment_type')
```

Out[92]:
```
<pandas.core.groupby.generic.DataFrameGroupBy object at 0x7fc19b95e3a0>
```

Applying Functions to Groups of Data

In [92]:
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1 df_taxi.groupby('payment_type')
```

Out[92]:
```
<pandas.core.groupby.generic.DataFrameGroupBy object at 0x7fc19b95e3a0>
```

In [93]:
```
1 df_taxi.groupby('payment_type').mean()
```

```
/var/folders/78/vhnqkq8n45dd4gj4f5qx8yb00000gn/T/ipykernel_9996/2464981742.py:1: FutureWarning: The default value of numeric_on
ly in DataFrameGroupBy.mean is deprecated. In a future version, numeric_only will default to False. Either specify numeric_only
or select only columns which should be valid for the function.
  df_taxi.groupby('payment_type').mean()
```

Out[93]:

	trip_distance	fare_amount	tip_amount	day_of_week	is_weekend
payment_type					
Cash	2.732209	11.856716	0.000000	2.898507	0.152239
Credit card	2.961870	12.761086	2.683322	3.039216	0.149321
No charge	0.500000	5.000000	0.000000	0.500000	0.000000

In [94]:
```
1 df_taxi.trip_distance
```

Out[94]:
```
0       0.89
1       2.70
2       1.41
3       0.40
4       2.30
       ...
995     6.50
996     0.36
997     2.80
998     0.79
999     5.90
Name: trip_distance, Length: 1000, dtype: float64
```

Applying Functions to Groups of Data

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Out[92]:
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<pandas.core.groupby.generic.DataFrameGroupBy object at 0x7fc19b95e3a0>
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```

In [95]:
```
1 # applying multiple aggregation functions
```

Applying Functions to Groups of Data

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1 df_taxi.groupby('payment_type')
```

Out[92]:
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<pandas.core.groupby.generic.DataFrameGroupBy object at 0x7fc19b95e3a0>
```

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```
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```
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or select only columns which should be valid for the function.
  df_taxi.groupby('payment_type').mean()
```

Out[93]:

	trip_distance	fare_amount	tip_amount	day_of_week	is_weekend
payment_type					
Cash	2.732209	11.856716	0.000000	2.898507	0.152239
Credit card	2.961870	12.761086	2.683322	3.039216	0.149321
No charge	0.500000	5.000000	0.000000	0.500000	0.000000

In [94]:
```
1 df_taxi.trip_distance
```

Out[94]:
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0       0.89
1       2.70
2       1.41
3       0.40
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       ...
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997     2.80
998     0.79
999     5.90
Name: trip_distance, Length: 1000, dtype: float64
```

In [95]:
```
1 # applying multiple aggregation functions
```

Aside: Dealing with long chains

- long chains may not be visible in notebooks

Aside: Dealing with long chains

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In [97]:

```
# df_taxi[df_taxi.payment_type.isin(['Cash','Credit card'])].groupby(['payment_type','is_weekend']).trip_distance.agg(['mean','
# use backslashes
df_taxi.loc[df_taxi.payment_type.isin(['Cash'])]\
    .groupby(['payment_type','is_weekend'])\
    .trip_distance.agg(['mean','median'])
```

Out[97]:

		mean	median
payment_type	is_weekend		
Cash	False	2.593063	1.28
	True	3.507059	2.10

Aside: Dealing with long chains

- long chains may not be visible in notebooks

In [97]:
```
# df_taxi[df_taxi.payment_type.isin(['Cash','Credit card'])].groupby(['payment_type','is_weekend']).trip_distance.agg(['mean','
# use backslashes
df_taxi.loc[df_taxi.payment_type.isin(['Cash'])]\
    .groupby(['payment_type','is_weekend'])\
    .trip_distance.agg(['mean','median'])
```

Out[97]:

		mean	median
payment_type	is_weekend		
Cash	False	2.593063	1.28
	True	3.507059	2.10

In [98]:
```
# wrap in parentheses
(
    df_taxi
    .loc[df_taxi.payment_type.isin(['Cash'])]
    .groupby(['payment_type','is_weekend'])
    .trip_distance.agg(['mean','median'])
)
```

Out[98]:

		mean	median
payment_type	is_weekend		
Cash	False	2.593063	1.28
	True	3.507059	2.10

Questions?

Visualizations in Python

- dataframes as tables
- plotting with `matplotlib.pyplot`
- plotting with `pandas`
- plotting with `seaborn`

- need interactive plots? `plotly`

DataFrames as Tables

DataFrames as Tables

In [99]:
```
1 df_taxi[['trip_distance','fare_amount']].head(10)
```

Out[99]:

	trip_distance	fare_amount
0	0.89	5.5
1	2.70	14.0
2	1.41	8.0
3	0.40	4.0
4	2.30	11.0
5	0.80	5.5
6	0.20	4.5
7	2.68	11.5
8	0.60	4.5
9	0.90	6.0

Styling dataframes with `style`

Styling dataframes with `style`

In [100]:
```
(
    df_taxi[['trip_distance','fare_amount']]
    .head(10)
    .style
    .format(precision=1)
    .background_gradient()
)
```

Out[100]:

	trip_distance	fare_amount
0	0.9	5.5
1	2.7	14.0
2	1.4	8.0
3	0.4	4.0
4	2.3	11.0
5	0.8	5.5
6	0.2	4.5
7	2.7	11.5
8	0.6	4.5
9	0.9	6.0

Styling dataframes with `style`

In [100]:
```
(
    df_taxi[['trip_distance','fare_amount']]
    .head(10)
    .style
    .format(precision=1)
    .background_gradient()
)
```

Out[100]:

	trip_distance	fare_amount
0	0.9	5.5
1	2.7	14.0
2	1.4	8.0
3	0.4	4.0
4	2.3	11.0
5	0.8	5.5
6	0.2	4.5
7	2.7	11.5
8	0.6	4.5
9	0.9	6.0

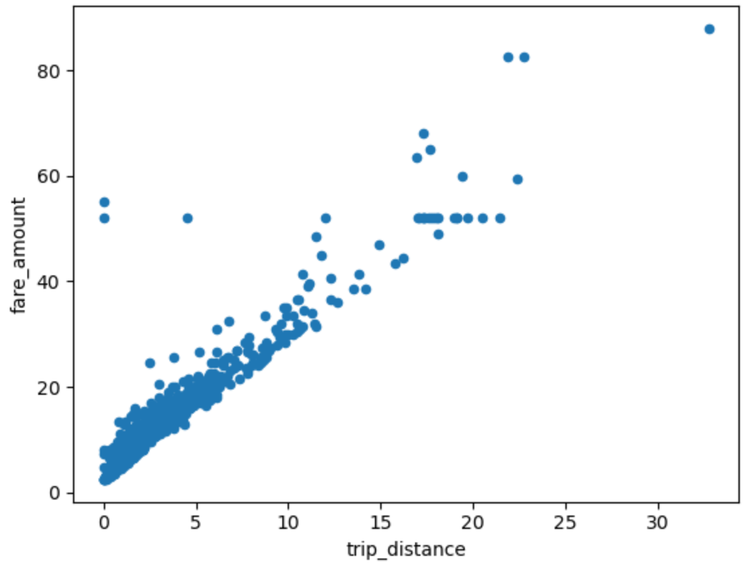
For more info: https://pandas.pydata.org/docs/user_guide/style.html

Plotting via Pandas

Plotting via Pandas

In [101]:
```
1 df_taxi.plot.scatter(x='trip_distance',y='fare_amount')
```

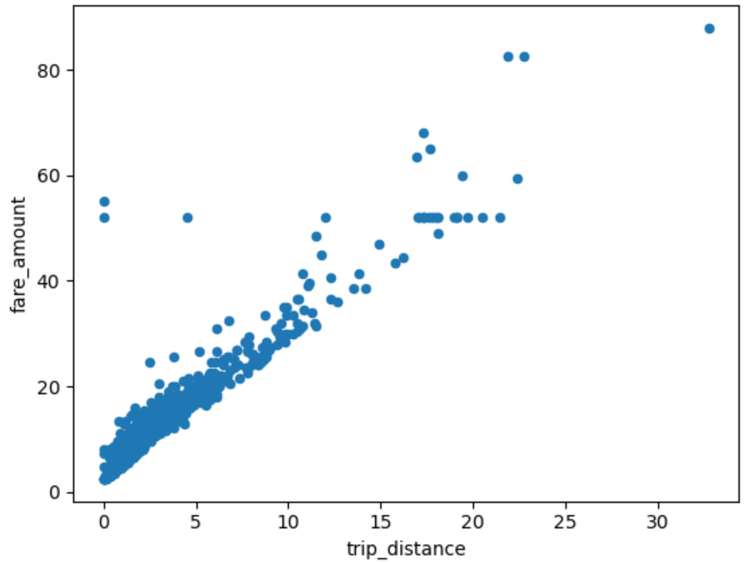
Out[101]: <AxesSubplot: xlabel='trip_distance', ylabel='fare_amount'>



Using semi-colon to hide supress ”end of cell print”

Using semi-colon to hide supress ”end of cell print”

In [102]:
```
1 df_taxi.plot.scatter(x='trip_distance',y='fare_amount');
```



Manipulating plots with Matplotlib

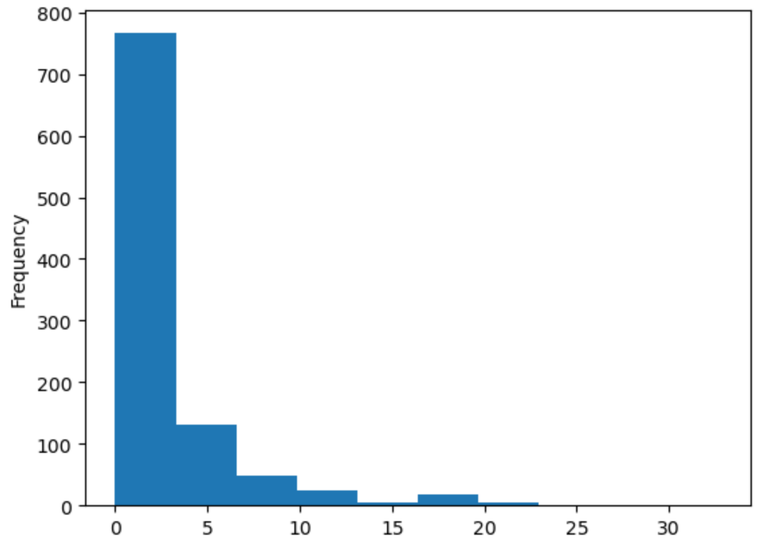
- sizing
- adding titles
- changing axis labels
- changing axis tics

Manipulating plots with Matplotlib

- sizing
- adding titles
- changing axis labels
- changing axis tics

In [103]:
```
1 ax = df_taxi.trip_distance.plot.hist();
2 type(ax)
```

Out[103]: matplotlib.axes._subplots.AxesSubplot



Import matplotlib.pyplot

Import matplotlib.pyplot

In [104]:

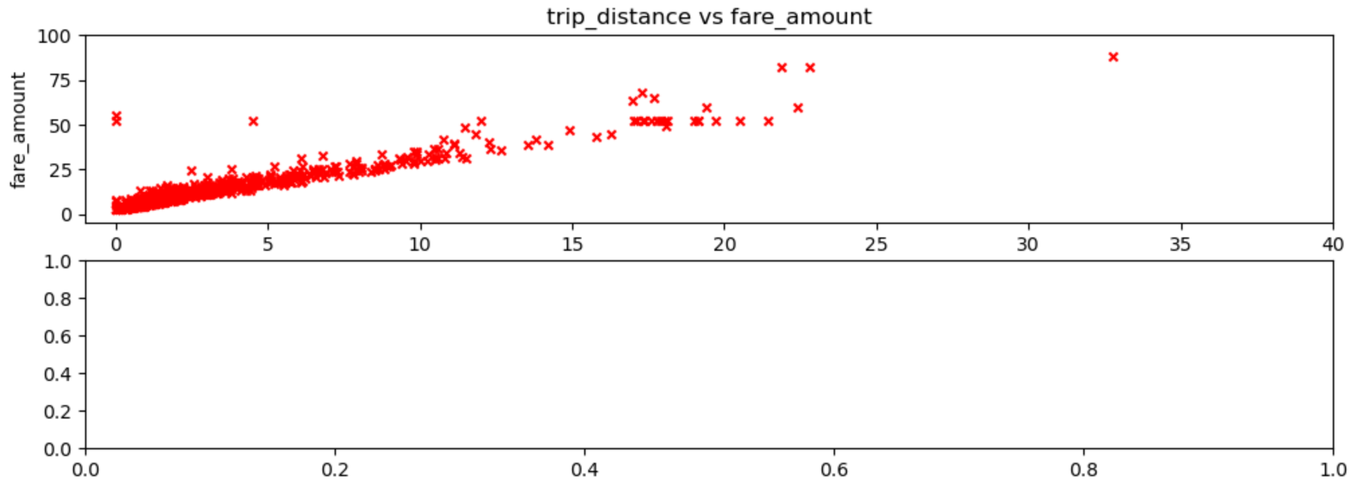
```
1 import matplotlib.pyplot as plt
2
3 %matplotlib inline
```

Matplotlib Axes

Matplotlib Axes

In [105]:

```
fig,(ax,ax1) = plt.subplots(2,1,figsize=(12,4)) # set the figure size
(
    df_taxi
    .plot.scatter(
        x = 'trip_distance',
        y = 'fare_amount',
        marker='x',
        color='red',
        ax=ax
    )
)
ax.set_xlabel('trip_distance') # set x and y axis labels
ax.set_ylabel('fare_amount')
ax.set_xlim([-1,40]) # set x and y axis limits
ax.set_ylim([-5,100])
ax.set_title('trip_distance vs fare_amount'); # set axis title
```



Matplotlib and dpi

Matplotlib and dpi

In [106]:

```python
def find_dpi(w, h, d):
    """
    https://medium.com/dunder-data/why-matplotlib-figure-inches-dont-match-your-screen-inches-and-how-to-fix-it-993fa0417dba
    w : width in pixels
    h : height in pixels
    d : diagonal in inches
    """
    w_inches = (d ** 2 / (1 + h ** 2 / w ** 2)) ** 0.5
    return round(w / w_inches)

find_dpi(1920, 1080, 13.25) # approx what my native dpi is
```

Out[106]:

```
166
```

Matplotlib and dpi

In [106]:
```python
def find_dpi(w, h, d):
    """
    https://medium.com/dunder-data/why-matplotlib-figure-inches-dont-match-your-screen-inches-and-how-to-fix-it-993fa0417dba
    w : width in pixels
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    """
    w_inches = (d ** 2 / (1 + h ** 2 / w ** 2)) ** 0.5
    return round(w / w_inches)

find_dpi(1920, 1080, 13.25) # approx what my native dpi is
```

Out[106]: 166

In [107]:
```python
fig.dpi # from previous figure
```

Out[107]: 100.0

Matplotlib and dpi

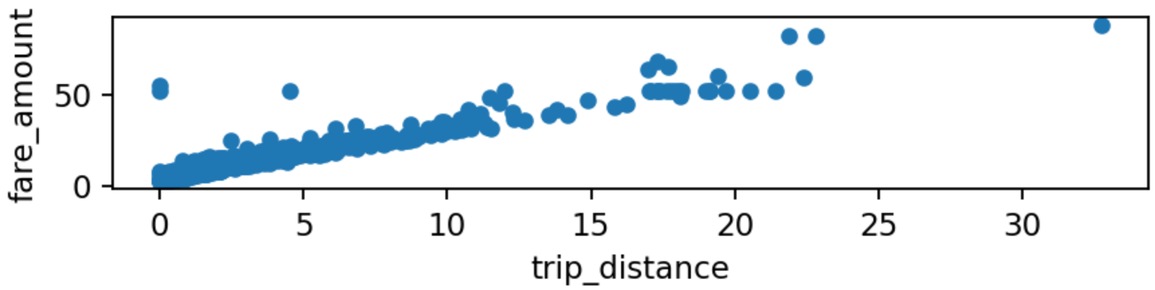
In [106]:
```
def find_dpi(w, h, d):
    """
    https://medium.com/dunder-data/why-matplotlib-figure-inches-dont-match-your-screen-inches-and-how-to-fix-it-993fa0417dba
    w : width in pixels
    h : height in pixels
    d : diagonal in inches
    """
    w_inches = (d ** 2 / (1 + h ** 2 / w ** 2)) ** 0.5
    return round(w / w_inches)

find_dpi(1920, 1080, 13.25) # approx what my native dpi is
```

Out[106]: 166

In [107]:
```
fig.dpi # from previous figure
```

Out[107]: 100.0

In [108]:
```
fig, ax = plt.subplots(figsize=(6, 1), dpi=166)
df_taxi.plot.scatter(x = 'trip_distance',y = 'fare_amount',ax=ax);
```

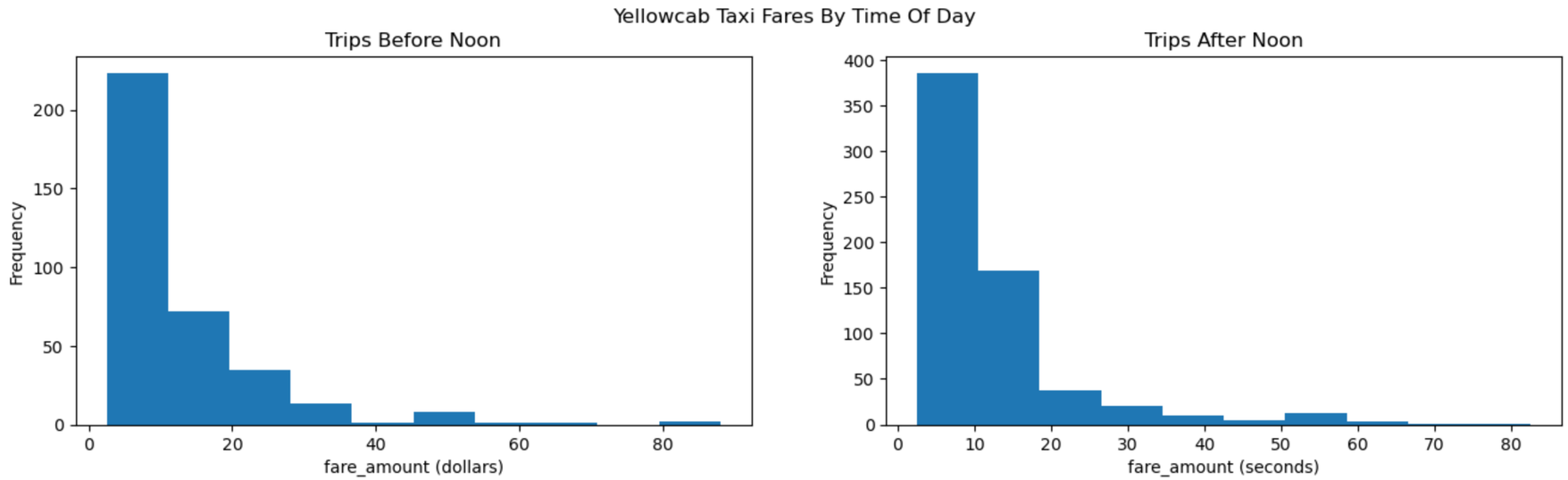


Matplotlib: Subplots, Figure and Axis

Matplotlib: Subplots, Figure and Axis

In [109]:

```
fig,ax = plt.subplots(1,2,figsize=(16,4))

df_taxi[df_taxi.pickup_datetime.dt.hour < 12].fare_amount.plot.hist(ax=ax[0]);
ax[0].set_xlabel('fare_amount (dollars)');
ax[0].set_title('Trips Before Noon');

df_taxi[df_taxi.pickup_datetime.dt.hour >= 12].fare_amount.plot.hist(ax=ax[1]);
ax[1].set_xlabel('fare_amount (seconds)');
ax[1].set_title('Trips After Noon');
# Matplotlib: Subplots, Figure and Axis
fig.suptitle('Yellowcab Taxi Fares By Time Of Day');
```

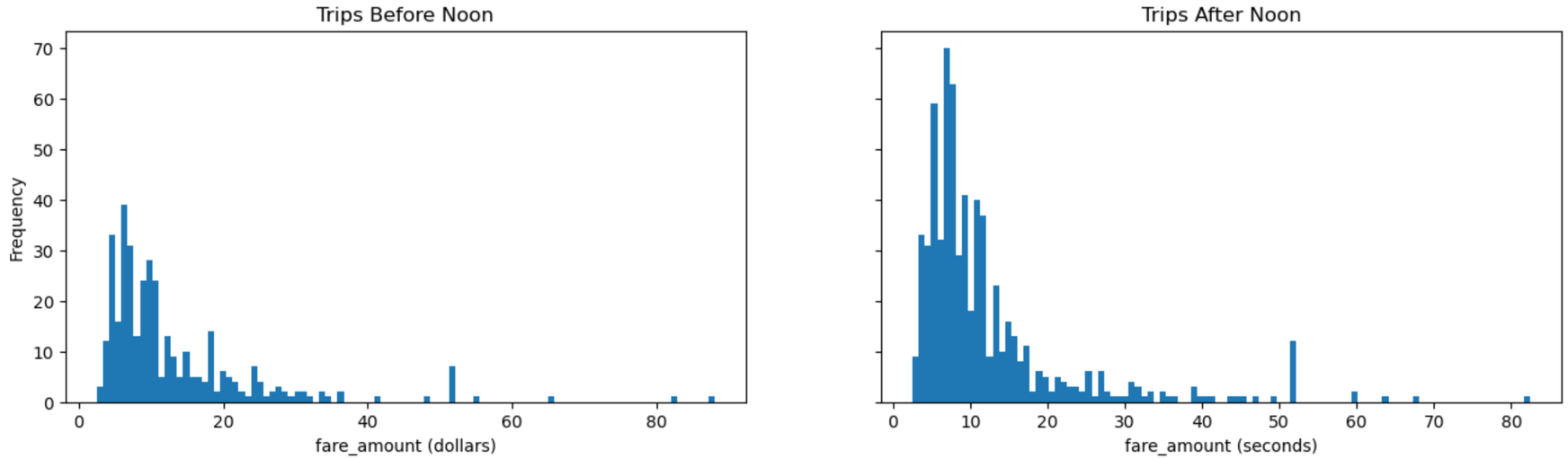


Matplotlib: Sharing Axes

Matplotlib: Sharing Axes

In [110]:

```
fig,ax = plt.subplots(1,2,figsize=(16,4), sharey=True)

df_taxi[df_taxi.pickup_datetime.dt.hour < 12].fare_amount.plot.hist(bins=100,ax=ax[0]);
ax[0].set_xlabel('fare_amount (dollars)');
ax[0].set_title('Trips Before Noon');
df_taxi[df_taxi.pickup_datetime.dt.hour >= 12].fare_amount.plot.hist(bins=100,ax=ax[1]);
ax[1].set_xlabel('fare_amount (seconds)');
ax[1].set_title('Trips After Noon');
```

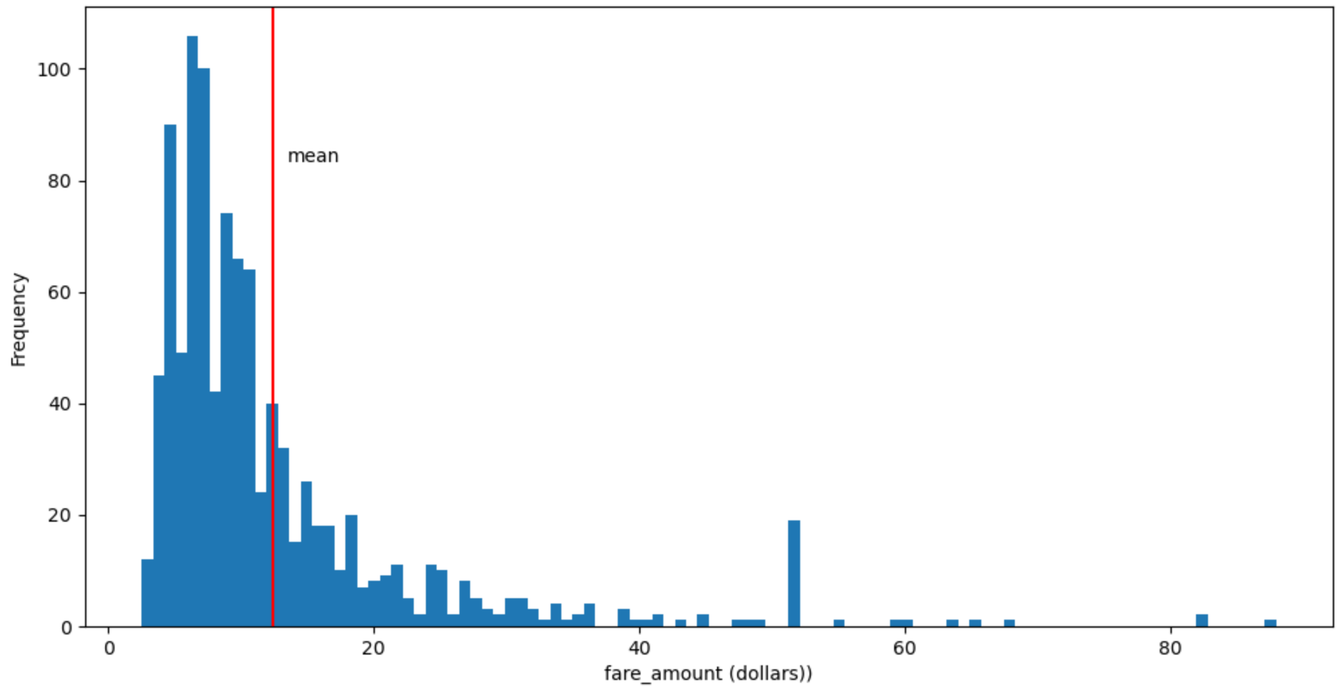


Matplotlib: adding lines and annotations

Matplotlib: adding lines and annotations

In [111]:

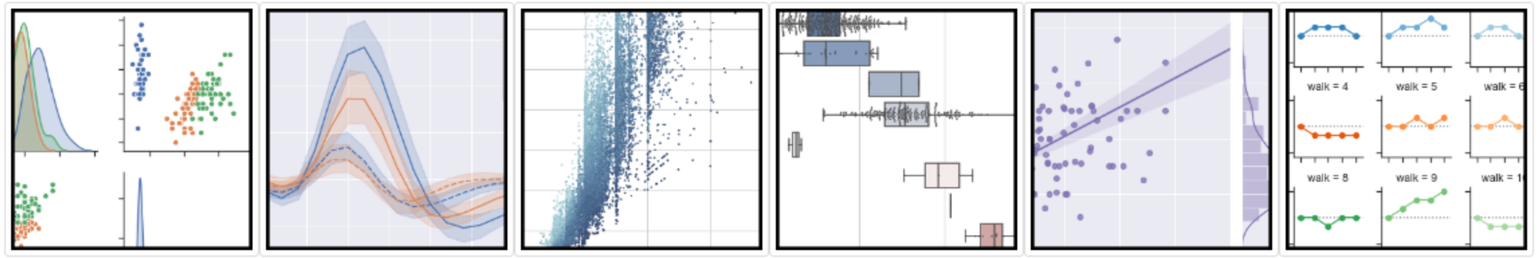
```
fig,ax = plt.subplots(1,1,figsize=(12,6));

df_taxi.fare_amount.plot.hist(bins=100, ax=ax);
ax.set_xlabel('fare_amount (dollars))');

# add a vertical line
ax.axvline(df_taxi.fare_amount.mean(),color='r');
#ax.vlines(df_taxi.fare_amount.mean(),*ax.get_ylim(),color='r');

# add some text
ax.text(df_taxi.fare_amount.mean()+1,ax.get_ylim()[1]*.75,'mean');
```



Plotting with Seaborn

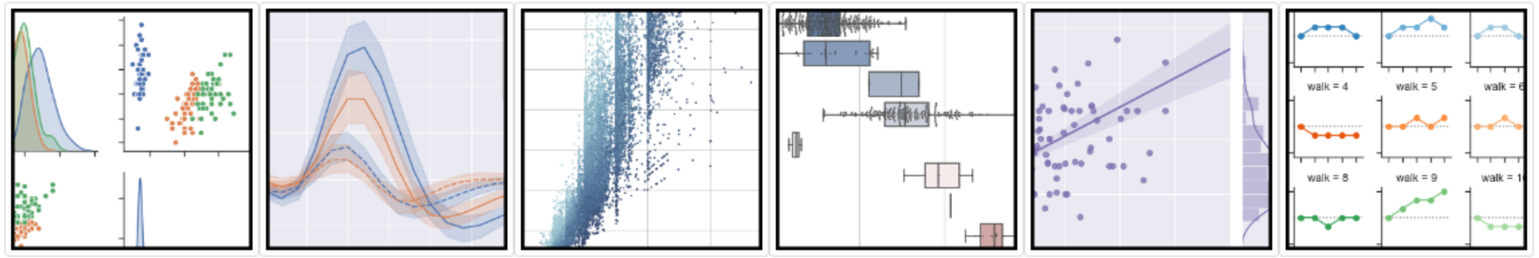
Plotting with Seaborn

- Python data visualization library
- Based on matplotlib.
- It provides a high-level interface for drawing attractive and informative statistical graphics.



Plotting with Seaborn

- Python data visualization library
- Based on matplotlib.
- It provides a high-level interface for drawing attractive and informative statistical graphics.



In [112]:
```
1 import seaborn as sns
2 sns.__version__
```

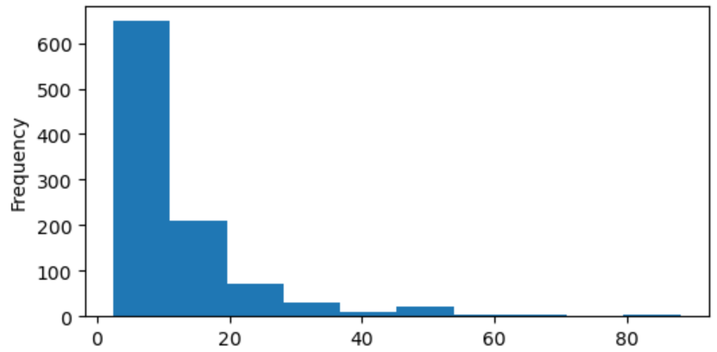
Out[112]: '0.12.2'

Univariate Distribution: Histograms

Univariate Distribution: Histograms

In [113]:

```
fig,ax = plt.subplots(1,1,figsize=(6,3))

df_taxi.fare_amount.plot.hist(ax=ax);
```



Univariate Distribution: Histograms

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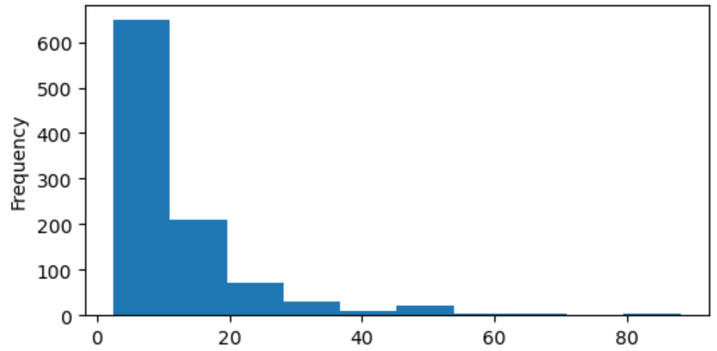
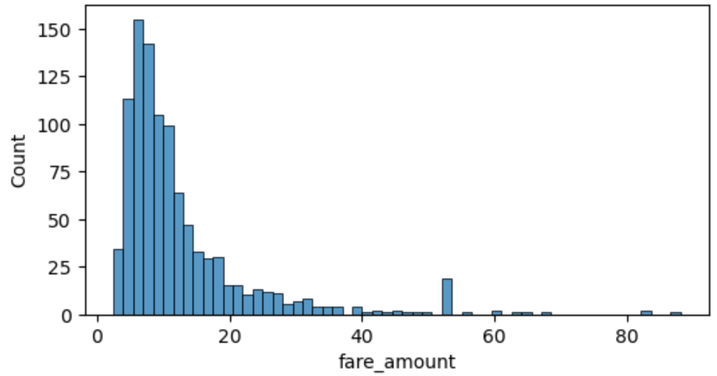


In [114]:
```
fig,ax = plt.subplots(1,1,figsize=(6,3))

sns.histplot(x='fare_amount',data=df_taxi,ax=ax); # sns.histplot(x=df_taxi.fare_amount,ax=ax);
```

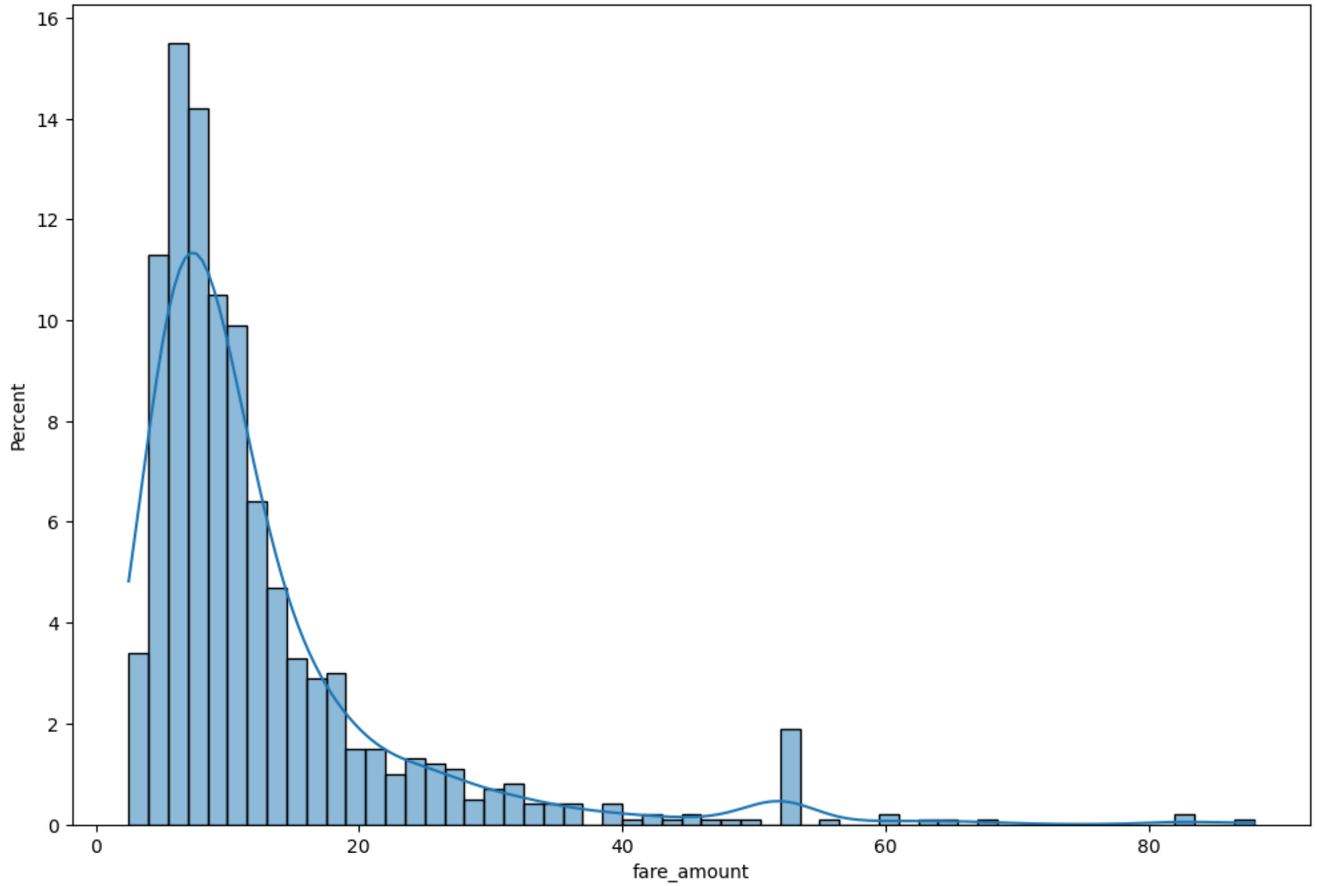


Univariate Distribution: Histograms

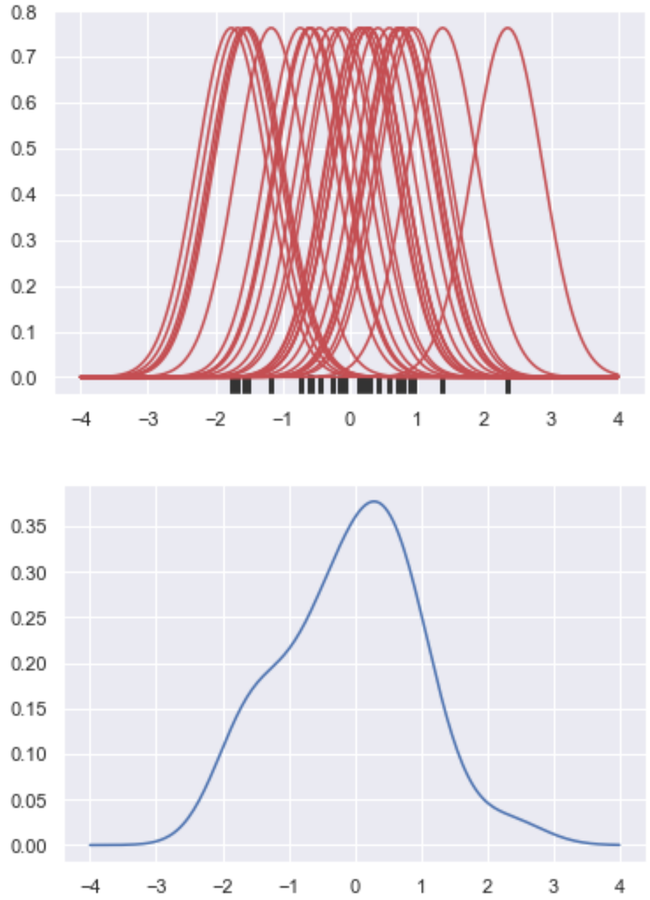
Univariate Distribution: Histograms

In [115]:
```
fig,nd = plt.subplots(1,1,figsize=(12,8))

# many other parameters to play with
sns.histplot(x='fare_amount',data=df_taxi,ax=nd,kde=True,stat='percent');
```



Aside: KDE


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−4
−3
−2
−1
0
1
2
3
4
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−4
−3
−2
−1
0
1
2
3
4

Seaborn Styles

Seaborn Styles

In [116]:

```
# for a single plot using a context
with sns.axes_style('whitegrid'):
    fig,ax = plt.subplots(1,1,figsize=(10,1))
    sns.histplot(x='fare_amount',data=df_taxi);
```

Seaborn Styles

In [116]:
```
# for a single plot using a context
with sns.axes_style('whitegrid'):
    fig,ax = plt.subplots(1,1,figsize=(10,1))
    sns.histplot(x='fare_amount',data=df_taxi);
```

In [117]:
```
# set style globally: darkgrid, whitegrid, dark, white, ticks
sns.set_style('darkgrid')
```

Seaborn Styles

In [116]:
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# for a single plot using a context
with sns.axes_style('whitegrid'):
    fig,ax = plt.subplots(1,1,figsize=(10,1))
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```

In [117]:
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sns.set_style('darkgrid')
```

In [118]:
```
fig,ax = plt.subplots(1,1,figsize=(10,1))
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Seaborn Styles

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# set style globally: darkgrid, whitegrid, dark, white, ticks
sns.set_style('darkgrid')
```

In [118]:
```
fig,ax = plt.subplots(1,1,figsize=(10,1))
sns.histplot(x='fare_amount',data=df_taxi);
```

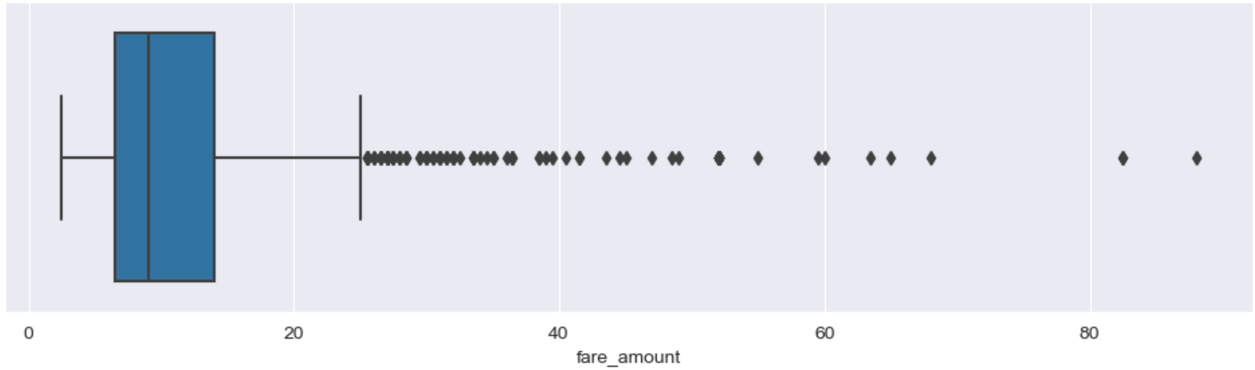
In [119]:
```
# to reset to matplotlib defaults
#import matplotlib
#matplotlib.rc_file_defaults()
```

Univariate Distributions: Boxplot

Univariate Distributions: Boxplot

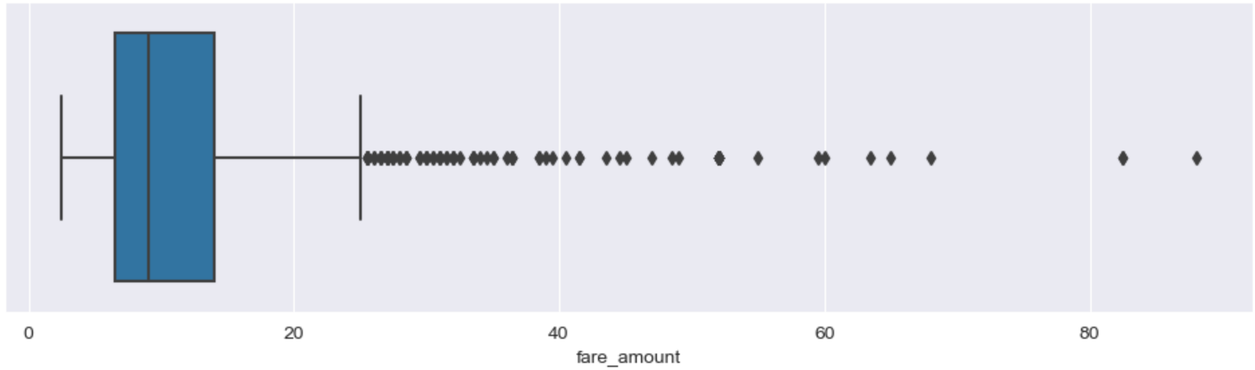
In [120]:

```
1 fig,ax = plt.subplots(1,1,figsize=(12,3))
2
3 sns.boxplot(x='fare_amount',data=df_taxi,ax=ax);
```



Univariate Distributions: Boxplot

In [120]:
```
1 fig,ax = plt.subplots(1,1,figsize=(12,3))
2
3 sns.boxplot(x='fare_amount',data=df_taxi,ax=ax);
```



- first quartile
- second quartile (Median)
- third quartile
- whiskers (usually 1.5*IQR)
- outliers

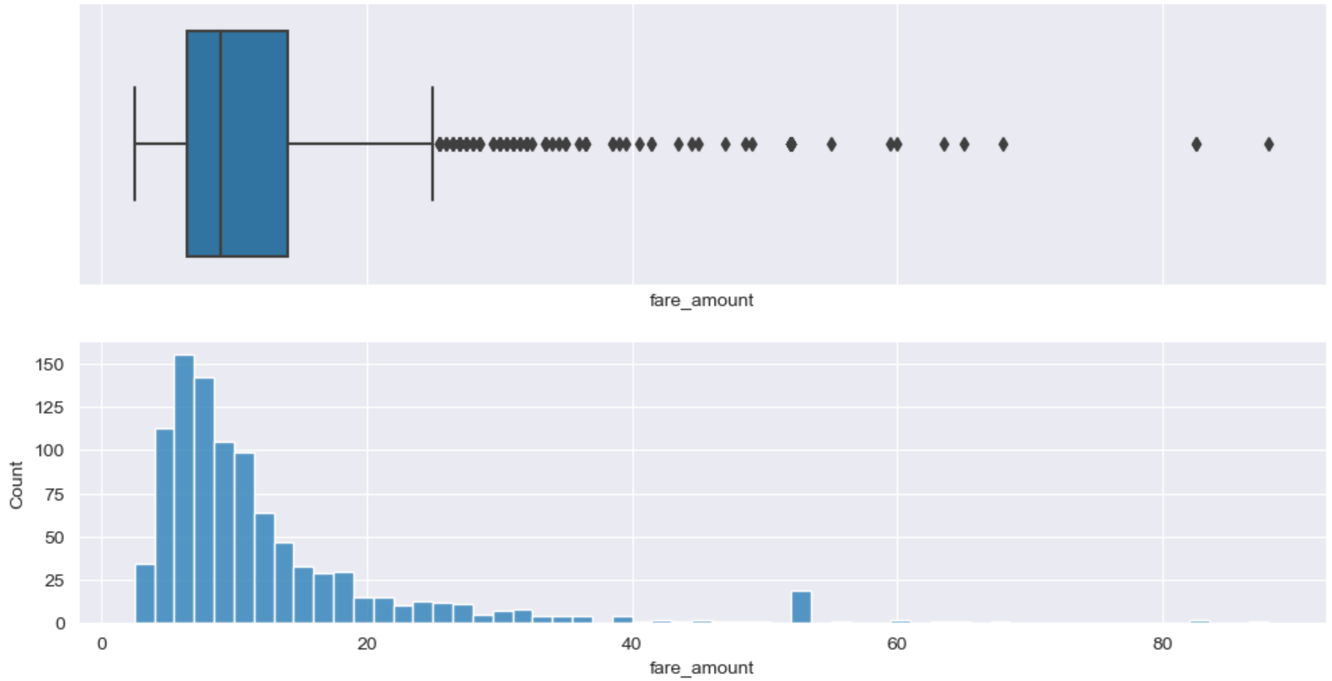
Seaborn: Combining Plots with Subplots

Seaborn: Combining Plots with Subplots

In [121]:

```
fig,ax = plt.subplots(2,1,figsize=(12,6), sharex=True)

sns.boxplot(x='fare_amount', data=df_taxi, ax=ax[0]);
sns.histplot(x='fare_amount', data=df_taxi, ax=ax[1]);
```



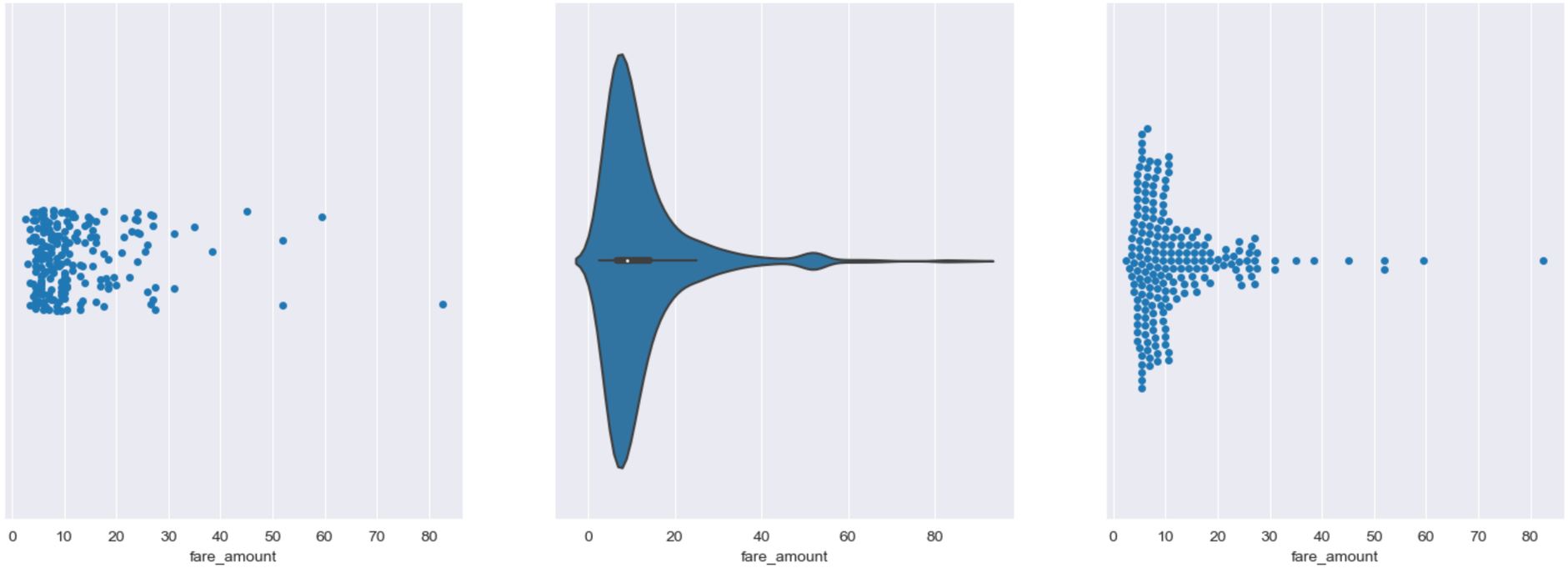
Other Univariate Distribution Visualizations

Other Univariate Distribution Visualizations

In [122]:

```
fig,ax = plt.subplots(1,3,figsize=(18,6))

sns.stripplot(x='fare_amount',data=df_taxi[:200],ax=ax[0])
sns.violinplot(x='fare_amount',data=df_taxi,ax=ax[1])
sns.swarmplot(x='fare_amount',data=df_taxi[:200],ax=ax[2]);
```

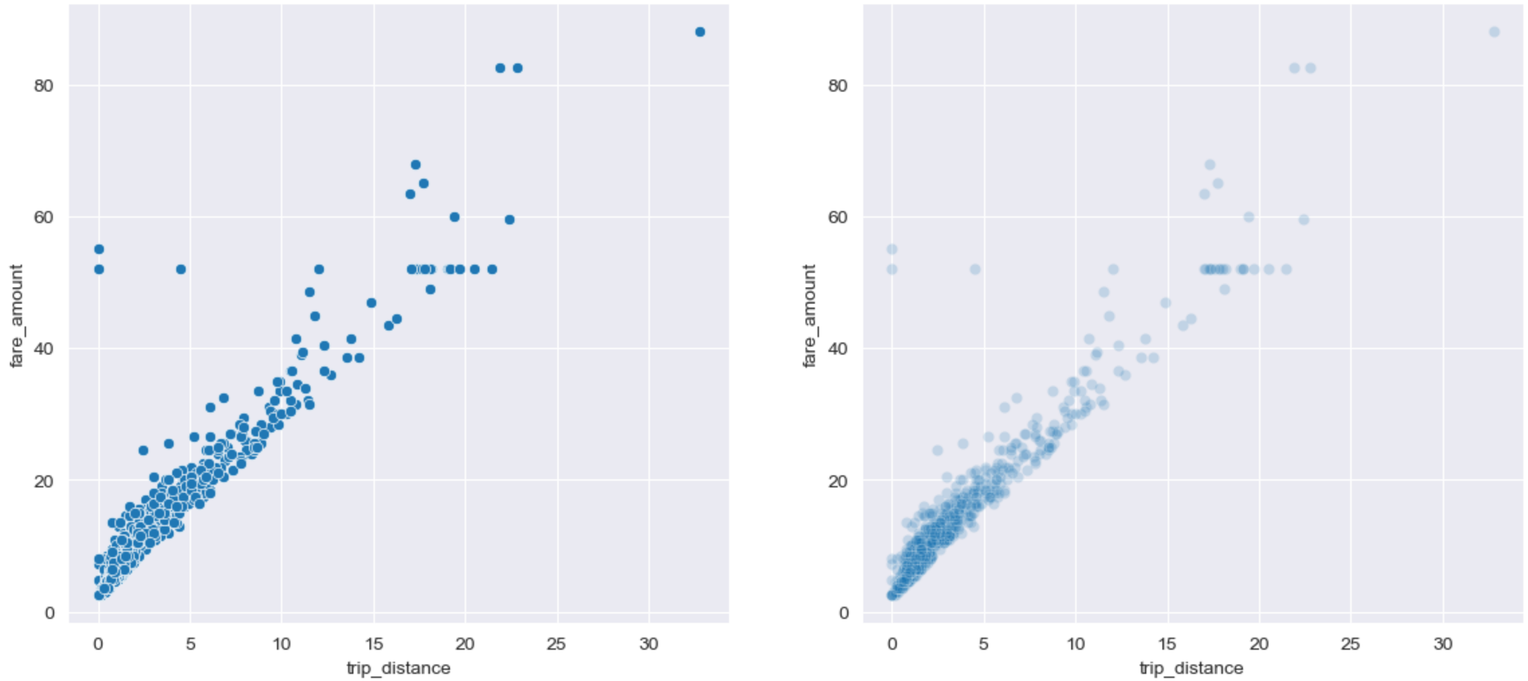


Bivariate: Scatterplot (with alpha)

Bivariate: Scatterplot (with alpha)

In [123]:

```
fig,ax = plt.subplots(1,2,figsize=(14,6))
sns.scatterplot(x='trip_distance', y='fare_amount', data=df_taxi, ax=ax[0]);
sns.scatterplot(x='trip_distance', y='fare_amount', data=df_taxi, ax=ax[1], alpha=0.2);
```



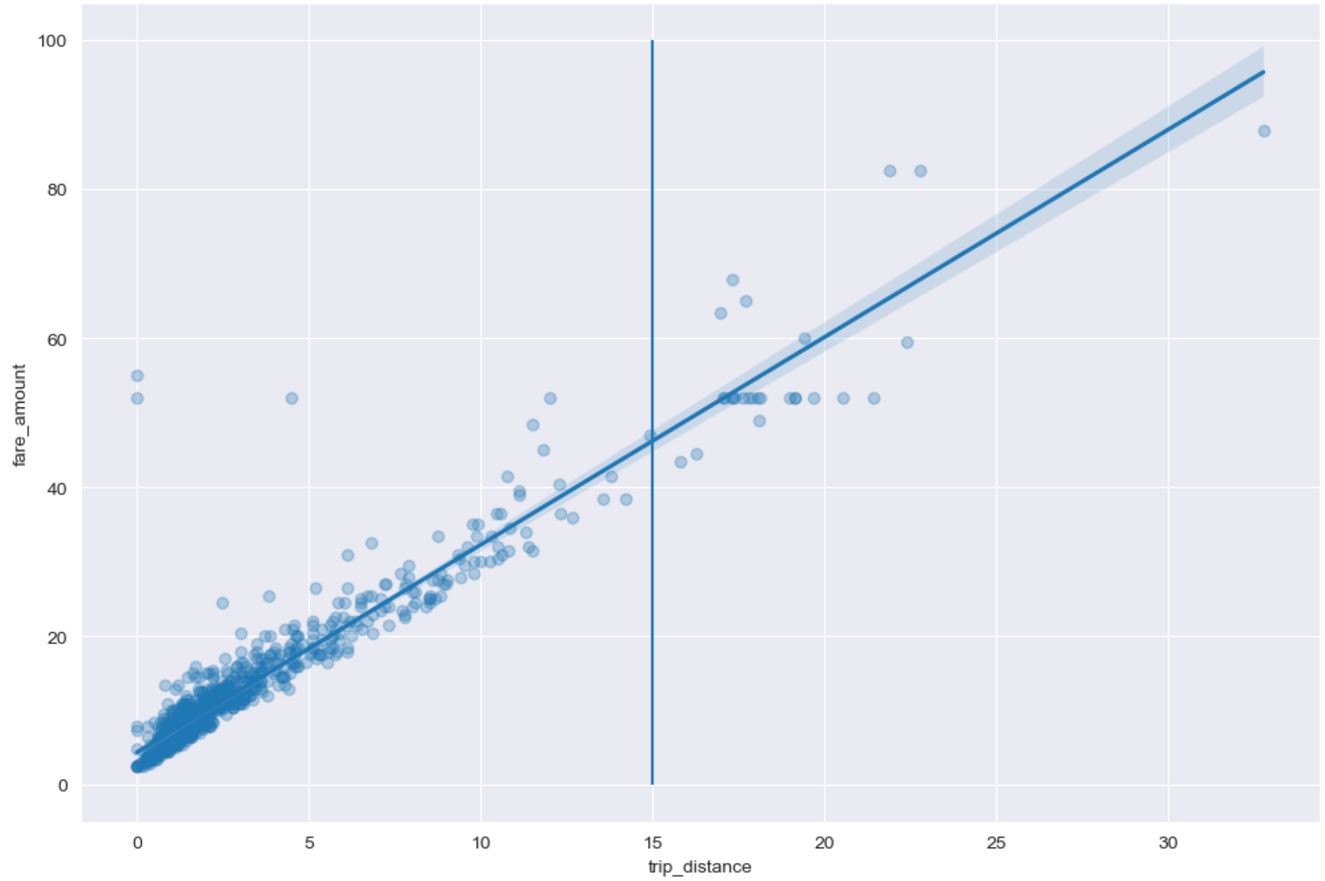
Bivariate: Add Regression Line

Bivariate: Add Regression Line

In [124]:
```
fig,ax = plt.subplots(1,1,figsize=(12,8))

sns.regplot(x='trip_distance', y='fare_amount', data=df_taxi, ax=ax, scatter_kws={'alpha':0.3});
plt.vlines(x = 15, ymin=0, ymax=100)
```

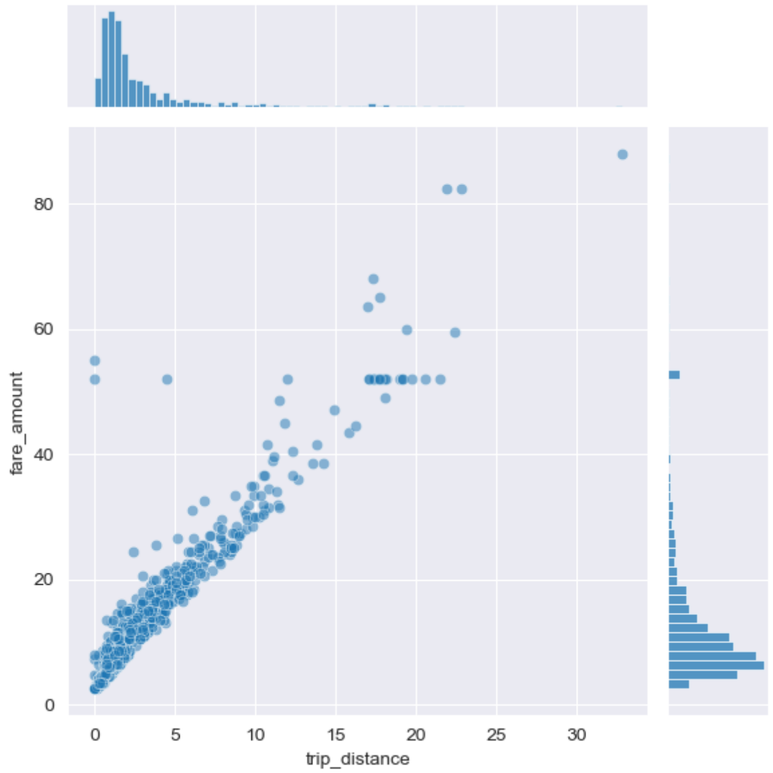
Out[124]: <matplotlib.collections.LineCollection at 0x7fc17fe7f100>



Bivariate: Joint Plot

Bivariate: Joint Plot

In [125]:
```
1 sns.jointplot(x='trip_distance',y='fare_amount',data=df_taxi,alpha=0.5);
```

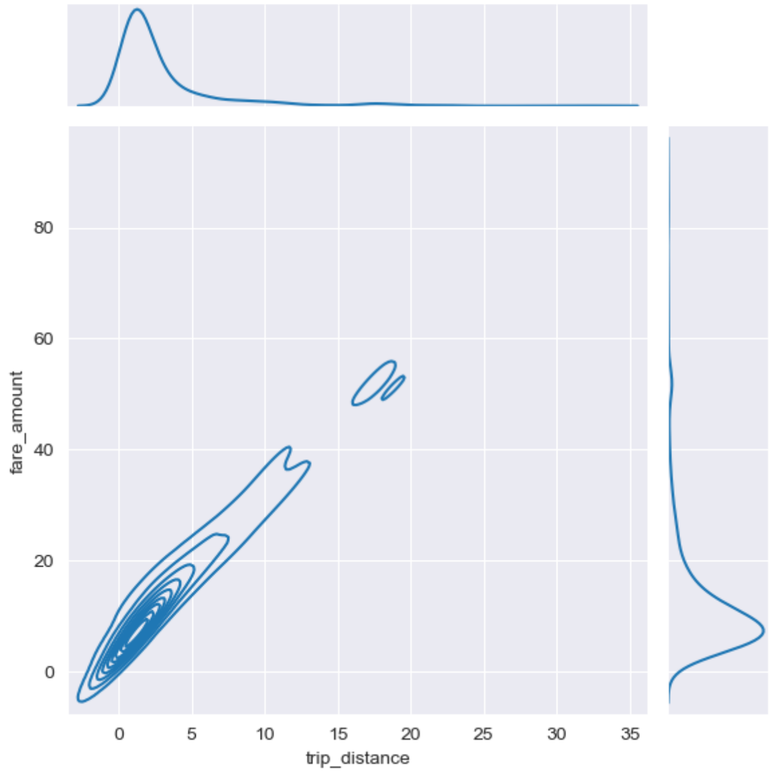


Bivariate: Joint Plot with KDE

Bivariate: Joint Plot with KDE

In [126]:

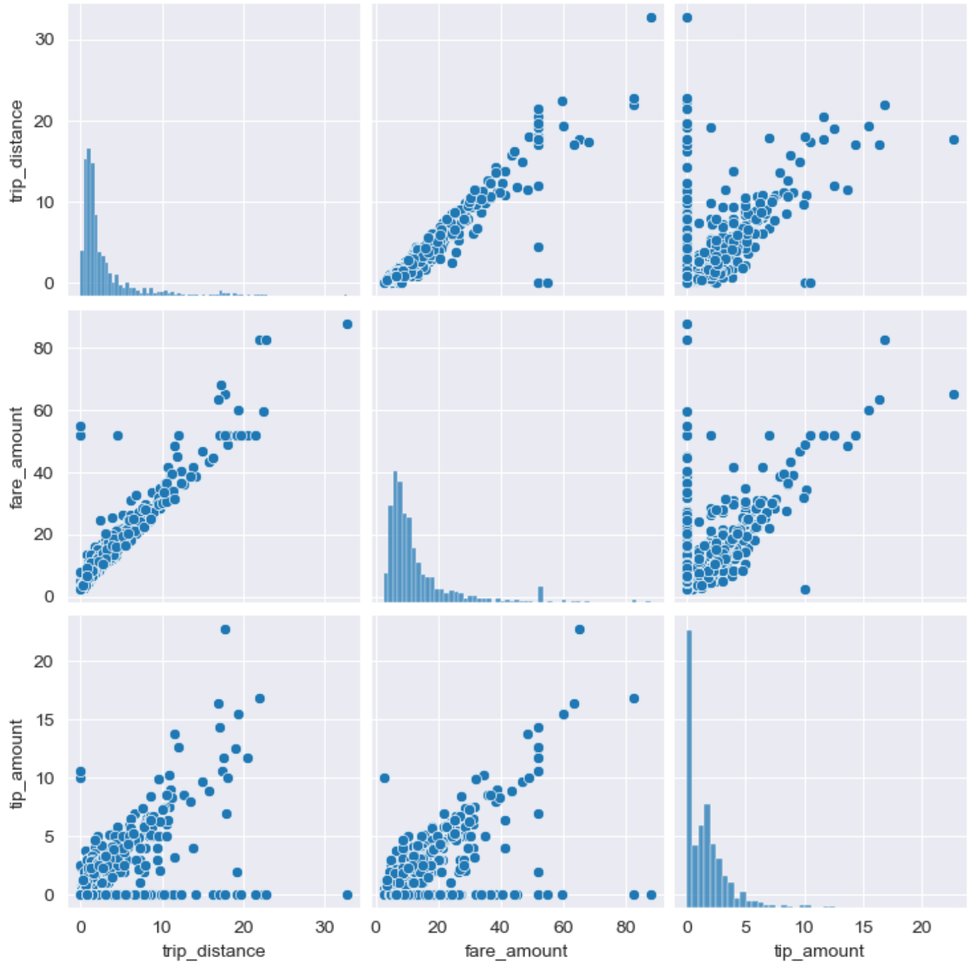
```
sns.jointplot(x='trip_distance', y='fare_amount',
              data=df_taxi,
              kind='kde');
```



Comparing Multiple Variables with `pairplot`

Comparing Multiple Variables with `pairplot`

In [127]:
```
1 sns.pairplot(data=df_taxi[['trip_distance','fare_amount','tip_amount']]);
```



Categorical Variables: Frequency

Categorical Variables: Frequency

In [128]:
```
1 df_taxi.payment_type.value_counts()
```

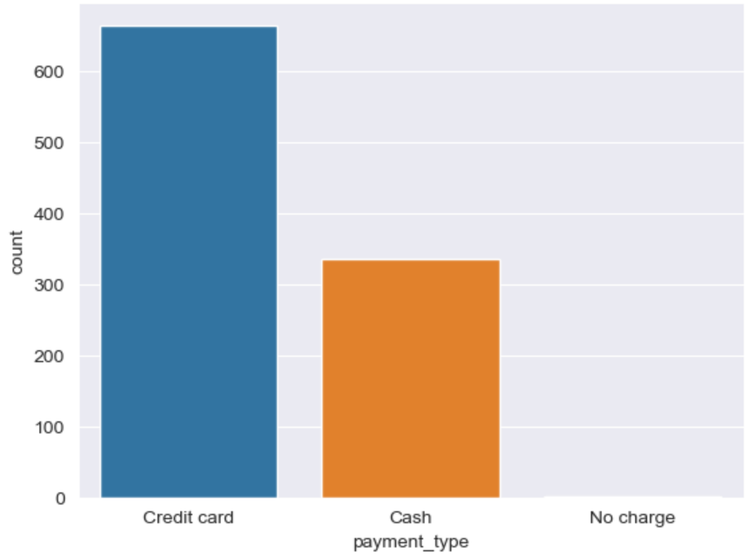
Out[128]:
```
Credit card    663
Cash           335
No charge        2
Name: payment_type, dtype: int64
```

Categorical Variables: Frequency

In [128]:
```
1 df_taxi.payment_type.value_counts()
```

Out[128]:
```
Credit card    663
Cash           335
No charge        2
Name: payment_type, dtype: int64
```

In [129]:
```
1 sns.countplot(x='payment_type',data=df_taxi);
```



Plotting Numeric and Categorical

Plotting Numeric and Categorical

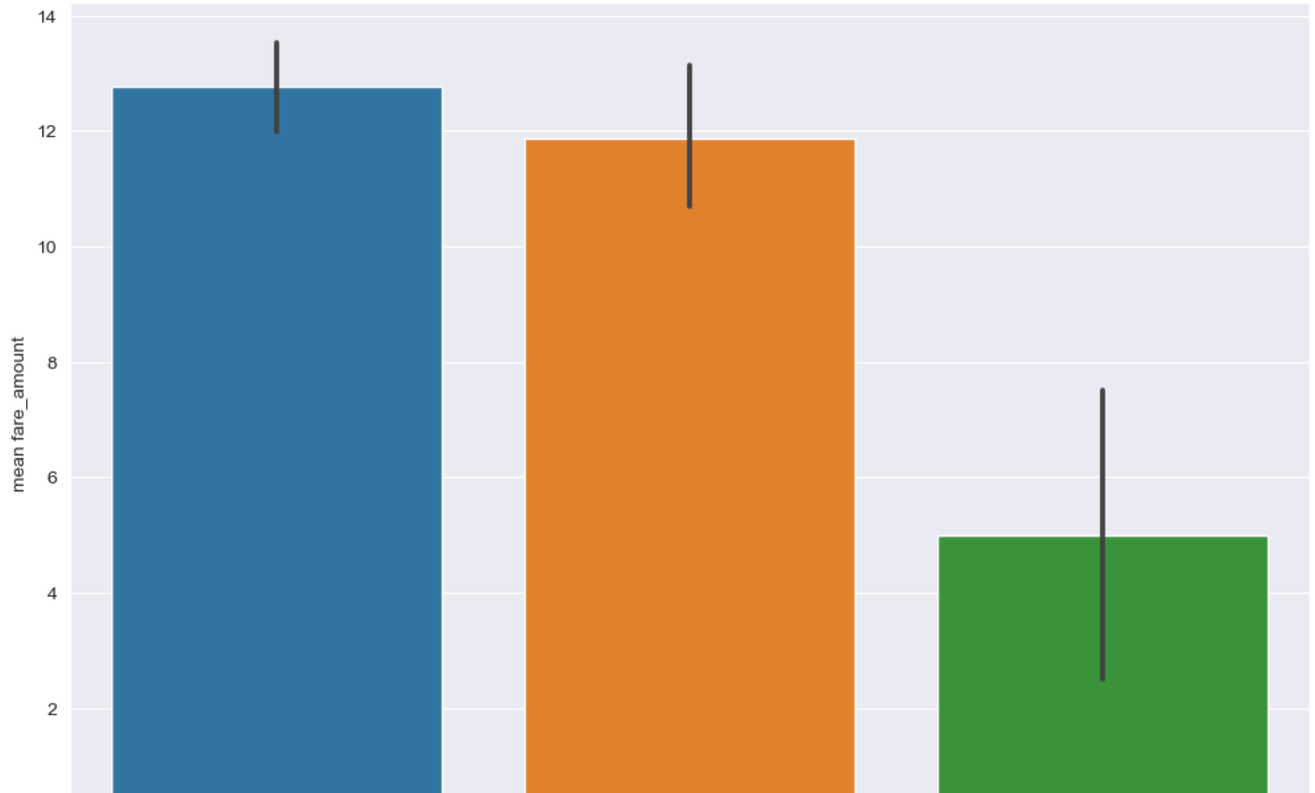
In [130]:

```
1 fig,ax = plt.subplots(1,1,figsize=(12,8))
2
3 sns.barplot(x='payment_type',y='fare_amount',data=df_taxi,estimator=np.mean,ci=95);
4 ax.set_ylabel('mean fare_amount');
```

```
/var/folders/78/vhnqkq8n45dd4gj4f5qx8yb00000gn/T/ipykernel_9996/1040376770.py:3: FutureWarning:

The `ci` parameter is deprecated. Use `errorbar=('ci', 95)` for the same effect.

  sns.barplot(x='payment_type',y='fare_amount',data=df_taxi,estimator=np.mean,ci=95);
```



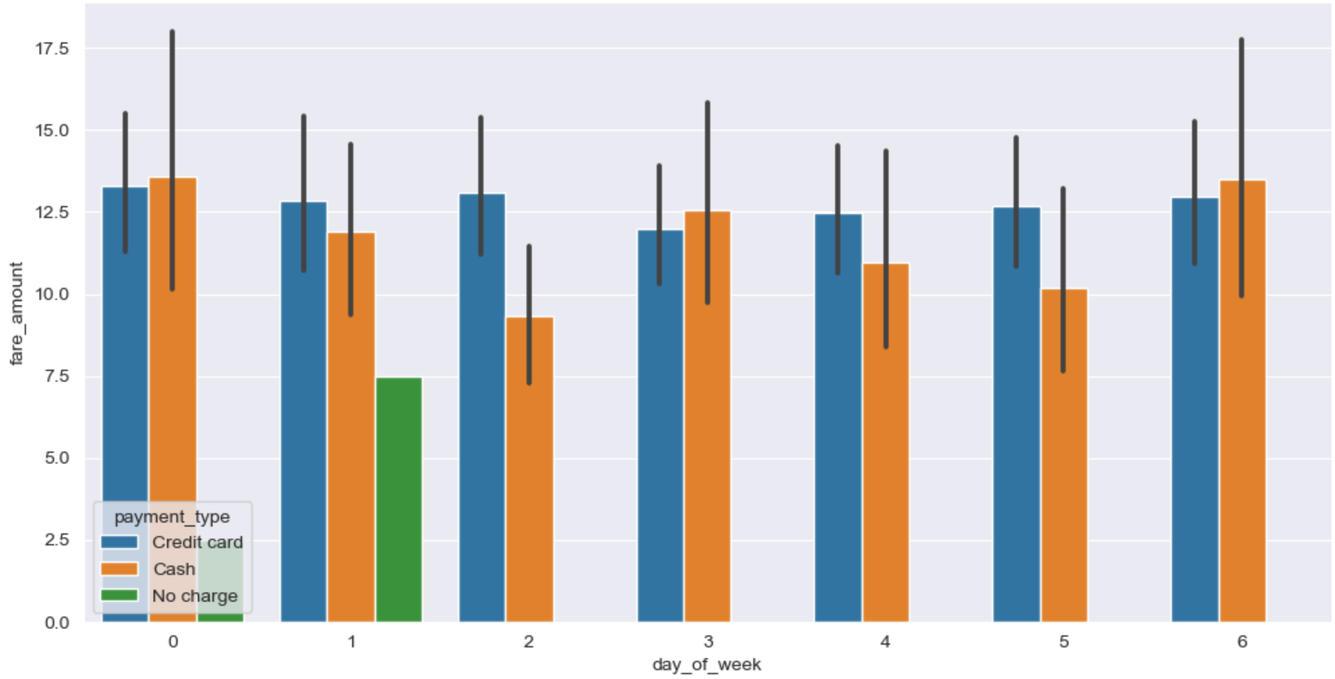
Plotting with Hue

Plotting with Hue

In [131]:

```
fig,ax = plt.subplots(1,1,figsize=(12,6))

# add a second categorical variable day_of_week
sns.barplot(x='day_of_week',
            y='fare_amount',
            hue='payment_type',
            data=df_taxi,
            ax=ax,
           );
```

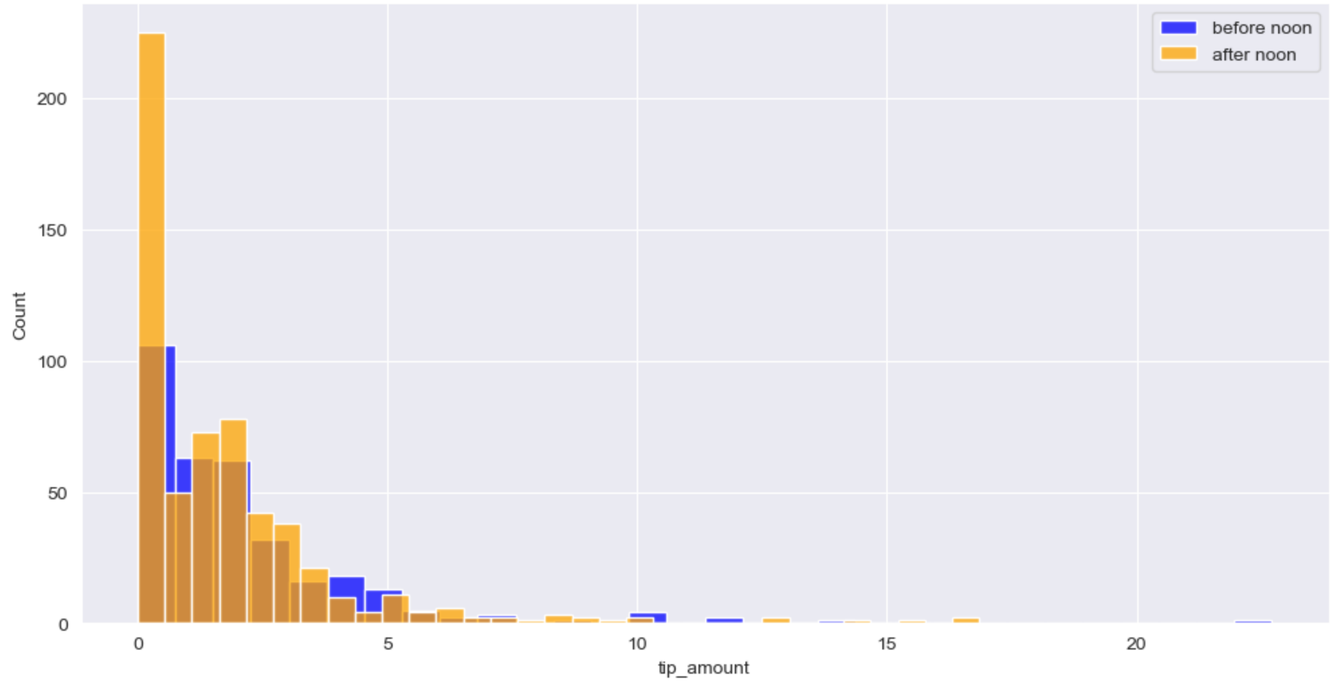


Same Axis, Multiple Plots with Seaborn (with legend)

Same Axis, Multiple Plots with Seaborn (with legend)

In [132]:

```
fig,ax = plt.subplots(1,1,figsize=(12,6))
sns.histplot(x='tip_amount',data=df_taxi[df_taxi.pickup_datetime.dt.hour  < 12], label='before noon',color='blue', ax=ax);
sns.histplot(x='tip_amount',data=df_taxi[df_taxi.pickup_datetime.dt.hour >= 12], label='after noon', color='orange',ax=ax);
plt.legend(loc='best');
```



Data Exploration and Viz Review

- central tendencies: mean, median
- spread: variance, std deviation, IQR
- correlation: pearson correlation coefficient
- plotting with Matplotlib and Seaborn
- plotting real valued variables: histogram, scatter, regplot
- plotting categorical variables: count, bar
- plotting interactions: jointplot, pairplot

Where to go from here

- Additional Dataframe styling with `.style()` (https://pandas.pydata.org/docs/user_guide/style.html)
- Seaborn Figure-level plots: `relplot`, `displot`, `catplot` (https://seaborn.pydata.org/tutorial/function_overview.html)
- Interactive visuals with plotly (https://plotly.com/python/plotly-fundamentals/)

Questions?