Introduction to Data Visualization Techniques

Using Microsoft Excel 2013 & Web-based Tools

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Introduction

This exercise provides an overview of basic best practices for tabular data visualization techniques using Microsoft Excel 2013 and various web-based tools. It covers determining the best type of data visualization for one's data, how to create and format charts/graphs in Microsoft Excel, and how to create a word cloud from a variety of information sources.

Choosing the Most Appropriate Type of Chart or Graph for Data Visualization

The first step to visualizing data in graphical form is to determine what type of visualization technique works best for the data. This tutorial presents several types of graphs and charts for data visualization.

Read through the following descriptions to determine which type of graph or chart is most appropriate, and to discover best practice tips for each type of visualization.

I. Summary Tables

Summary tables display data in simple, digestible ways. When data is presented as a summary table, specific values can be emphasized with different techniques. Both raw and processed data may be displayed in a summary table, depending upon the application and emphasis. A summary table should help inform the intended audience about the related work.

Figure 1 depicts a summary table of the 4 major household cooking fuel sources in each of the districts of Phnom Penh province as recorded by the 2008 Cambodian census[1]. This particular summary table highlights the most used cooking fuel source in each district. The use of a summary table allows the viewer to assess data and to note significant values or relationships. In **Figure 1**, the summary table quickly shows the prominent use of firewood in Dangkao District compared to the other districts of Phnom Penh. This table also highlights the overall usage of liquid natural gas as the primary cooking fuel source in the entire province.

Main Cooking Fuel Source, Phnom Penh Districts, 2008[1]

District	Firewood	Charcoal	Liq. Natural Gas	Electricity
Chamkar Mon	1558	5615	25408	602
Doun Penh	803	4400	17458	480
Prampir Meakkakra	502	3103	14361	255
Tuol Kouk	1713	6570	23012	730
Dangkao	18790	6971	10045	325
Mean Chey	8428	14448	27167	721
Ruessei Kaev	7979	9724	14113	519
Saensokh	5355	7090	9905	362
Total	**45128**	**57921**	**141469**	**3994**

Figure 1: This summary table lists Cambodian households' main source of cooking fuel for the districts contained within Phnom Penh province in 2008.

II. Bar Charts

Bar charts use a horizontal (X) axis and a vertical (Y) axis to plot **categorical data** or **longitudinal data**. Bar charts compare or rank variables by grouping data by bars. The lengths of the bars are proportional to the values the group represents. Bar charts can be plotted **vertically** or **horizontally.** In the vertical column chart below, the categories being compared are on the horizontal axis, and on the horizontal bar chart below, the categories being compared are on the vertical axis.

Bar Graphs for Categorical Data

Bar charts are useful for ranking **categorical** data by examining how two or more values or groups compare to each other in relative magnitude, at a given point in time.

Figure 2 shows both a vertical column chart and horizontal bar chart representing the same data. **The vertical column chart** measures the categorical data (household light source) at one point in time and "ranks" the categorical data so that it is easy to compare values between the various light sources in 2008. This **horizontal bar graph** represents the same data, but shows an alternative method for visualizing categorical data at one point in time.

Cambodian Households' Main Source of Light, 2008[1]

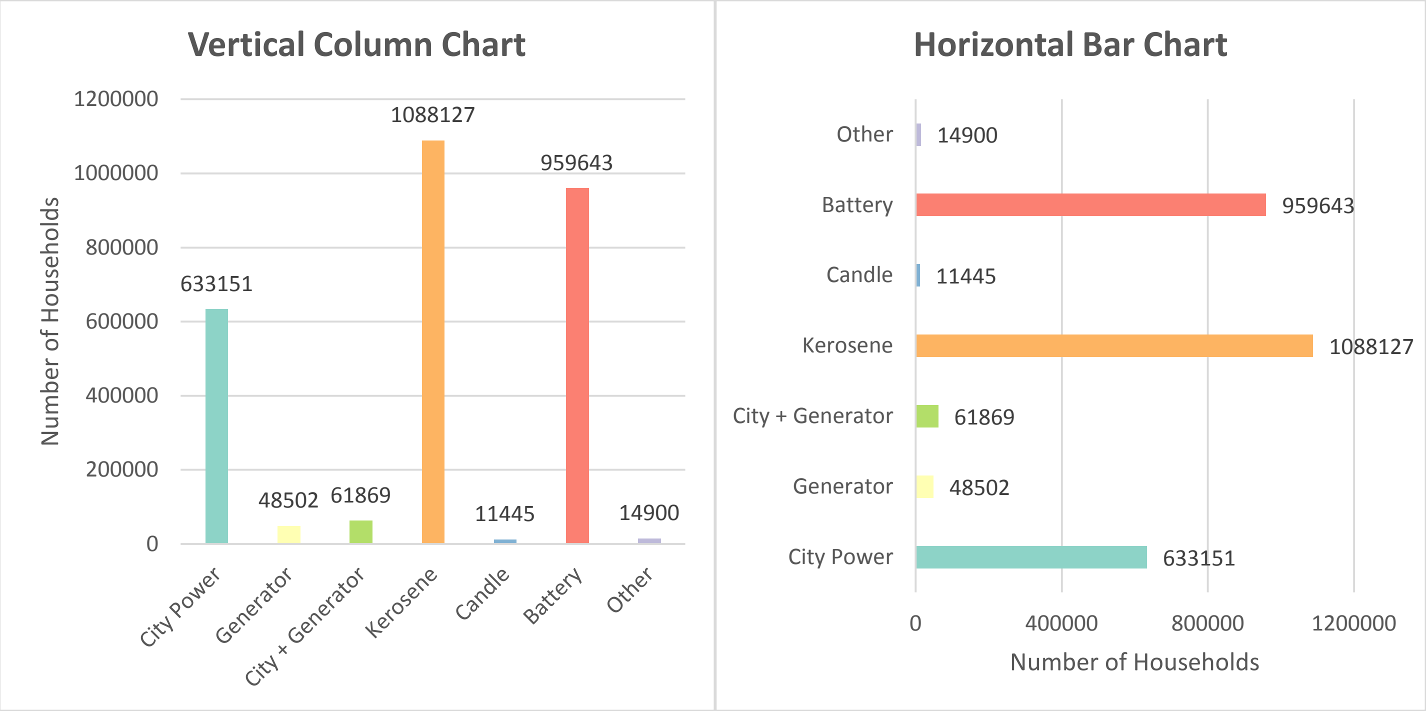


Figure 2 shows both a vertical column chart and horizontal bar chart that displays the main source of light for each Cambodian household in 2008.

Bar Graphs for Longitudinal Data

Bar charts can be used to represent **longitudinal data** repeated over time to help identify temporal trends and patterns. **Figure 3** examines a single variable (number of Trunk Website views) for the entire 2014 calendar year by month. It allows the viewer to see temporal trends in the single dataset, such as high use during the school months and low use over the summer break.

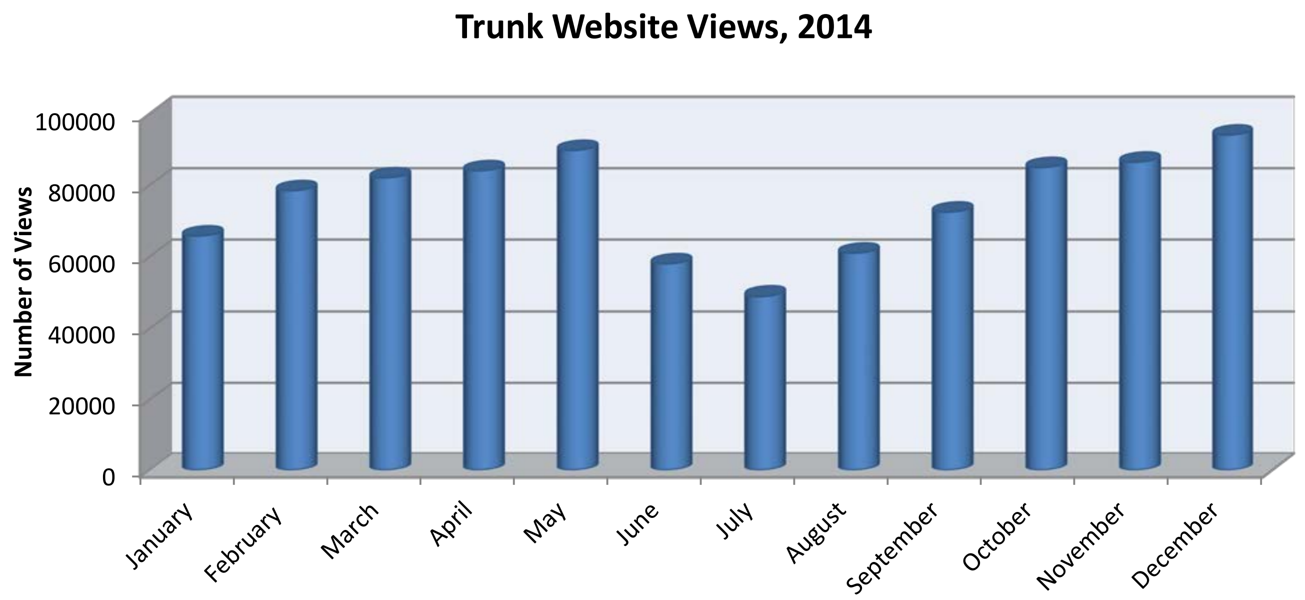


Figure 3: Total number of Trunk Website views for 2014.

Stacked Bar Charts vs Clustered Bar Charts

Stacked bar charts are useful when the sum of all the values is as important as the individual categories/groups. Stacked bar charts show multiple values for individual categories, along with the total for all of the categories combined.

While stacked graphs are helpful for conveying multiple levels of meaning simultaneously, they also have some limitations. While it's easy to interpret the values for the total bar and the first group of the bar, it is challenging to quantify the values for subsequent groups (strips) in the same bar, or to compare the groups within the same bar. [2]

Clustered Bar Charts display categorical data next to each other, rather than stacked in the same bar, in order to easily compare values between groups.

Bar charts can effectively display **raw data** over time. **Figure 4** demonstrates two methods for displaying the number of Cambodian households in a district using a particular cooking fuel source. In the **Stacked Bar Chart,** each bar represents the total number of households in each district, with each color representing the number of households using a type of fuel source. This method shows how the total number of households varies by district, but is less effective at comparing the actual numbers for each fuel source over all districts. In the **Clustered Bar Chart,** the same data is depicted, but the cooking fuel sources are clustered next to each other. This allows for group comparisons over multiple districts, but makes it more challenging to see how the total number of households vary.

Main Cooking Fuel Source, Phnom Penh Districts, 2008[1]

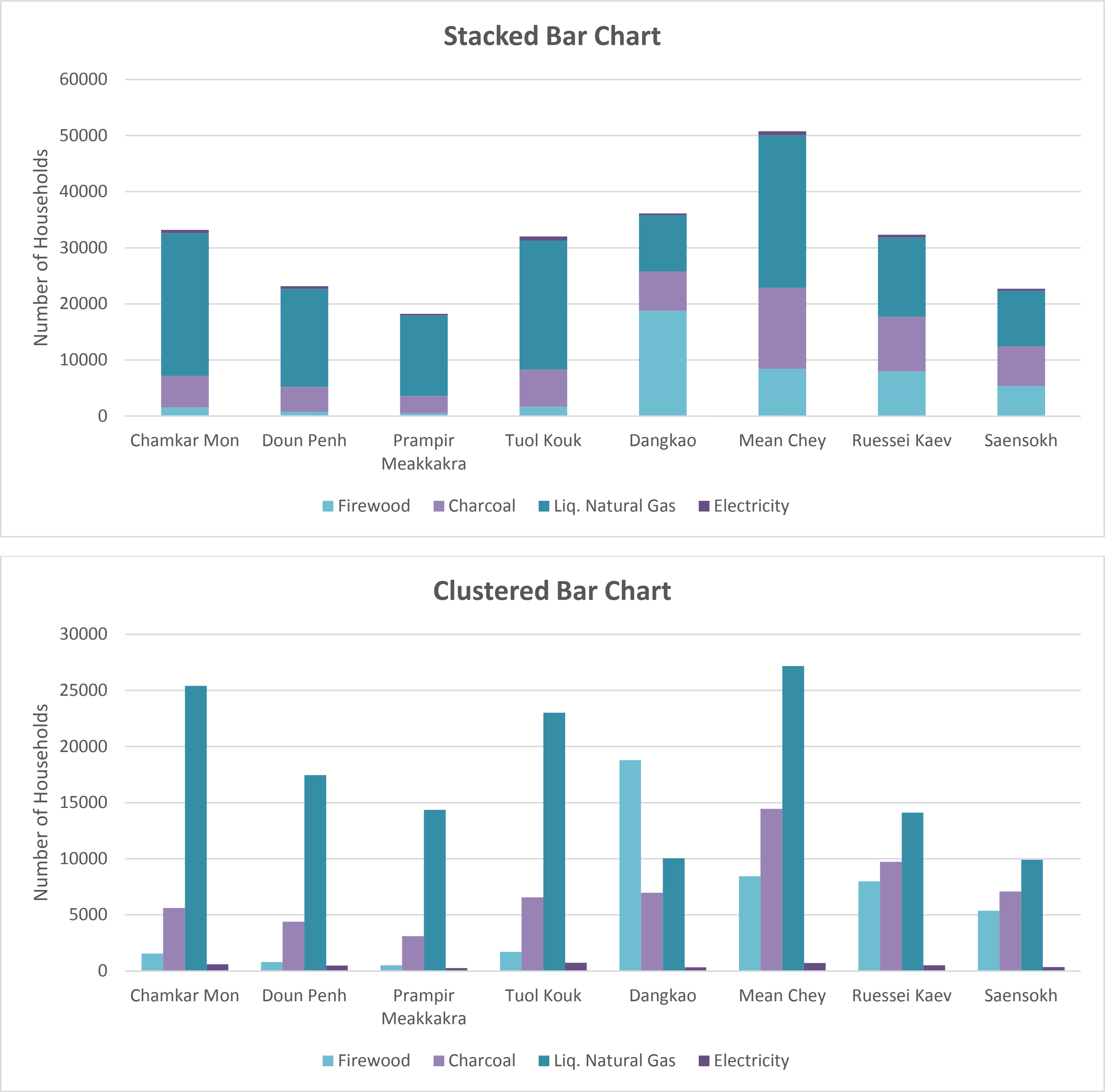


Figure 4: These two bar charts display Cambodian households' main source of cooking fuel for the districts contained within Phnom Penh province in 2008.

III. Pie Charts

Pie charts are useful for cross-sectional visualizations, or for viewing a snapshot of categories at a single point in time. Pie charts divide categories into slices to illustrate numerical proportions of a whole, typically out of 100%. This data is usually only measured once. One challenge with pie charts is the ability to compare the numerical values of each group.

Figure 5 visualizes the Cambodian 2008 census survey results of each household's main source of light again. This is the same data used in the above example of horizontal and vertical bar charts, but this time the visualization emphasizes the relative use of each light source and obscures the total number of households using each light source.

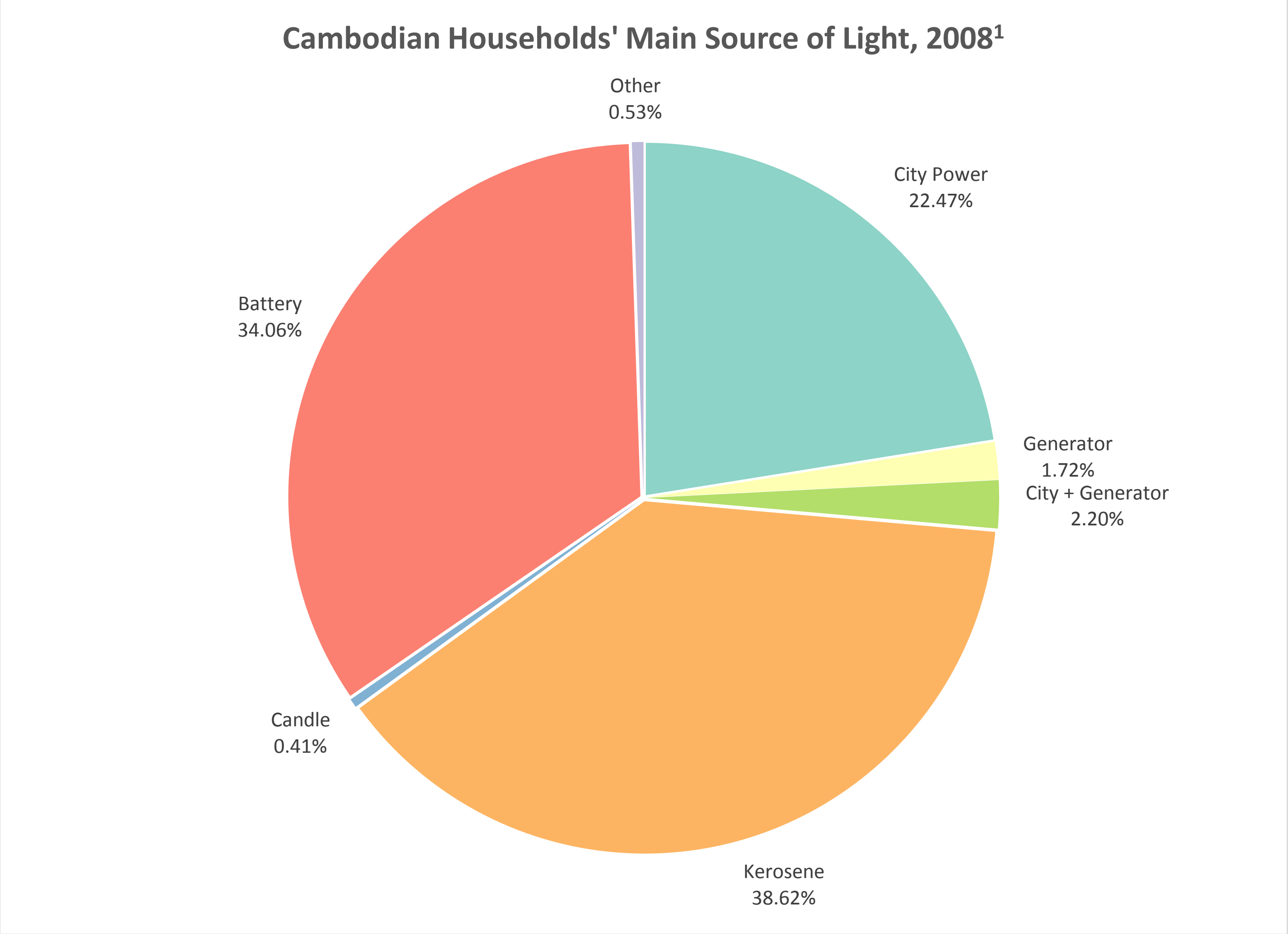


Figure 5: The pie chart above depicts household light sources according to the 2008 Cambodian census.

IV. Histograms

Histograms are a graphical representation of the distribution and frequency of numerical data. They show how often each different value occurs in a quantitative, continuous dataset. Histograms group data into bins or ranges to show the distribution and frequency of each value. **Figure 6** shows a standard histogram of a grade distribution on a final exam. Here the grades are grouped into "bins", rather than displaying each individual grade.

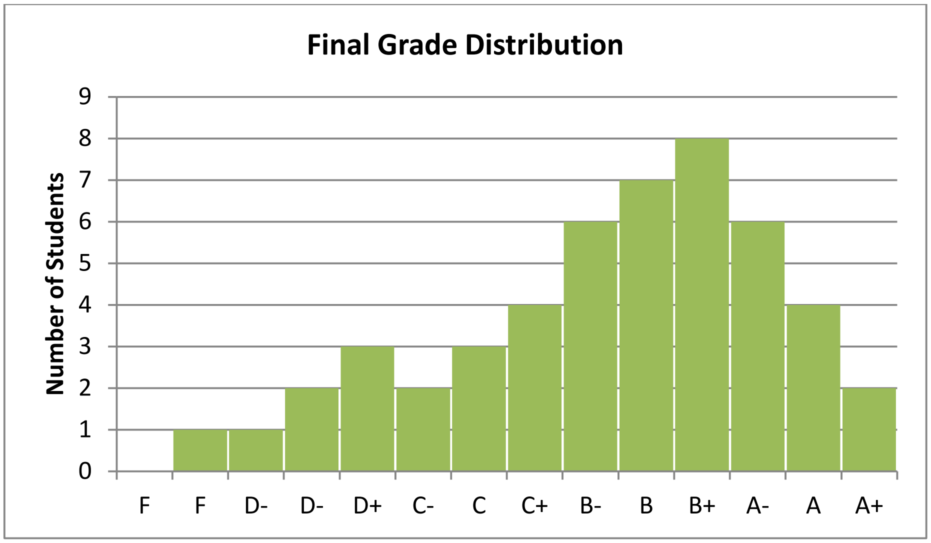


Figure 6: Histogram of Final Exam Grades

For Reference: How to make a histogram chart in Excel

1. Activate **Data Analysis** Add-Ins if it is not on already. Go to File → Option → Add-Ins
2. Under Add-Ins, find **Analysis ToolPak** and hit **Go...** This will activate the add-in.
3. If an Add-Ins window pops up, check Analysis ToolPak and hit OK.
4. Start with a list of all values in one column; for this example it would have been all the final grades.
5. In another column, create a **bin** table which will be used to group values into a frequency table.
6. Group the values by letter grades, so each "**bin**" would be the value associated with a particular letter grade.
7. Click on the **Data Analysis** icon under the **Data t**ab and select **Histogram.**
8. In the **Input Range,** select all the individual grade values, including the title of the column.
9. In the **Bin Range,** select the bins ranges.
10. Check the Labels button and press **OK**, creating a **Frequency Table,** showing the number of grades within ranges.
11. Edit the Bin values as necessary. For example, in the above histogram 60 - 63 was changed to a D-.
12. Highlight the data and headings and click on the **Insert Tab** and select **Column Bar Chart**.
13. To remove the gaps, right click on the bars and select **Format Data Series.**
14. Under **Series Options,** move the Gap Width slider to no gap.
15. Press close.

For a helpful video on setting up a histogram in Excel, check out this YouTube video.

V. Line Graphs

Line graphs are a commonly used visualization technique that use horizontal (X) and vertical (Y) axes to map **quantitative**, **independent** or **dependent** variables. Like scatter plots below, line graphs record individual data points; however, line graphs connect each data point together to determine local change from one point to the next. Line graphs are often used to display time-series relationships by tracking changes in continuous data, using equal intervals of time between each data point.

Figure 7 shows a time-series relationship between infant mortality rates (IMR) and five-year time spans in Ghana[3]. This graph shows that there is a negative relationship between the two variables. A line graph is used because the desired goal is to visualize the change in infant mortality rate from one time range (point) to the next.

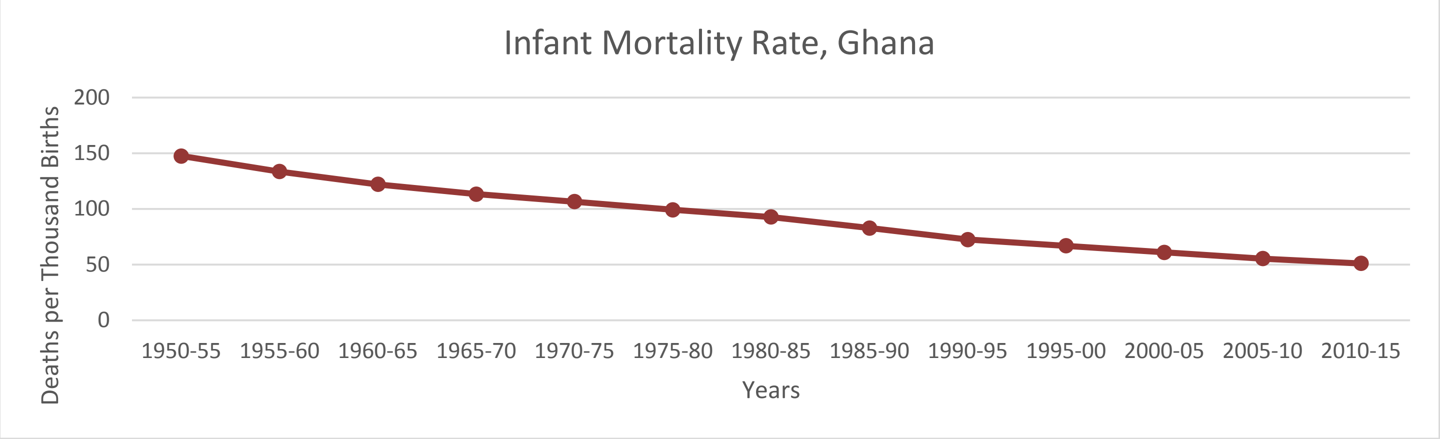


Figure 7: Infant Mortality Rate in Ghana 1950-2015.

When to use a Line Graph

Line graphs allow a quick assessment of acceleration (lines curving upward), deceleration (lines curving downward), and volatility (up/down frequency). Line graphs can also be used to show and **compare several groups or variables over the same metric of time** to see any correlation in trends[4].

Figure 8 illustrates the change in IMR in Ghana from 1950-2015, along with the change in infant mortality rate for the other countries in the western half of the Volta river basin. This eases the comparison of the overall decline in IMR of the four countries over time.

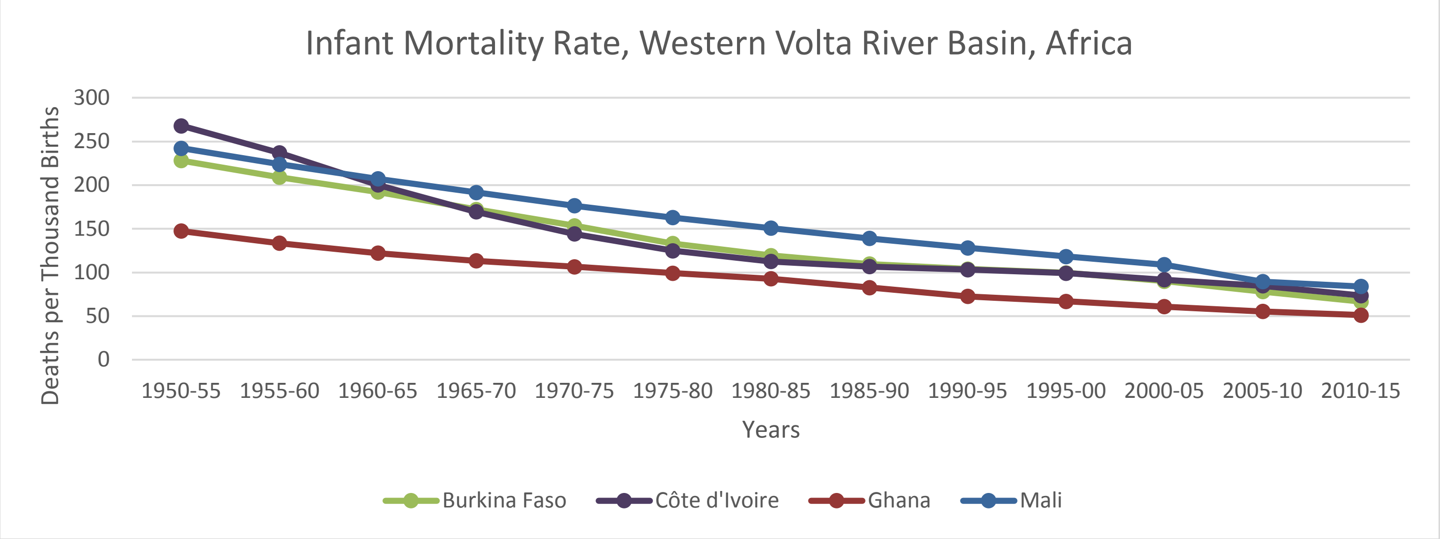


Figure 8: The change in infant mortality rate in the western part of the Volta River Basin from 1950-2015.

VI. Scatter Plots

Scatter plots use horizontal (X) and vertical (Y) axes to plot **quantitative**, **independent**, or **dependent variables** in order to visualize the correlation between two variables. Scatter plots are similar to line graphs in that they graph quantitative data points; however, scatter plots do not connect individual data points with a line but instead express a trend. This trend can be represented through the distribution of points or through the addition of a trend line/regression line[5].

Figure 9 depicts the relationship between the illiterate population and marginal workers for a town in India[6]. Within this depiction a positive correlation exists between these two variables. If the illiterate population (the independent variable) increases, there is a linear increase in the marginal worker population (the dependent variable).

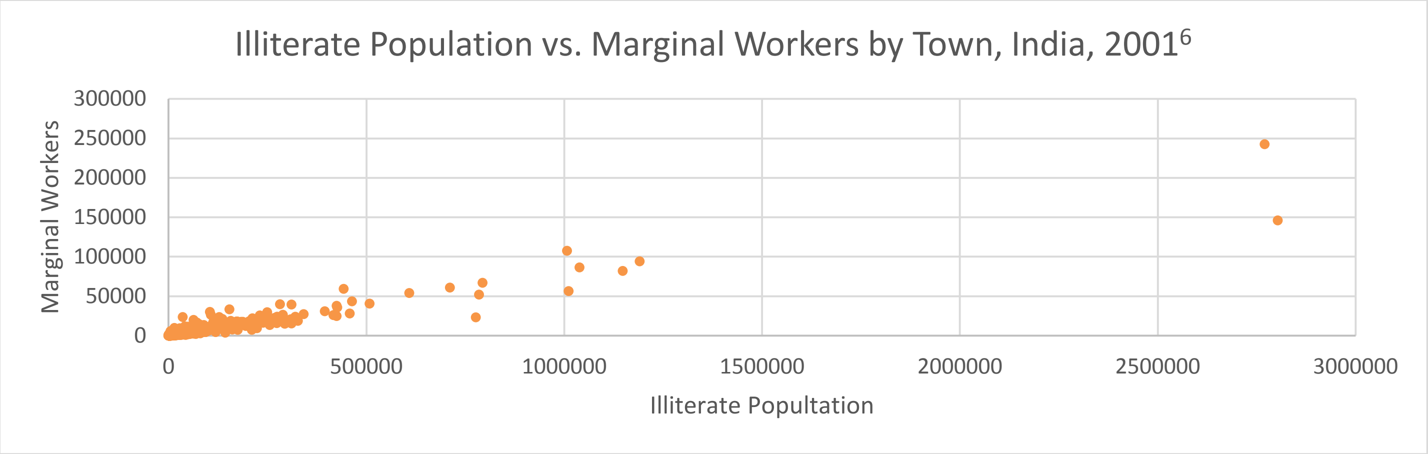


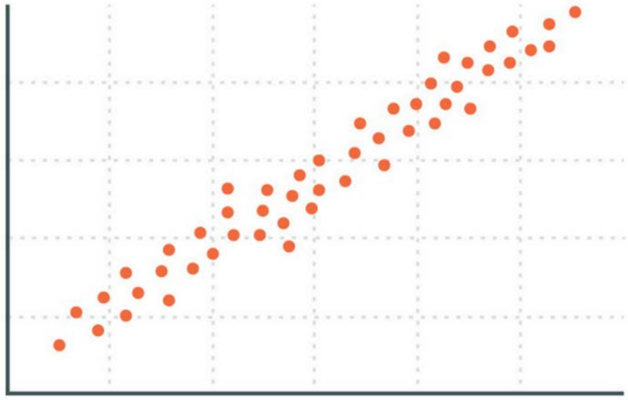
Figure 9: The relationship between a town's illiterate population vs. marginal workers, India, 2001.

When to use a Scatter Plot

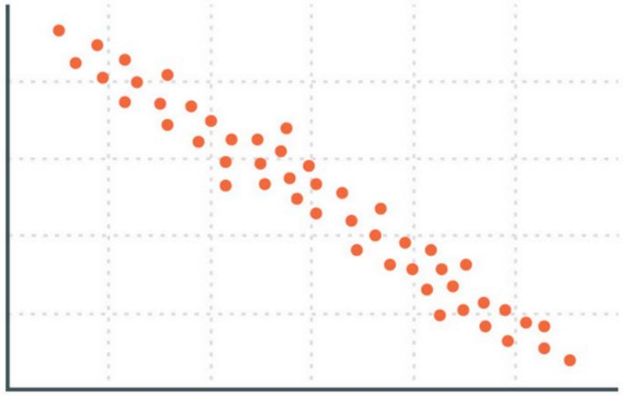
Unlike other charts, scatter plots have the ability to show trends, clusters, patterns, and relationships in a cloud of data points – especially a very large dataset.

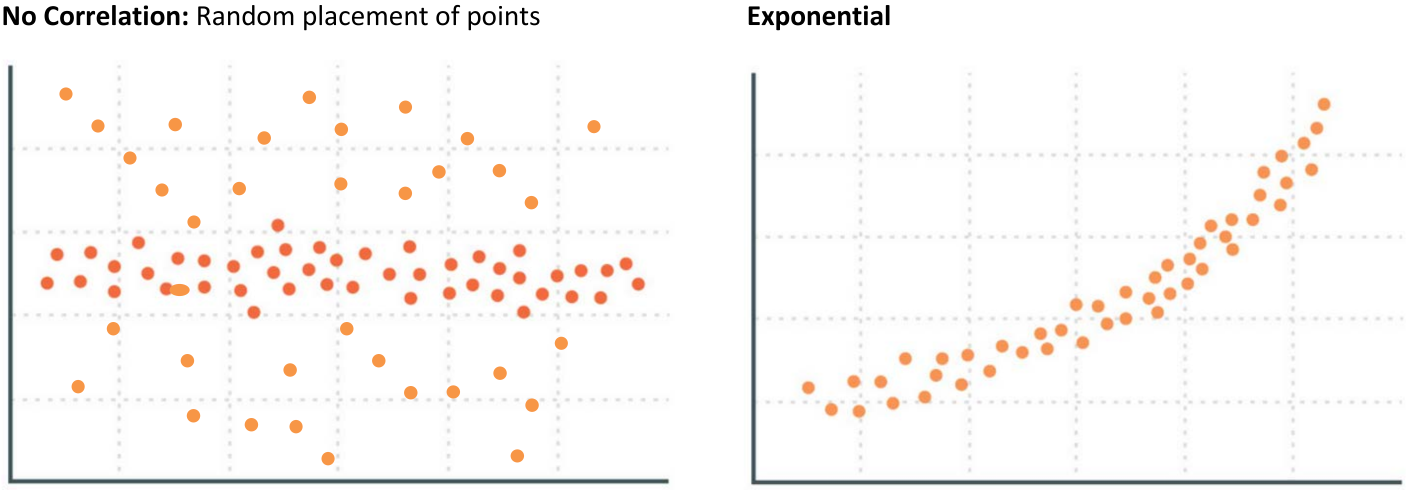
Types of Correlation[4]:

Positive Linear Correlation: Both values increase in unison



Negative Linear Correlation: One increases while the other decreases





No Correlation: Random placement of points

Exponential

Figure 10: Examples of different types of correlation trends.

Note: It's important to remember that **correlation does not always equal causation**, and other unnoticed variables could be influencing the data in a chart.

When to use a Trend Line or Regression Line

Trend lines can help visualize correlations between the variables. A **regression line** could be added, which is a calculated "best fit" line through the data points. There are many trend line options, including linear, exponential, logarithmic, polynomial, power, or moving average. Regression lines can help **interpolate** and **extrapolate** datasets for predicting values outside of observed data.

In addition to adding a regression line, you can add in its **R-squared value**, which is a statistical measure of how close the observed data are fitted to the regression line. R-squared is always between 0 and 100%. 0% indicates that the model explains none of the variability of the response data around its mean. 100% indicates that the model explains all the variability of the response data around its mean. In general, the higher the R-squared, the better the model fits the data.

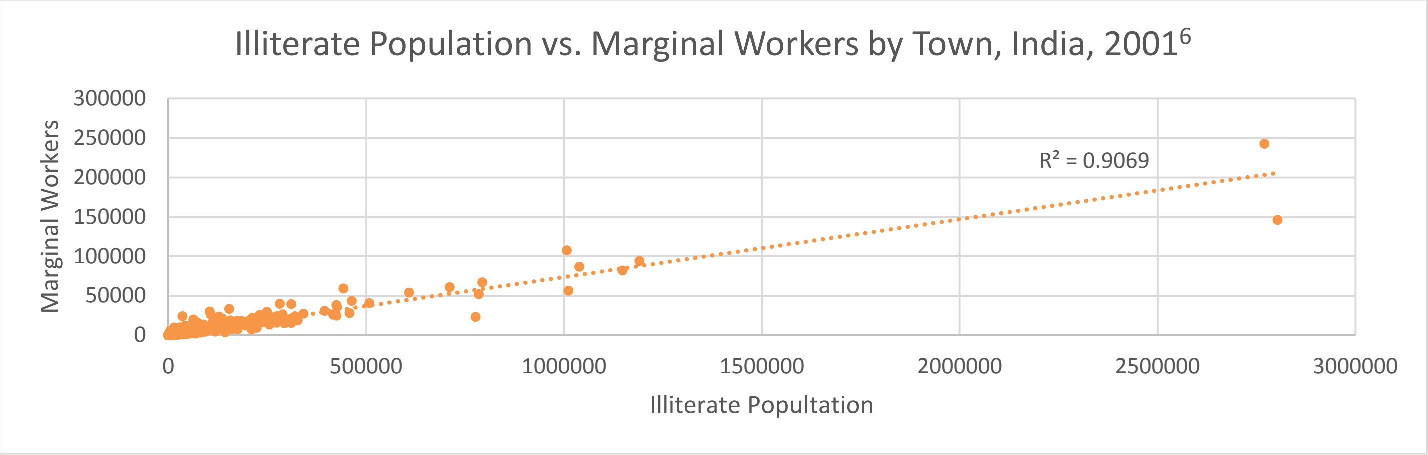


Figure 11: Trendline and R^2 for relationship between a town's illiterate population vs. marginal workers, India, 2001.

In this example, a **Linear Regression Line (or trend line)** has been added to the data and the R^2 value of .9069 or 90.69% is displayed. This is a relatively high R-squared value, meaning that this model is a good fit. See below on directions for adding a trend line.

How to add a trend line to data in Excel:

1. Left click on the data points in the chart to select them then right click → Select **Add Trendline…**
2. Under **Trendline Options**, select the most appropriate trend/regression type.
3. To show the R-squared value, check the last box to "Display R-squared value on Chart".

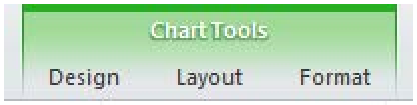
How to Create a Graph/Chart in Excel

1. Open to the sheet containing the data.
2. Organize the data so each variable is in a separate column. Highlight the data that will be included in the graph.
3. On the top menu bar, select **Insert** → **Charts** → select the desired type of graph.
4. A graph will be inserted into the current *Sheet* in Excel.
5. To put the chart in its own sheet, press the **Move Chart** icon (or right click on the chart and press **Move Chart)** and select **New Sheet.**
6. Enter a name for the **New Sheet.**

How to Style a Graph/Chart in Excel

It is important to include all necessary elements of a chart, so the reader is able to understand the data.

1. When one clicks on a chart, there are many formatting options under **Chart Tools** on the top menu bar.



2. First, go to the **Design** tab to determine the design of the chart. Select a *Chart Layout* and a *Chart Style.* Chart Layouts include various elements of a chart (labels, legends, titles, axis, etc.) depending on the style chosen. Elements can also be added individually. Chart styles determine the size and design of the points.
3. Make sure the graph is given an appropriate title. Click on the title of the scatter plot to change the title. To format the title, double click in the title box or click on the **Format** tab on the main menu. Here one can add a background *fill*, add a *border color* or *border style*, adjust the *alignment*, and much more. To format the text, right click in the text box to pull up size, font, and color options. If there is no chart title to begin with, under the **Design** tab click *Add Chart Element* → *Chart Title* and then select the desired position.
4. Next, it's important to make sure the **Axes** are labeled and include information on the units. If the labels are not already created, go to the **Design** tab and add them by selecting the axis needed from *Add Chart Element* → *Axis Titles.* If the axis labels are not adequate, double click on the *Y Axis* label and give it an appropriate label. Then, click on the *X Axis* label and do the same. Again, one can format the labels by double clicking or selecting the **Format** Tab at the top. To adjust size and font, right click on the label.
5. Legends are important to making sure the visualization is easy to understand. With a single dataset (such with a line graph or a bar chart with one variable), a legend is most likely not necessary. If a graph has multiple groups or categories, such as a stacked or clustered bar chart, then make sure to include a legend. This can be done in the Layout Tab. Here, the location of the legend can be chosen as well.
6. In general, right clicking on an element of a chart will pull up its properties. Here, one can change the format styles, along with several other options.

How to Export a Graph/Chart Created in Excel

Charts created in Excel can be exported to other software packages such as Word, PowerPoint, Publisher, ArcGIS, and InDesign. Depending upon the software, different methods may be required.

1. In other Microsoft products (including Word, PowerPoint, and Publisher), a chart can be copied directly. The chart will retain all data and formatting. It can continue to be styled in any of these products the same way as in Excel described above. To copy a chart, make sure the chart itself (rather than any of the elements contained within the chart) is selected before copying.
2. In ArcGIS, a chart can be copied into either **Data view** or **Layout view** with a simple *Copy* in Excel and *Paste* in ArcGIS. Unlike charts copied into Microsoft products, this copied chart will be an image. All changes and styling must be completed in Excel before copying.
3. In Adobe InDesign, a chart can be copied from Excel and pasted into a layer. Similar to ArcGIS, the copied chart will be an image, so all editing should be completed before copying.

Introduction to Word Clouds/Tag Clouds

Similar to a histogram, word clouds represent the frequency of certain words, terms or expressions. Unlike histograms, word clouds use **categories or terms from text**. They show the frequency of terms used in a paragraph, RSS feed, or other block of text by scaling the size of the terms and color to highlight the frequency of occurrence.

Unlike the other techniques for displaying information, word clouds are not easy to create in Excel; however, many web-based generators exist to create colorful and informative word clouds.

Figure 12 is a word cloud of the location of over 17,000 incidents in the *Armed Conflict Location and Event Data Project* (*ACLED*) database for 1997-2015 in Somalia[7]. This word cloud shows that the location with the most incidents over this time period was Mogadishu and scales all other incident locations to reflect their frequency in the database.

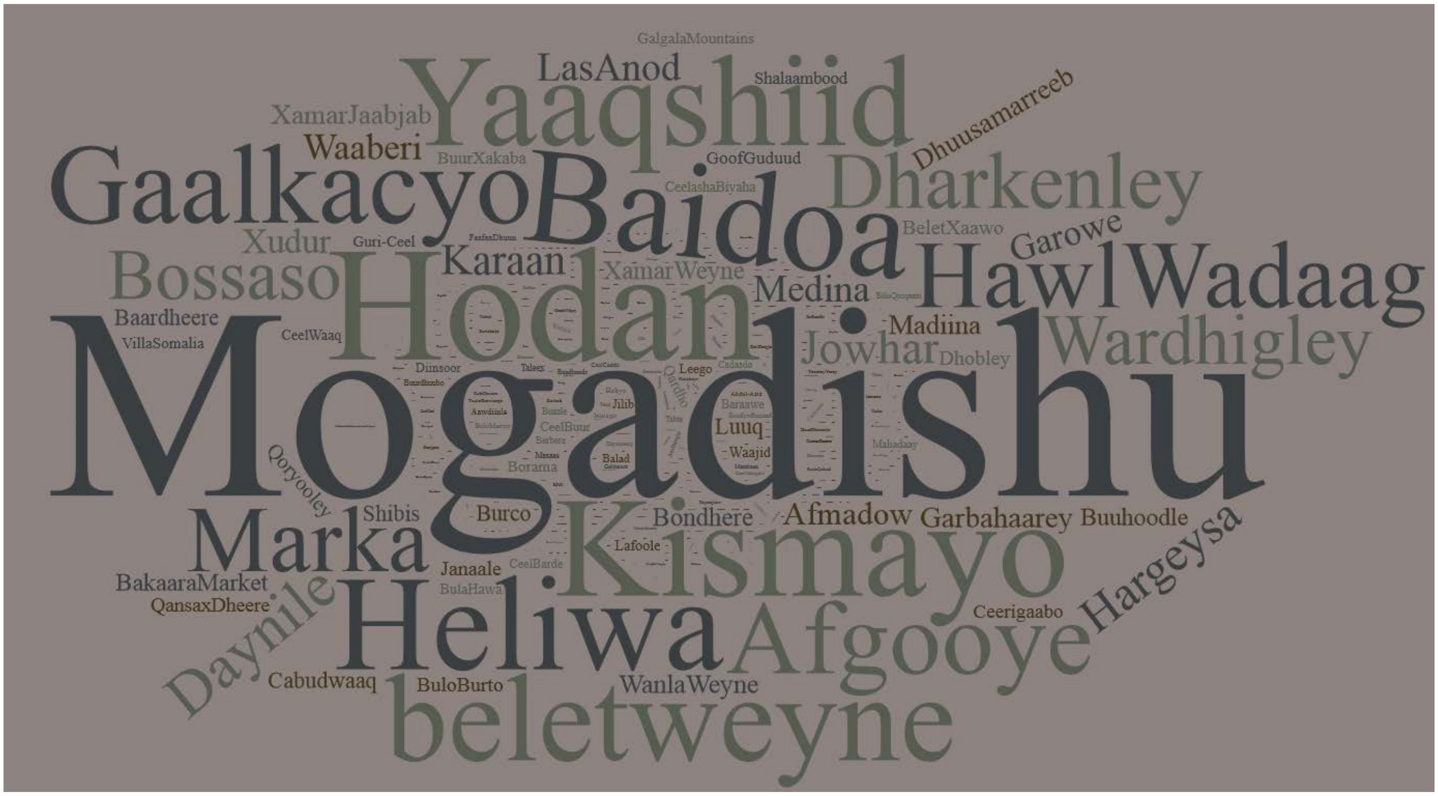


Figure 12: *ACLED* incident locations in Somalia 1997-2015.

When to Use a Word Cloud

Word clouds are useful to **qualitatively** display the frequency of many categories or terms within a large body of text or data. They are helpful when a dataset **has many categories or terms** beyond those that can easily be summarized in other charts or when using **unstructured data**. Unstructured Data refers to information that either does not have a pre-defined data model or is not organized in a pre-defined manner. Unstructured information is typically text-heavy, but may contain data such as dates, numbers, and facts as well. An example of unstructured data is a news article, report, journal article, etc.

How to create a Word Cloud using a generator on the web

1. Copy the desired spreadsheet column or document text.
2. Navigate to http://timdream.org/wordcloud/
3. In the popup, scroll down to the *Copy & Paste* option on the left-hand side and click it.
4. Paste the text into the text box that appears and click *Start* in the lower right corner.
5. Click the *Edit List* button and remove some commonly-used words in order to highlight more significant words or phrases. Click *Confirm* to regenerate the new word cloud.
6. Try exploring different styles using the various tools at the top.
7. The *Save* button allows one to save the word cloud graphic as PNG image file.
8. To create a new word cloud, use the *Back* button on the top left.

Excel Exercise

Exercise data is located **S:\Tutorials & Tip Sheets\Tufts\Tutorial Data\Introduction to Data Visualization**
Use the ***DataVisualization_ExcelExercise.xlsx*** *file* to create the following charts and graphs using the instructions provided within the ***How to Create a Graph/Chart in Excel*** section above. Be sure to include appropriate titles, legends, axis labels, etc. Note how to export your chart or graph into MS Word, PowerPoint, Publisher, ArcGIS, or Adobe InDesign.

1. Using the “Cambodia (Light)” sheet, create a **vertical bar chart** of the main sources of household light in Cambodia.
2. Using the “Phnom Penh (Cooking Fuel)” sheet, create a **stacked bar chart** of each district’s main sources of cooking fuel.
3. Once again using the “Cambodia (Light)” sheet, create a **pie chart** of the main sources of household light in Cambodia.
4. Using the “Volta Basin (Infant Mortality)” sheet, create a **line graph** of the infant mortality rate in these West African countries.
5. Using the “India Towns” sheet, create a **scatter plot** of the relationship between illiterate population and marginal workers for Indian towns. Use the instructions if you get stuck, also add in a **trend line** and display the R^2 value.

Note: The graphs of 1-5 can be checked by looking at the examples in this tutorial.

Word Cloud Exercise

Exercise data is located **S:\Tutorials & Tip Sheets\Tufts\Tutorial Data\Introduction to Data Visualization**
Use the instructions provided within the ***How to Create a Word Cloud Using a Generator on the Web*** section above to create the following word clouds from the different sources of information.

1. Using the “Somalia (ACLED)” sheet provided within ***DataVisualization_ExcelExercise.xlsx***, and the http://timdream.org/wordcloud/ application, create a **word cloud** of the incident locations in Somalia between 1997 and 2015.

2. With the same generator, create a word cloud from the PDF provided of the UN Secretary-General's Monthly Report on the Implementation of the Resolutions by All Parties to the Conflict in the Syrian Arab Republic[8].
3. Copy all the text from the PDF and paste it the same way as Excel. This is an example of unstructured data visualized in a word cloud. Use the *Edit List* button to remove insignificant commonly used words to better highlight the meaningful terms. Try switching themes.
4. With the same generator, create a word cloud using a *Reuters Africa* country level RSS news feed found here: http://af.reuters.com/tools/rss . Select a country. Then click the "View Feed XML" button. Copy and paste the new URL. In the word cloud generator site, click *RSS Feed.* Paste the RSS feed URL into the site and click *Start*. Use the *Edit List* button to remove "Reuters" and "Jan" and any other commonly used words to better highlight the meaningful terms.
5. Try using a global events web-based word cloud generator such as the *Global Database of Events, Language, and Tone (GDELT).* Read an overview of *GDELT* here: http://gdeltproject.org/#intro
6. Next, create your town word cloud here: http://analysis.gdeltproject.org/module-gkg-wordcloud.html.

Resources

Data 101 Series. http://visage.co/category/data-101
A series of tutorials on best-practices of data usage and visualization techniques.

Color Advice for Maps. http://colorbrewer2.org
A diagnostic tool for evaluating the robustness of individual color schemes.

Global Database of Events, Language, and Tone (GDELT). http://www.gdeltproject.org
A database and visualization platform of broadcast, print, and web news that identifies the people, locations, organizations, counts, themes, sources, emotions, counts, quotes and events.

Web-based Word Cloud Generators

Timdream - http://timdream.org/wordcloud

Tagul - https://tagul.com

Tagxedo - http://www.tagxedo.com

Additional Visualization Tools

Visualizing Data - http://www.visualisingdata.com/resources

Data Visualization - http://selection.datavisualization.ch

"Chart Choosers"

Juice Analytics - http://labs.juiceanalytics.com/chartchooser/index.html

Extreme Presentation - http://extremepresentation.typepad.com/blog/2006/09/choosing_a_good.html

Data Visualization Fundamentals

Lynda - http://www.lynda.com/Design-Infographics-tutorials/Data-Visualization-Fundamentals/153776-2.html?org=tufts.edu

Data Visualization for Data Analysts

Lynda - http://www.lynda.com/Excel-tutorials/Data-Visualization-Data-Analysts/178123-2.html?org=tufts.edu

[1] Royal Government of Cambodia. General Population Census of Cambodia, 2008. Phnom Penh, Cambodia: National Institute of Statistics, 2010.

[2] Stacked Graph. (2014, October 1). Retrieved January 2016, from http://betterevaluation.org/evaluation-options/stacked_graph

[3] United Nations Population Division. Department of Economic and Social Affairs. Infant Mortality Rate. New York, New York. United Nations Environment Programme, 2015. http://geodata.grid.unep.ch/options.php?selectedID=776&selectedDatasettype=1

[4] Starr, B. (2015, January 05). Data Visualization 101: Line Charts. Retrieved January 2016, from http://visage.co/data-visualization-101-line-charts

[5] Carter, M., Wiebe, E. N., & Ferzli, M. (2015, May 15). Graphing Resources. Retrieved January 2016, from https://www.ncsu.edu/labwrite/res/gh/gh-linegraph.html

[6] ML InfoMap. IndiaMap: Town Socio-Demographic. New Delhi, India: ML InfoMap, 2001.

[7] Raleigh, Clionadh, Andrew Linke, Håvard Hegre and Joakim Karlsen. 2010. Introducing ACLED-Armed Conflict Location and Event Data. Journal of Peace Research 47(5) 651-660.

[8] United Nations Security Council Report. Report of the Secretary-General on the Implementation of Security Council Resolutions 2139 (2014), 2165 (2014), 2191 (2014) and 2258 (2015). Retrieved January 2016, from http://www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/s_2016_60.pdf