Data Science 100

Lecture 5: Exploratory Data Analysis

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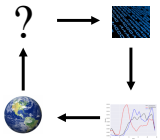
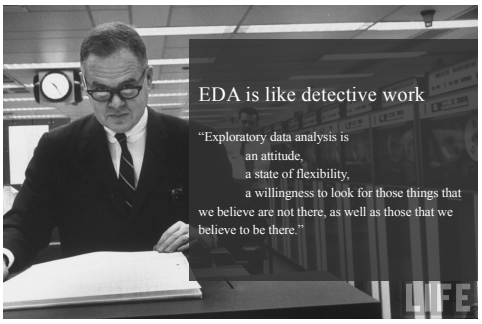
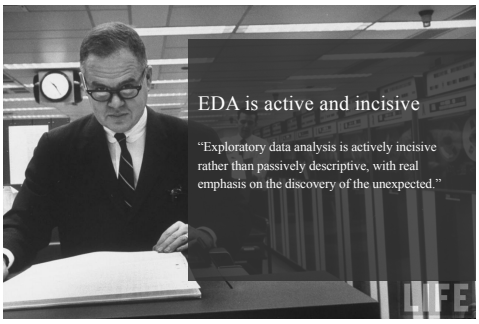


Data Analysis & Statistics, Tukey 1965





Philosophy of EDA

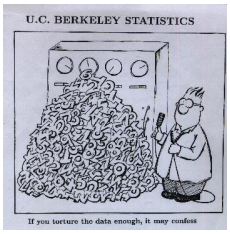
- Confirm understanding of the data
- Keep an open mind and be willing to find something surprising
- Iterate
  - Uncover new aspects of our data
  - Re-examine our understanding of the data
  - Continue exploration

Where does EDA help?

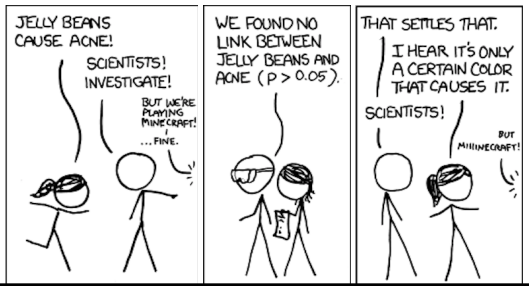
- Clean data
- Transform variables and derive new variables – put data in format suitable for analysis
- Better understand data/situation (no formal analysis pursued)
- Inform formal analysis – uncover important features that impact the analysis
- Examine formal analysis – explore output from an analysis, e.g., predictions, parameter estimates, model fit

Caution about EDA

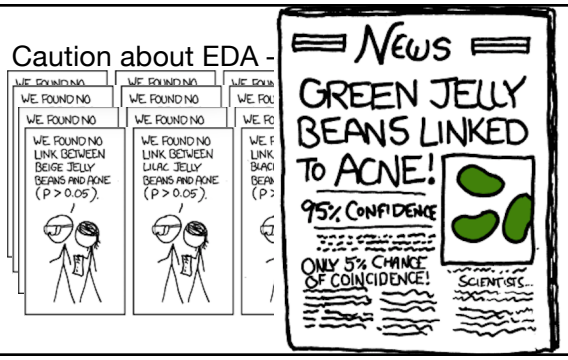
- Considered data snooping
- With enough data, if you look hard enough you will find something "interesting"
- Related to p-hacking



Caution about EDA – ala xkcd



Caution about EDA -



On The Other Hand

EDA can provide valuable insights about a model and its assumptions

What to do?

- Additional Data
  - Pilot study
  - Perform a second experiment
  - Collect more data
  - Short of that – divide data in two at random and explore half
- Reporting
  - Describe EDA that was performed
  - Understand and describe the limitations of your analysi
- Differentiate between descriptive analysis and formal inference

How to Carry out EDA?

- Plot data in multiple ways to get different insights
- Transform variables to symmetrize distributions
- Transform to straighten relationships
- Derive new variables
- Consider effect of other variables on distributions & relationships

Connect what you find to the question and context

A Case Study

Question

Taxi driver claim:
When traffic on a freeway begins to break down, the fasts lane breaks down first so you should move immediately to the right.

Can we confirm this phenomena?

Can we turn this claim into a statistics question that is answerable with data?

Question

When traffic on a freeway begins to break down, the fast lane breaks down first so they move immediately to the right.

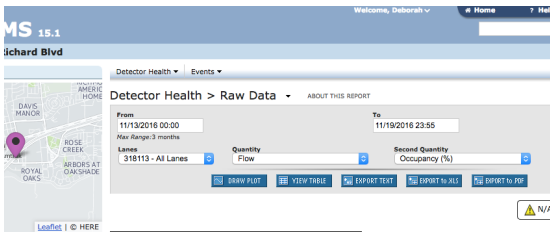
What information do we need to study this question? –
- Observe traffic on a freeway
- Include time to see when traffic is heavy and break downs
- Record traffic in lanes to differentiate traffic levels between in lanes

Simpler Related Questions

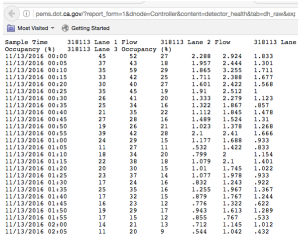
- Do the 3 lanes serve the same amount of traffic?
- When 1 lane is congested, are the other lanes also congested?
- What's the relationship between amount of traffic served and congestion?
- How are answers to these questions impacted by time of day and day of week?

Let's Get Some Data

PEMS Data – Available in online form



PEMS Data – Available in online form



Loop Detector Data:

Number of vehicles that pass over a loop detector in a 5-minute period

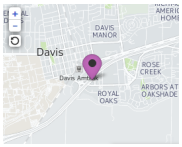
Percentage of time in the 5-minute period that a vehicle was over the loop detector

Statistical Issues:
What is the context Question?
What is the Population?
Data Represent Population?

Population

5-minute intervals at any time and place on a freeway

Data:
Time: Nov 13 to Nov 19, 2016 (one week)
Place: Loop 318113 on I 80 Eastbound



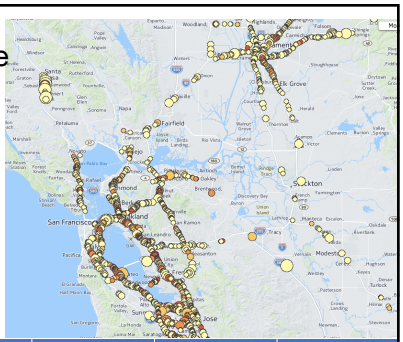
Representative

Traffic may behave differently at:

- Other locations
- Other times of year

Such as?

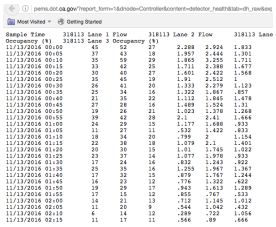
Keep this in mind as we analyze the data



Data Wrangling Issues:
Structure
Granularity
Faithfulness
Time
Scope

Structure

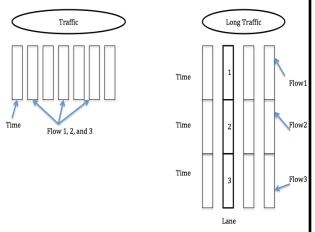
- Rectangular?
- Record delimiter?
- Variable value delimiter?
- Primitive Data Types?



Sample Time	318113 Lane 1 Flow		318113 Lane 2 Flow		318113 Lane
Occupancy (%)	318113 Lane 3 Occupancy (%)				
11/13/2016 00:00	45	52	27	2.288	2.924	1.833
11/13/2016 00:05	37	43	18	1.957	2.444	1.301
11/13/2016 00:10	35	59	29	1.865	3.255	1.711
11/13/2016 00:15	33	40	25	1.711	2.233	1.677
11/13/2016 00:20	30	42	19	1.611	2.422	1.568
11/13/2016 00:25	30	45	27	1.91	2.522	
11/13/2016 00:30	26	41	20	1.333	2.279	1.123
11/13/2016 00:35	25	34	16	1.322	1.867	.857
11/13/2016 00:40	21	35	22	1.112	1.845	1.478
11/13/2016 00:45	27	28	16	1.489	1.524	1.31
11/13/2016 00:50	19	26	21	1.023	1.378	1.268
11/13/2016 00:55	39	42	28	2.1	2.41	1.466
11/13/2016 01:00	24	29	15	1.177	1.688	.933
11/13/2016 01:05	11	27	11	.532	1.422	.833
11/13/2016 01:10	18	34	20	.799	2	1.154
11/13/2016 01:15	20	30	18	1.079	2.1	1.401
11/13/2016 01:20	22	36	19	.977	1.745	1.033
11/13/2016 01:25	23	37	14	1.077	1.978	.933
11/13/2016 01:30	17	24	16	.832	1.243	.922
11/13/2016 01:35	25	35	16	1.255	1.967	1.367
11/13/2016 01:40	17	32	15	.879	1.767	1.244
11/13/2016 01:45	16	23	12	.776	1.322	.622
11/13/2016 01:50	19	29	17	.843	1.613	1.289
11/13/2016 01:55	17	15	12	.855	.767	.533
11/13/2016 02:00	14	21	13	.712	1.145	1.012
11/13/2016 02:05	11	20	9	.544	1.042	.422
11/13/2016 02:10	6	14	12	.289	.722	1.054
11/13/2016 02:15	11	17	11	.566	.89	.666

Granularity

- Key – date/time (5 minute interval
- Alternative Key – more useful in our analysis:
  - Date + Lane
  - Need to stack our data table
  - Need to create a new variable



Faithfulness

- Census of all 5-minute intervals in the time period for all 3 lanes
- Check detector health to see if all working in that time period, missing and faulty values are imputed
- Dependency –
  - percentages between 0 & 100
  - Number of records 12 (intervals/hr) * 24 (hr/day) * 7 day/wk = 2016

Temporality & Scope

- Temporality - One week in November 2016
- Scope – Recordings for some (which?) 5-minute intervals in the time period may be imputed from historical data

Ready for 2nd EDA

Do the 3 lanes serve the same amount of traffic?

When 1 lane is congested, are the other lanes also congested?

What's the relationship between amount of traffic served and congestion?

How are answers to these questions impacted by time of day and day of week?

Distribution of Variable Values

Always a good place to start

Get your head in the game

Distribution of Values

- Rug plots show exact location of values

- This tends not to be useful when we have many values
- Typically, we want a summary of this distribution

Histograms & Density Curves

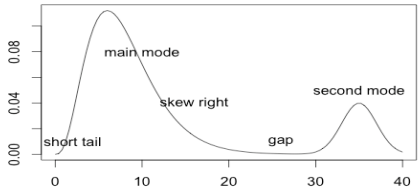
- Histogram bar:
  Height * Width = Area = Proportion (or count)
- Similar property for area beneath a density curve

- No longer see individual values
- Smooth data values over a bin/region (histogram/density curve)
- Focus on the main features of the distribution
- Caution: Smoothing can reveal or disguise features

Features Seen in a Visual Summary

- Mode(s) - values concentrate around particular points
- Symmetry – skew left, symmetric, skew right distribution of values about center
- Tails - long, short, normal (what expect for normal distribution)
- Gaps - regions where no values observed
- Outliers - unusually large/small values

Distribution of Values



What to Expect for Traffic Flow Distribution?

- Skew or Symmetric? Why?
- Long or short tails?
- Number of modes?

Flow Density

?

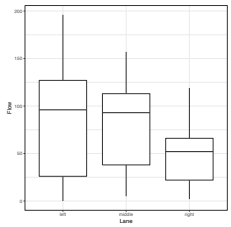
Do the 3 lanes serve the same amount of traffic?

Flow = count of vehicles in 5-minute intervals
Sum flow - left: 11k, center: 13k, right: 8k lanes

Compare Flow Across 3 Lanes

?

Summary Stats for 3 Flow Distributions



- Quartiles
- Skewness
- Longer right tail

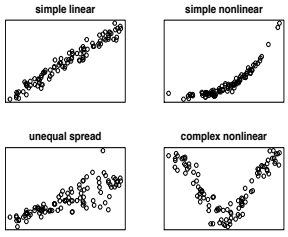
- What don't we see?

How Do Lane Flows Vary Together in Time?

Plotting Pairs of Variables

- Scatter plot uncovers form of relationship between 2 variables
- Linear relationships are particularly simple to interpret
- Simple and elegant statistical theory for linear relationships
- Models are typically approximations, choose a simpler model over a complex one

Plotting Pairs of Variables



Flow in: Middle & Right Lanes and Left and Right Lanes

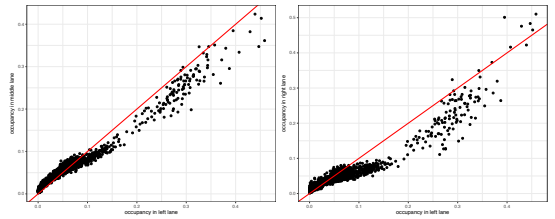
Do we expect:
- flow in two lanes increase together?
- flow in two lanes to be linearly associated?
- Slope to be roughly 1?

Flow in Lanes for the Same 5 Minutes

?

When a lane is congested, are the other lanes congested too?

Occupancy in Lanes for 5 Min. Intervals

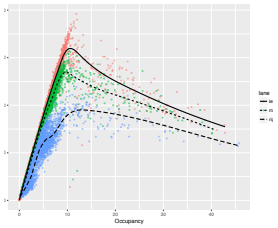


What's the relationship between amount of traffic and congestion?

Flow and Occupancy Pairs

Do we expect:
- flow and occupancy to increase together?
- flow and occupancy to be linearly associated?
- 3 lanes to have the same relationship?

Flow & Occupancy

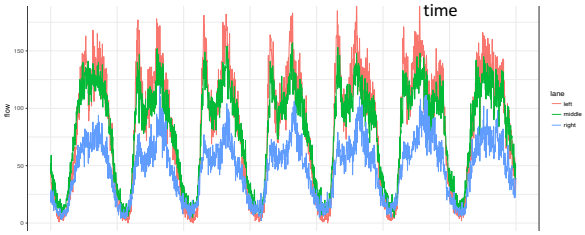


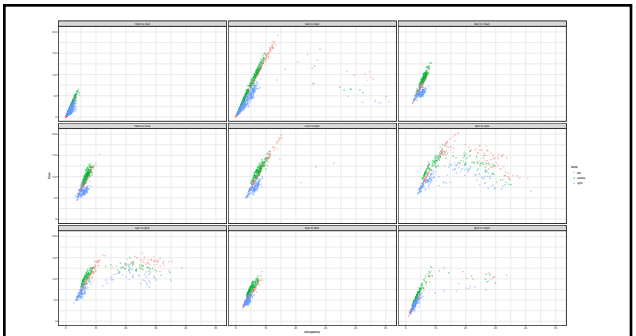
- Flow and occupancy are linearly related for occupancy below 10%
- As occupancy (congestion) increases traffic breaks down and flow decreases
- Breakdown appears to occur at different occupancy levels for the lanes

How are these findings affected by time of day and day of week?

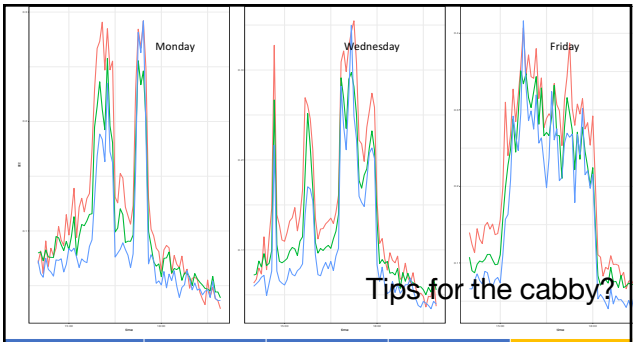
Examine Flow in Time

We want to see flow AND occupancy in time

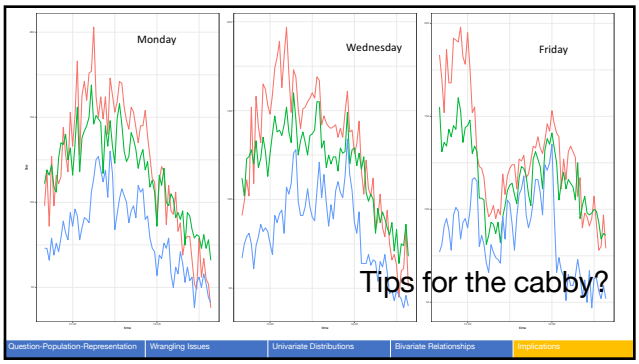




Focus on Certain Times of Day



Tips for the cabby?



Implications for Formal Analysis

- Lane matters – distributions are similar in shape, but locations of peaks and size of spread differ
- Relationship between flow and occupancy is linear until traffic breaks down
- Traffic jams do not have the same relationship, spread increases, negative association between flow and occupancy
- Distinct patterns within a day and for day of week

Question-Population-Representation | Wrangling Issues | Univariate Distributions | Bivariate Relationships | Implications