PRIMER ON
INFORMATION DESIGN FOR EFFECTIVE
DOT DECISION-MAKING

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on Planning

Prepared by:

William Schroeer, PI
ICF International
Fairfax, VA

June, 2006
Acknowledgements

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of National Cooperative Highway Research Program (NCHRP) Project 08-36. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 08-36 is intended to fund quick response studies on behalf of the AASHTO Standing Committee on Planning. The report was prepared by William Schroeer and colleagues at ICF International. The work was guided by a task group chaired by Mary Lynn Tischer, Virginia DOT, which included Missy Cassidy, Maryland DOT; Alison S. Lebwohl, Wisconsin DOT; and David Lee, Florida DOT. The project was managed by Ronald D. McCready, NCHRP Senior Program Officer.

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1 Introduction

State Departments of Transportation (DOTs) are collecting, storing, and analyzing unprecedented amounts of data, from highly local traffic flow data to environmental data covering vast regions, taking advantage of information technology advances to enhance their ability to carry out their missions. In an era of performance-based management and demand for transparency and accountability, communicating the content of this data, and how it informs complex topics, has become an essential part of how DOTs now conduct business. Effective graphic depictions of quantitative information matter more than ever.

DOTs are striving to make sense of information they collect about travel conditions and transportation system performance, as well as to convey the conclusions they reach about the data to decision-makers, including the public, in order to build and maintain support for the strategies they develop to respond to these conditions. Depicting data graphically is an efficient and powerful way of conveying and making sense of information.

Graphics need careful design to be genuinely informative. Information graphics are sometimes created purely as a way to add visual interest, serve as decoration, and break up a sea of text. Graphics’ first purpose must be to help the reader understand the topic at hand. Further, if not carefully constructed, graphics can unintentionally misrepresent the information being conveyed, distorting data to suggest patterns and relationships that do not accurately reflect the underlying data.

Designed effectively, graphics can convey large amounts of information more quickly and effectively than text alone. In many cases, graphics are the only way to convey large amounts of information: a picture is worth a thousand words, and in most cases many more. Properly designed depictions of information both reveal and communicate trends, patterns, and correlations. Good graphics do their job without losing their decorative function; information graphics can be both beautiful and informative.

This Primer aims to educate and guide transportation professionals as they create information graphics for documents and presentations.

1.1 Data for Reference versus Information Design

With the explosion in the amount of data that society—including DOTs—collects, “information design” has become a popular topic for debate and discussion. All information is designed in one way or another, so what does “information design” mean, and what are its implications for organizations like DOTs? Where does “data” stop, and “information” begin? Chapter 2 gives a brief introduction to the substantial literature on these questions. This Primer takes as its point of departure the most basic question that people who work with data must answer: am I organizing this data to be used as a reference, or to help communicate? Both purposes are fundamental to the missions of DOTs. Communication, specifically, communication in support of decision-making, is the focus of this Primer, and organizing and presenting data to serve that purpose, is what this primer calls “information design”.

The fundamental information design question

Am I organizing this data to be used as a reference, or to help communicate in support of decision-making? All design decisions flow from the answer.
The decision how to organize a simple chart exemplifies this distinction between reference and communication in support of decision-making. Do you choose:

- an ordering that makes it easy to find data, or
- an ordering that communicates or reveals something about the data itself?

The most obvious example of this question is the decision whether to organize information alphabetically, or in some other way? This chart works as a reference:

**Crashes per Billion Ton-Miles in Each State, as Percent of National Average**

The states are listed alphabetically, so it is easy to look up whether a state is above or below the national average, and by how much. The text in the document from which this example is taken also explains that the black bars indicate states allowing gross vehicle weight of greater than 80,000 pounds in normal operation.

Applying a different design to the same data produces a chart that reveals something about the data, and so communicates.

**Crashes per Billion Ton-Miles in Each State, as Percent of National Average**
It is a little more difficult to use the second chart as a reference—one might have to spend a minute finding a particular state—but it is far more useful as an aid to decision-making. It becomes immediately clear, for example, that of the eleven states which allow gross vehicle weight greater than 80,000 lbs, eight have crash rates that are lower than the national average. This way of displaying the data—that is, this information design—shows much more clearly that allowing trucks of this weight does not seem to lead to significantly higher crash rates.

A single chart should not and will not in most cases be the basis for answering an important question such as, “do higher weight limits cause more crashes?” but it helps the reader to use the data to explore the question, in a way that a reference chart containing the same data does not.

This distinction between reference and communication is at the core of information design.

Both “reference” and “communication” imply use by, or with, other people. Both of these are distinct from data analysis, which should precede either reference or communication. Good information design organizes data so that other people can draw conclusions from it. This is distinct from an analyst trying out different ways of looking at data so that the analyst herself understands it. None of the guidelines in this Primer should be taken to mean that one should not try looking at data in a variety of ways on the way to understanding it. The goal of this Primer is to help DOT staff present information in the most useful way once that data has been understood.

Good graphics can combine both reference and decision-making purposes. This Primer is organized primarily to help state DOTs design information to support decision-making.

1.2 Information Design by and for DOTs

This Primer focuses on the types of information and graphics most useful and relevant to transportation agencies. When possible, examples have been chosen to demonstrate design for such information as: population projections, funding levels; travel behavior; traffic volumes; performance indicators; geographic features; accident data; organizational structures; and planning processes.

In order to focus as topically as possible on DOT issues, all of the examples are taken from DOT or other transportation-related materials. To be as clear and useful as possible, the Primer gives both good and bad examples. The nature of the examples necessarily suggests their source in some cases, but the point is not to identify any particular agency as a source of good or bad design. Thus in most cases the Primer breaks with standard attribution practice and does not identify the source of the graphics.

Technology has allowed vast advances in our ability to develop numbers into information; for example, exciting and highly effective work has been done in visualization, including the ability to “travel through” potential transportation facility designs on a video screen. Those kinds of examples are beyond the scope of this Primer, although the principles discussed here cover those kinds of advanced applications as well.

The Primer also discusses effective use of information processing and design tools such as Excel and PowerPoint and their equivalents. The Primer is not aimed at trained graphic designers, but rather at transportation professionals who work with quantitative information and who need ways to present it effectively using tools generally available to them. Given the nature of modern transportation work, that is almost everyone in the profession.
1.3 **Primer organization**

The Primer is structured to describe each of the most common types of information graphics that are used to display transportation-related data.

- Chapter 2 briefly reviews the in-depth literature on information design.
- Chapter 3 describes information design principles and key considerations for creating high-quality information graphics.
- Chapter 4 then discusses developing several types of information graphics, beginning with data tables, and then turning to the variety of chart formats available. Chapter 4 also covers other visual aids, such as maps showing geographic information and diagrams showing organizational structures and planning processes.
- Moving from the graphics to the tools with which we create them, Chapter 5 discusses working with common information design software.
  
  Chapters 4 and 5 both proceed almost exclusively through the use of example graphics and brief case studies; what works, what doesn’t, and why, taking those examples from the transportation literature. In many cases, examples are reworked to illustrate how a graphic could communicate better.
- Chapter 6 is a single, more extended case study, which contains most of the good design principles discussed to that point.
- Finally, the Appendix contains a very brief introduction to some basic graphics terms used in the Primer.
2 A Brief Literature Review on Information Design

This Primer discusses information design using examples from the transportation literature, using principles drawn, largely, from more in-depth literature on information design. This section gives a brief introduction to that in-depth literature.

2.1 The state of information design

“Information design” as a recognized activity is relatively new. Nonetheless, everyone who writes on the subject agrees that creating high-quality information displays requires a multi-disciplinary approach. Transportation agencies will need to call on knowledge from a variety of fields, including those in the following table.

**Information Design Disciplines**

<table>
<thead>
<tr>
<th>Field of Knowledge</th>
<th>Relevant Contribution to Information Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information technology</td>
<td>To gather and manage data effectively, especially electronic databases</td>
</tr>
<tr>
<td>Strategic business management</td>
<td>To understand what kinds of data are needed to help organizations manage their operations and achieve strategic goals</td>
</tr>
<tr>
<td>Marketing and public relations</td>
<td>To understand what kind of messages are compelling to key audiences, and how those messages are conveyed most effectively</td>
</tr>
<tr>
<td>Statistics and technical analysis</td>
<td>To make sense of the data and conduct analysis, including distinguishing trends from noise</td>
</tr>
<tr>
<td>Graphic design</td>
<td>To understand how to create graphics that are purposeful, coherent, and aesthetically pleasing</td>
</tr>
</tbody>
</table>

To these, transportation agencies must necessarily add:

**Transportation**

To understand the conditions and phenomena the data describe

Considering the diverse array of skills required to produce good information design, agencies may need to augment existing skill sets with experts, training, and/or additional reference texts.

2.2 Useful reference texts

Although many texts address information design, most do not appear to agree on consistent principles, sometimes offering guidance contrary to high-quality information design. With the exception of texts by Edward Tufte, which have received almost universal praise, many information design reference texts have received mixed reviews, pointing to a lack of consensus on true information design principles.
### Title | Author | Information Design Relevance
--- | --- | ---
**The Visual Display of Quantitative Information** | Edward Tufte | The three basic and largely indispensable texts (“pictures of numbers, pictures of nouns, and pictures of verbs,” respectively) in the field provide the fundamentals of information design. Each gives numerous examples of successful and unsuccessful information graphics with a discussion of the details that determine the success of the graphics.

**Envisioning Information** |  |  |

**Visual Explanations: Images and Quantities, Evidence and Narrative** |  |  |

**Elements of Graph Design** | Stephen Kosslyn | Advises on creating straightforward graphs, based on research regarding how humans perceive and process images into understanding.

**Graphic Discovery** | Howard Wainer | Presents excellent examples about how visual displays of data can either obscure or reveal important patterns.

### 2.3 Other useful texts

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Information Design Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Information Design</strong></td>
<td>Robert Jacobson, Editor</td>
<td>This collection of essays provides substantial background on Information Architecture and Design as an introduction to the subject.</td>
</tr>
<tr>
<td><strong>Information Anxiety 2</strong></td>
<td>Richard Saul Wurman</td>
<td>A somewhat quirky but consistently thought-provoking examination of the state of information in today’s U.S.</td>
</tr>
</tbody>
</table>

The best summary of the literature as it relates to this Primer is given by Tufte, in eight overarching principles for information display:

1. *Enforce wise visual comparisons.* Force answers to the question “compared to what”?
2. *Show those comparisons side by side,* rather than sequentially, and especially not on separate pages.
3. *Use small multiples to facilitate comparisons.* Show the same basic chart several times, with different data in each.
4. *Show causality by linking variables.* For example, don’t just show VMT increases over time; show what might be linked with them.
5. *The world we seek to understand is multivariate, and so should our displays.* Again, VMT does not increase by itself; what changes with it / because of it? Show those as well in the same chart.
6. *Integrate word and image.* Almost all reports or presentations use both text and graphics. Make sure they work together as closely as possible.
7. *Content is key.* If your numbers are boring, you have the wrong numbers.
8. *Don’t throw out data,* or “dequantify” by (for example) changing numbers to “yes” or “no”.

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1 Adapted from the one-day course by Edward Tufte, taught around the country, “Presenting Data and Information”.

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**ICF International**
Section 3.2 expands on and adapts these. Some of the principles, in this one-line form, may not be immediately understandable. The rest of this Primer, especially Chapters 4 and 6, illustrate and discuss them using transportation examples.
3 Creating Good Information Design for Decision-making

“When we reason about quantitative evidence, certain methods for displaying and analyzing data are better than others. Superior methods are more likely to produce truthful, credible, and precise findings. The difference between an excellent analysis and a faulty one can sometimes have momentous consequences.”


Well-designed information graphics follow basic rules. Their object is not to dazzle with elaborate graphic elements, nor to distort the information. Rather, they seek to convey—to communicate—information clearly and efficiently. Information graphics should convey their information more clearly and concisely than text only. Good graphics allow readers to see key points and patterns in the data, and are free of graphic elements that distract from the data.

The philosophy that an agency adopts toward information, decision-making, and communication will affect the ways in which data will be presented. Some agencies approach information design believing that the central purpose of conveying information is simply to report, allowing others to interpret the data according to their own perspective. In this philosophy, the information designer’s charge is to present clearly the full set of information that will allow this interpretation to occur. Another perspective is that the central purpose is to tell a story, offering an interpretation of the data and providing supporting evidence.

In the end, agencies need to balance these two perspectives to design information that informs decisions by both internal and external decision-makers.

3.1 Key questions in designing information displays

To create effective information displays, it is helpful to consider several questions before selecting an appropriate display format.

3.1.1 Who is the audience?

The audience determines the level of detail and technical specificity, as well as type of communication that will be most effective.

As noted above, designers of information graphics must balance the need to allow the audience to draw conclusions from the data with the need to guide the audience through the nuances of the data. While it is important to respect the intelligence of the audience in understanding the broader picture being painted by the data, it is also important to recognize that many audiences – particularly executive managers and other decision-makers – do not have large amounts of time to spend looking for insights within the data.

3.1.2 What is the medium?

Is it printed, part of a projected presentation, or to be used on a computer? There are important differences regarding legibility and effectiveness between displays on paper versus projected slides. What is legible on paper is often illegible on a screen, and what is effective when shown and discussed as part of a presentation may not make sense as a stand-alone graphic on a page.

The medium used should be considered in conjunction with two key questions. First, can color be used? Color can be a powerful and effective way to display information and place visual emphasis on particular aspects of the data. However, a very effective color graphic may not survive the transition to black and white (for example, if it is photocopied). Will the intended audience be able to see the display in color? Color is easily re-produced in computer-projected slide presentations, but less so in printed reports. If it is expected that most of the audience will only see reproductions of the report, then a black and white graphic differentiated with shades of gray may be the most appropriate route.

Second, how complex is the information? The amount of detail required by a graphic may outstrip the carrying ability of its medium, if not carefully chosen. Paper can display far more complex information than a slide presentation.

Thought should also be given to ‘secondary’ audiences and how they may access and look at the information displays. For instance, although a presentation or report may be created for a specific decision, such as a management budgeting process, that same presentation or report may eventually be made available to important external stakeholders or the general public, possibly via web downloads. The information graphics contained in such presentations or reports should be crafted to retain their ability to convey information when reproduced.

### 3.1.3 What is the question?

Information is not useful in and of itself. It is only useful if understood in relation to a context. For instance, knowing the percentage of miles of congested roadways this year is of limited utility; knowing that this percentage is much lower than in previous years is more useful. And if there is a correlation with other datasets, such as employment levels, or transit usage, or capital expenditures, the utility of the information grows substantially. The most useful information graphics help to answer questions that have significant strategic or policy implications for the agency. These implications usually imply a question, and well-constructed graphics make the data understandable in the context of that question.

### 3.2 Principles for designing information graphics

Decide first whether a graphic is needed. In many cases a well-designed table or straightforward text can be equally effective.

If the answer is yes, then use these 10 principles to design high-quality information graphics. Some of these principles may seem like common sense, while others may not be as intuitive. The concepts are presented briefly here, and are discussed in more detail, with examples, in the chapters that follow.

1. **Use the simplest display format appropriate for conveying the data.** For instance, do not use three-dimensional charts to ‘liven up’ the display if the data are in two dimensions.

2. **Show all the data, and show it in context.** Rather than showing only the part of the data that appear to contain key points, include all data. Since some of the most important insights can arise from discovery of correlations between phenomena, consider showing one dataset in relation other potentially relevant sets. If causality is clear, show it.

3. **Employ the size, scale, and units of a display to maintain and maximize integrity in communicating the data and data relationships.** Pay attention to design aspects such as units and height-to-width aspect ratios that can distort relationships. For instance, if one quantity is twice as large as another

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3 Adapted from Tufte and from Kosslyn.
quantity, their depictions should reflect exactly that proportion. If the differences are being shown through changes in height, the aspect ratio should maximize the graphic’s height rather than its width. Do not use three-dimensional displays if the data do not have three dimensions. If depicting monetary quantities, standardize for comparability across time; that is, use constant rather than nominal dollars.

4. **Use design elements that focus attention on the data**, rather than the designs themselves. Avoid design elements that distract from the data, such as finely striped lines, colors that are too intense, and unnecessary effects.

5. **Eliminate as many unnecessary elements from the graphic as possible**. Include marks, lines, symbols, numbers, shading, and color only if they convey needed information.

6. **Make lines and colors as unobtrusive as possible** without losing their visibility.

7. **Facilitate wise comparisons**. If comparing two or more data variables, put them on the same chart. Show the data where possible. Do not dequantify data by turning, for example, a pavement damage index into “damaged / not damaged”. When possible, show the actual data, rather than aggregations.

8. **Use small multiples**. When two graphics are to be compared, place them side-by-side. For many comparisons, consider small multiples, which employ the same formatting and design for multiple, small-sized diagrams, allowing the reader to move from diagram to diagram to distinguish changes from one to the next without needing to move back and forth among pages or slides.

9. **Use color judiciously**. If a graphic will be reproduced in black and white, create it in black and white. If using colors, select ones that have intuitive connections to the conditions the data are describing, or, at the very least, avoid colors that have counter-intuitive connections. For instance, for depicting traffic congestion, red is a more intuitive color than green for data conveying congested conditions.

10. **Integrate text and graphics**. Place labels directly on graphics, not in a key to one side. Note important events in the data directly on the chart.

Each of the examples in the next sections will refer back to these principles, using the same grey box format.

Finally, information graphics contain many different elements. As with any complex material, ensuring that information graphics communicate requires a certain amount of care. Before using any information graphic, check:

- Does the chart make the point you want it to make?
- Are all parts correctly and informatively labeled?
- Are the units correct?
- Do you know what each element of the chart means, and why it is there?

Spreadsheet and presentation software can automate the preparation of many information graphics, with the result that we do not always pay close attention to the choices that the programs make for us. Intentionality should be your guide at each step of turning data into information.
4 Brief Case Studies: Developing Information Graphics

The first step in communicating a message effectively with graphics is deciding which type of chart to use. These brief case studies cover each type of graphic; each section discusses the graphic type’s relative benefits, and then briefly outlines what types of information it is most suited to display. Examples particularly relating to the work of state DOTs have been included throughout the discussion to illustrate potential considerations which may arise in the practice.

In general, the subject matter of the data matters far less than the content when selecting a graphic type. In other words, data can describe traffic counts, population figures, or collisions by hour, but whether the information presented is descriptive, comparative, percentages, or available by geographic area will have far greater effect. The considerations involved in choosing an effective means for displaying information will determine whether the appropriate graphic is a table, bar or line chart, pie chart, map, or organizational/flow chart.

4.1 Tables

Tables are one of the simplest, yet most effective means of displaying quantitative information. Because individual data points are exhibited in as complete values, this type of information display is particularly well suited when precision is important.

The advantage of a graphic—that it is visual—is also its weakness. Graphics are pictures, and people interpret pictures differently. Perception changes with experience and is context-dependant, potentially changing the meaning of a graphic. Different interpretations can add richness to a decision-making debate, or impede it.

Tables reduce (but of course cannot eliminate) the risk of misinterpretation by requiring each reader to draw his or her own conclusions based only on the data. Interpretive differences will more likely be the result of different readings of the data, and less likely to be driven by information designer’s choices. But even tables are designed, and so include some of the designer’s interpretation of what is important.

Tables generally outperform all other graphics when the desired information is contained in a small data set (Tufte suggests less then 20 numbers4), generally along two parameters. Transportation data are often contained in this format, for example funding by year or level of service by road type. Though primarily used to display quantitative information, tables can also accommodate side-by-side comparisons of text, such as funding source, demographics, or municipality.

The following example, from a Long Range Statewide Multimodal Transportation Plan, shows a funding table that effectively compares two approaches. The use of two colors makes it easy to differentiate the two (this could also have been accomplished without the background color) and the notes call the reader’s attention to pertinent figures. (The feathers match the nautical map theme of the rest of the report.)

4 Visual Display of Quantitative Information, p. 56
Design principles illustrated:

4. Use design elements that focus attention on the data, rather than the designs themselves, and

9. Use color judiciously. The color helps distinguish Historical from Recommended datasets without being obtrusive.

7. Facilitate comparisons.

10. Integrate text and graphics. Annotations like those in the table can be fairly easily done with most standard computer suites.

A table will be most useful to the reader when patterns are not readily apparent or explainable, and when precision is called for. The funding scenario table above is probably at the edge of how many numbers can usefully be put in a table and still communicate usefully. Certainly it contains far more than Tufte’s recommended maximum of 20 numbers. Many tables, of course, contain far more than 20 numbers; these tend to be used for reference purposes. It is difficult to communicate well using a large table, and once one passes that threshold or roughly 20 numbers, one ought to consider organizing them into a chart. The next example illustrates how to think about moving from a table to a chart.

This example illustrates various ways to display the same population figures for a fictitious county, depending on the desired goal of the display.
The table below shows population figures from 1960 through 2000, plus the projections for 2010. It covers the basics: showing years from left to right, labeling the projection as a projection, and offering a total figure at the bottom.

### Population of Ashton County, 1960 to 2010 (Projected)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbus</td>
<td>1,781,335</td>
<td>1,875,090</td>
<td>1,973,779</td>
<td>2,077,662</td>
<td>2,303,607</td>
<td>2,657,064</td>
</tr>
<tr>
<td>Bismark</td>
<td>720,395</td>
<td>847,524</td>
<td>997,087</td>
<td>1,173,043</td>
<td>1,254,543</td>
<td>1,295,012</td>
</tr>
<tr>
<td>Eagleton</td>
<td>635,903</td>
<td>706,559</td>
<td>743,747</td>
<td>758,925</td>
<td>1,249,929</td>
<td>1,400,034</td>
</tr>
<tr>
<td>Haverton</td>
<td>221,305</td>
<td>260,359</td>
<td>306,305</td>
<td>360,359</td>
<td>583,888</td>
<td>593,712</td>
</tr>
<tr>
<td>Finstert</td>
<td>118,699</td>
<td>124,947</td>
<td>127,497</td>
<td>254,993</td>
<td>283,131</td>
<td>343,443</td>
</tr>
<tr>
<td>Darcy</td>
<td>84,568</td>
<td>93,964</td>
<td>98,909</td>
<td>100,928</td>
<td>133,772</td>
<td>123,534</td>
</tr>
<tr>
<td>Gresham</td>
<td>32,710</td>
<td>40,887</td>
<td>54,516</td>
<td>62,662</td>
<td>71,699</td>
<td>85,667</td>
</tr>
<tr>
<td>Ipswitch</td>
<td>16,326</td>
<td>18,141</td>
<td>19,095</td>
<td>19,485</td>
<td>28,080</td>
<td>29,597</td>
</tr>
<tr>
<td>Johnston</td>
<td>6,050</td>
<td>7,563</td>
<td>10,804</td>
<td>15,888</td>
<td>25,237</td>
<td>25,605</td>
</tr>
<tr>
<td>Unincorporated</td>
<td>842,891</td>
<td>769,844</td>
<td>662,869</td>
<td>325,134</td>
<td>254,577</td>
<td>200,766</td>
</tr>
<tr>
<td><strong>Total for Ashton County</strong></td>
<td><strong>4,460,184</strong></td>
<td><strong>4,744,876</strong></td>
<td><strong>4,994,607</strong></td>
<td><strong>5,149,079</strong></td>
<td><strong>6,188,463</strong></td>
<td><strong>6,754,434</strong></td>
</tr>
</tbody>
</table>

Note that this table is designed to communicate, rather than serve as a reference; the cities are arranged by size, rather than alphabetically.

Below the same data is displayed in a bar chart, using a common default Excel output, which has several flaws.

The table allowed the audience to view the underlying data while directing their attention to the total figures at the bottom. The bar chart, however, fails to convey a sense of the total county population or the proportion that each municipality comprises because of the disjointed groupings by year.

The bar chart uses a key to the right of the graphic, identifying which color coordinates with each population total. This requires the reader to flip his attention back and forth between the chart and the legend.

Several of the colors used in the chart will look identical when reproduced in black and white. An alternative solution to this problem would to use textures and patterns in place of color. However, in this case the bars are so numerous that their slim size would render this signifier useless.
This example of what not to do suggests several principles for creating effective bar charts.

### 4.2 Bar charts

While tables have the advantage of conveying information most precisely, bar and line charts can display the same types of information, while allowing quick comparisons and emphasizing changes over time. People intuitively perceive proportional relationships and relative differences in sizes, shapes, and colors. Graphs that take advantage of this will more effectively communicate a complicated message. Thus bar and line charts have the advantage of allowing and conveying comparisons between numbers quickly. Practically speaking, bar and line charts are the easiest to do well. Nonetheless, they will reward care in design with substantially increased power to communicate.

Bar charts use patterns, colors, and shapes to allow faster understanding of the information presented, so these elements are critical considerations in their design. When color coding is a major feature of the chart, it is important to consider how the graphic will look when it is reproduced in black and white. Sometimes a well-designed bar chart which relies totally on color differentiation can lose all meaning without that critical element.

Because they can accommodate so many different data situations, bar charts can be over-used. It is important to always consider if the available data could be more effectively presented using text or another type of graphic before deciding if a bar chart is the best means to display a given set of information.
Recall the first question in “3.2 Principles for Designing Information Graphics”: “Is a graphic needed?” If the answer is “yes,” be sure you can say why. For example, although the bar chart below clearly displays the information, it is a chart with little to say.

**Forecasted Revenue Growth for Highway and Street Construction**

![Bar chart showing forecasted revenue growth for highway and street construction from 2004 to 2007.]

These data could have been effectively conveyed in a single sentence:

“Revenue growth for highway and street construction is projected to vary between 3.8 and 4.0 percent from 2004 through 2007.”

Following is an example of a data set that needs to be charted in order to be usefully communicated. The table alone suggests that congestion varies considerably by month, getting higher in the summer, but this pattern isn’t particularly clear from the table. Because the table has more than twenty numbers, and especially because it is a time-series, graphing may usefully reveal or suggest a pattern. In this case, the answer to the question “why is a chart needed?” is, “because it is difficult to see or talk about a pattern in the data using the numbers alone.” One could not give that answer in the previous example, with four almost-identical revenue increases.

<table>
<thead>
<tr>
<th>MONTH</th>
<th>AADT</th>
<th>% OF AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>JANUARY</td>
<td>19,341</td>
<td>81.2%</td>
</tr>
<tr>
<td>FEBRUARY</td>
<td>19,546</td>
<td>82.0%</td>
</tr>
<tr>
<td>MARCH</td>
<td>23,419</td>
<td>96.3%</td>
</tr>
<tr>
<td>APRIL</td>
<td>25,404</td>
<td>105.6%</td>
</tr>
<tr>
<td>MAY</td>
<td>24,252</td>
<td>101.8%</td>
</tr>
<tr>
<td>JUNE</td>
<td>25,820</td>
<td>103.4%</td>
</tr>
<tr>
<td>JULY</td>
<td>27,955</td>
<td>113.7%</td>
</tr>
<tr>
<td>AUGUST</td>
<td>26,266</td>
<td>113.3%</td>
</tr>
<tr>
<td>SEPTEMBER</td>
<td>24,547</td>
<td>103.0%</td>
</tr>
<tr>
<td>OCTOBER</td>
<td>24,156</td>
<td>101.4%</td>
</tr>
<tr>
<td>NOVEMBER</td>
<td>22,994</td>
<td>96.5%</td>
</tr>
<tr>
<td>DECEMBER</td>
<td>23,049</td>
<td>98.7%</td>
</tr>
</tbody>
</table>

In the document from which this example was taken, a bar chart was added to the table to graphically display average annual daily traffic (AADT) by month. As an aid to discussion or decision-making, the combination of data table and chart is only partially helpful. First, the data table to the left of the chart forces the audience to shift attention back and forth from the data and text to the bars in the chart. Second, the wide aspect ratio and choice of Y axis compresses the differences in AADT by month.
Staying with a bar chart, but reconfiguring it according to good information design principles produces a much more useful chart. By placing the 100 percent line in the middle of the Y-axis scale, this chart more clearly illustrates which month’s AADT levels are above or below the overall average. Showing the data values directly above the bars maintains the precision available in the former data table, while taking advantage of the benefits of a visual data display. One can now quickly identify, for example, the precise AADT in the highest and lowest months.

### Percent of Average Annual Daily Traffic, by Month

<table>
<thead>
<tr>
<th>Month</th>
<th>Percent</th>
<th>AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>80%</td>
<td>19,341</td>
</tr>
<tr>
<td>Feb</td>
<td>90%</td>
<td>19,546</td>
</tr>
<tr>
<td>Mar</td>
<td>100%</td>
<td>23,418</td>
</tr>
<tr>
<td>Apr</td>
<td>110%</td>
<td>25,404</td>
</tr>
<tr>
<td>May</td>
<td>110%</td>
<td>24,252</td>
</tr>
<tr>
<td>Jun</td>
<td>120%</td>
<td>25,820</td>
</tr>
<tr>
<td>Jul</td>
<td>120%</td>
<td>27,095</td>
</tr>
<tr>
<td>Aug</td>
<td>120%</td>
<td>26,266</td>
</tr>
<tr>
<td>Sep</td>
<td>90%</td>
<td>24,574</td>
</tr>
<tr>
<td>Oct</td>
<td>90%</td>
<td>24,156</td>
</tr>
<tr>
<td>Nov</td>
<td>80%</td>
<td>22,994</td>
</tr>
<tr>
<td>Dec</td>
<td>80%</td>
<td>23,049</td>
</tr>
</tbody>
</table>

The decision whether to place data values directly in a chart should be driven by both the numbers and how the chart will be used. Do the absolute values matter? In this case, is a capacity limit reached at, say, 26,000 ADT? Will the chart be used in a fast-paced briefing to make a single point, or will it be used in a setting where the numbers can be discussed? The answers to these kinds of questions will guide development of a chart that works in its context.

### Design principles illustrated. Compared to the original, the reworked chart:

7. Facilitates comparisons, of each month to the average, and of the months to each other.

10. Integrates word and image—again, all of the information is in one place, rather than splitting it between chart and table. The labels are on the graph, not next to it.

After asking whether a chart is necessary, and if so, what kind, the information designer must also ask: which precise set of numbers will be most useful to a decision-maker?

The following three charts, from the Texas Transportation Institute’s (TTI) 2005 Urban Mobility Study, tell essentially—although not exactly—the same story: that congestion has increased over the past 20 years in urban areas of every size. The first uses TTI’s Travel Time Index, the second uses “hours of
peak traveler delay”, and the third, “percent congested travel” data. Because each measure of congestion is different, each tells a somewhat different story. For example, different things are happening in Very Large urban areas according to each measure of congestion. No one measure—and thus no one chart—tells the whole story.

Which chart is most useful? The Travel Time Index is not as “close” to the raw data as are the other two. On the other hand, TTI developed the Travel Time Index precisely because TTI believed that the index tells a more complete story than any single set of raw data. This example illustrates a frequent and important choice. In some cases, transformed data will help reveal a policy-relevant story and so be more useful to decision makers. In other cases, the distance from the original data may interfere with a decision-maker’s ability to explore the data for her- or himself and use it to make a choice.

Again, the person developing the material must keep clearly in mind the purpose of the chart and the context in which it will be used. Is the goal to enable a decision-maker to explore the data, or is the goal to make a point and move on? In making the choice of whether to use transformed data or not, one needs to take into account the time or space necessary to explain the transformation. In this example, it is not obvious what a “Travel Time Index” is, while “Percent of Travel in Congested Conditions” probably does not require additional explanation. The report from which these charts are taken chose to use all of them to give the reader as much information as possible. In a different context, such as a briefing, that is unlikely to be the right choice. There will always be a tension between

- showing more data to tell a complex story, and/or allow the audience to explore the data themselves; and

- showing less data to tell a more straightforward, memorable story.

No general principle can help resolve this tension; the goal should be to be aware of the tension, and know on which side a particular chart is erring.

These first two charts compared to the third also illustrate a principle discussed later; it is easier to read data values off of the third chart, because it does not use the unnecessary 3-D look.
Design principles illustrated:

7. *Facilitate wise comparisons.* That is, force answers to the question “compared to what”?  

Each chart helps the reader compare changes in congestion from year to year, and helps guide the reader to a conclusion such as “Most of the trend information indicates that the 2003 average values for each population group are near the 1990 value for the next highest population group.” For example, “Medium-sized areas now have the congestion of Large areas 10 years ago.”

If one wanted to show two or more of these charts as an aid to talking about how different measures of congestion tell a different story, then one would be using principle:

8. *Use small multiples to facilitate comparisons,* i.e., the same chart several times, with different data in each. Note that in order to do so, one has to use a small multiple display as above; putting each chart on a different page does not help facilitate comparisons.

And compared to the first two charts, the third chart illustrates principle

1. *Use the simplest display format appropriate* for conveying the data. Do not use three-dimensional graphs to ‘liven up’ the display if the data are in two dimensions.

Note that although these three charts nicely illustrate those principles, the charts could be made more useful still. For starters, both the time-series and the size-series run opposite to the usual directions; 2003 comes is to the left of 1982, and Large is to the left of Small. Why?
After choosing the right numbers and chart type, the next step is to use design to let the data speak for themselves and, ideally, tell a story.

Letting the data speak starts with a mundane but vital task: getting the size and shape of the chart right. The AADT example above gave one illustration of how squeezing the data into a narrow visual range interferes with letting the data speak. The chart on the left, below, gives a more extreme example (again, from an actual publication) of the importance of an appropriate aspect ratio in bar charts. The aspect ratio is the ratio of chart height to width. While there is no single rule concerning the optimal ratio, it should be created such that differences look different and similarities look similar. For example, the chart on the left does not reveal that the number of intoxicated in vehicle arrests dropped by half from 2000 to 2001. That is, differences don’t look different. One way to interpret the chart on the left is that intoxicated in vehicle arrests have stayed “low” since 1995. That story might have one policy implication for decision makers. However, the aspect ratio is too compressed to reveal any discernable, useful information because the Y axis reaches 140 when none of the data are higher than 20. The figure to the right shows the same numbers graphed with a maximum value of 8, which brings out the differences in the data. Those differences tell a story—a story different than “arrests have stayed low”—and the second story may have implications for decision makers.

**Intoxicated in vehicle arrests**

![Intoxicated in vehicle arrests chart](image)

Design principles illustrated. Compared to the original, the reworked graph:

3. **Employs the size, scale, and units of a display to maintain and maximize integrity in communicating the data and data relationships.** The aspect ratio maximizes the graphic’s height rather than its width.

8. **Facilitates comparisons,** of the years to each other.

In this case it is not necessary to **integrate word and image**—the values are easy enough to read off the Y axis.

### 4.2.1 The stacked bar chart

The stacked bar chart builds on the traditional L-shaped bar chart framework, by adding an additional information display. The bars of the chart are subdivided into segments, representing parts of the whole variable.

To return to the population chart example, the chart below shows total population growth in Ashton County over time, along with the relative proportion that each municipality contributed to the overall growth.
growth. A stacked bar chart should have the element that changes least on the bottom. This is because the reader must visually subtract the amount on the bottom of the bar from the top, in order to calculate the difference. In this case it is easy to see that while Columbus grew only slightly during the past 50 years, Bismark, Eagleton, and Haverton all grew more quickly. Stacked bar charts can be a very effective way to highlight overall trends in a set of complex information. However, they should be used with caution; this chart is probably an example of putting too many categories in a single bar. Stacked bar charts are best used when the number of categories in a bar will be small.

**Population Growth in Ashton County, 1960 to 2010 (Projected)**

Several additional elements present in this stacked bar chart should be used in any bar chart in order to increase legibility and effectiveness. These include placing the labels of the municipalities directly next to the columns, rather than in a separate key; keeping the background grid lines as light as possible so as not to interfere with the lines between the bar elements, and using an appropriate scale. For example a chart with a maximum population value of 10 million people would unnecessarily compress the bars.

### 4.2.2 The stacked area chart

A variation of the stacked bar chart is the stacked area chart. This graphic visually conveys an even greater sense of overall trends at the expense of specific data. By achieving a greater sense of continuity, the stacked area chart is particularly useful when displaying information with many consecutive data points. In this example, this type of chart would have been much more useful if the population growth figures had been collected every year, instead of every 10 years. This would have made a stacked bar chart illegible, and a stacked area chart much more informative. However, the graphic is still effective in showing the population growth trends, as well as the decreasing proportion of population living in unincorporated areas:
4.3 Line charts

Similar to bar charts, line charts should be used to highlight how quantities change over time, particularly when the elements of the data tell a more compelling story when shown together. Many of the same chart design principles applied to bar charts are also relevant to line charts, including placing labels inside the chart as opposed to a separate key; keeping the background grid lines as light as possible so as not to interfere with the data lines; and using an appropriate scale. One should be able to distinguish between the lines by using either color, dashes, or varying symbols.

The first example uses the same data as the previous examples to clearly show which municipalities growing and which are declining in population. The line chart still provides an accurate representation of the data to the audience, while identifying Columbus as the largest municipality in the county. Using a line chart here loses the compositional aspect of the stacked bar and area charts, but more clearly distinguishes the unique nature of Columbus’ growth and that of the smaller municipal area.

The following example shows how a line chart can be represent complex information clearly and concisely.
This chart does not display total population by year, but makes much clearer than either of the previous two chart types the trend in each city’s population, and how those trends compare to each other. It also makes it much easier to read off the rough actual population for any city in any year. That is, this chart does a much better job of a) showing trends, b) facilitating comparisons, and c) communicating the underlying data.

If the only goal of showing the chart in this case is show that county population is growing, and growing because most of the component cities are also growing, then one of the bar charts is appropriate. But if the one wants or needs the reader to look at trends in individual cities, then the line chart is by far the best choice.

*To generalize, if an overall trend with contributions is the point, the bar or the stacked area chart is better. If the individual contributors are more important, then the line chart is better.*
Extended case study: Ensure comparability by paying attention to units

If a chart’s goal is to facilitate comparison, one must take care that the comparisons are valid. The following example shows how a line chart can mislead by using the wrong units. (Any chart type can mislead by using the wrong units, but this example is particularly clear, and happens to be a line chart.)

Each of the charts below depicts two sets of pedestrian collision rates, one for weekdays and one for weekends. In the first chart, because the weekday rate combines five days of data, and the weekend chart only two days, each data set is shown on a different scale. However, when the data are standardized to show the average for weekdays and weekends, and charted on the same scale, the chart depicts something quite different:

In the first figure, the X-axis on the right goes up to 1,000 and the axis on the left goes up to 200. The line depicting weekday collisions shows a peak of approximately 950 collisions on Monday through Friday, while the line for weekend collisions shows a peak of about 190 collisions. Although these very different numbers can be read from the two scales on the axes, the obvious visual implication is that the peaks are roughly equivalent.

However, in the second figure, the two sets of collision data are standardized to show collisions on an average day (the weekday numbers were divided by five, and the weekend numbers were divided by two) and charted on the same scale. This figure suggests a completely different conclusion: more pedestrian collisions occur on weekdays than weekends, and the highest numbers of weekday collisions occur during the AM and PM peak. The only time when pedestrian collisions are higher on weekends is in the late evening, between 10 PM and 5 AM.

These two charts also highlight a difficulty one can encounter when trying to balance reference and decision-making goals in information design.

- The design decision in the first chart was motivated by a desire to show the data. Thus, the first chart shows the total numbers of collisions during the week, and the total number of collisions on weekends for each time period. If one needed one kind of data, one could read it off the chart.

- The second chart makes the two data series more usefully comparable by showing average collisions per time period. The chart designer may have been thinking that “total” is closer to “actual” than is “average”.

However, by adding together the daily collision statistics, the first chart has already departed from straight reference, and not yet reached communication/decision-making usefulness, which requires comparing like to like. Adding together five days’ collision statistics for the weekday series and only two for the weekend series distorts the data. Putting each day’s collision statistics on a comparable footing by treating each day’s data exactly the same is both more honest and (thus) more useful.
Design principles illustrated. Compared to the original, the reworked chart:

3. Employs the size, scale, and units of a display to maintain and maximize integrity in communicating the data and data relationships.

8. Facilitates wise comparisons, of each category of data to the other.

In this case, using the right **units** was the key both to maintaining the integrity of the data, and to facilitating comparisons between weekdays and weekend days.

*Although it is useful to facilitate comparisons, be very careful about how you do so. If two data categories are not genuinely comparable, don’t put them on the same chart.*
Extended case study: Communicating by choosing the right X axis

The next example shows how a chart can be made more useful by thinking about how to order the X axis (often called the Category axis if the data are discrete, like individual states).

The original graphic contains data on state crash rates as a percentage of the average crash rate, as well as whether the state allows gross vehicle weights over 80,000 lbs in normal operations. Since it shows the 50 states in alphabetical order, it is easy to locate the state of interest but difficult to discern any meaningful pattern. A secondary issue in this line chart is that the information is not continuous, yet the data points are connected with a line. Why? Data points should only be connected with a line when they are part of a continuous series.

Crashes per Billion Ton-Miles in Each State, as Percent of National Average

In a later use of this chart, a subsequent designer evidently thought that it was not as useful as it could be, and that it could be improved by adding color:
One might ask whether adding the color helps (and why or why not).

Returning to the original black and white chart, and applying a different design to the same data, does help. The chart below reconfigures the same crash data to communicate rather than store information. The X axis shows the states in ascending order, from lowest percentage crash rate to highest.

**Crashes per Billion Ton-Miles in Each State, as Percent of National Average**

It is now easy for the reader to see that of the eleven states that allow gross vehicle weight greater than 80,000 lbs, eight have crash rates that are lower than the national average. According to these data, allowing trucks of this weight does not seem to lead to significantly higher crash rates. In addition, the reconfigured chart represents each state as a data point, locating each state’s rate more precisely, and removing the meaningless connecting line.

Design principles illustrated. Compared to the original, the reworked chart:

3. **Employs the scale** (in this case, the X axis) of a display to communicate the data and data relationships.

5. **Eliminates as many unnecessary elements** (the connecting lines) from the graphic as possible.

7. **Facilitates wise comparisons**, of each month to the average.

10. **Integrates text and graphics**, and places 80,000-pound key directly on the chart.

A secondary lesson from this example is to be careful in going from tables to charts. It’s possible that the first chart was not intentionally set up to facilitate reference (finding a particular state), but rather was the result of simply loading a spreadsheet with data that happened to be in alphabetical order by state. Several default choices in a spreadsheet program would quickly produce a chart in alphabetical order, with data points connected by a line.

**Be careful of default spreadsheet outputs.**
4.3.1 Common bar and line chart Don’ts and Dos

While line and bar charts present many opportunities for innovative displays of information, they also fall prey to some common pitfalls. This subsection discusses some good and bad design choices. Although most of the example charts illustrate several design flaws, the discussion focuses on one or two in each case.

How to avoid common mistakes

**Make sure colors mean something (and if they don’t, why use them?)**

There are two problems with this bar chart. Both the unnecessary coloring of the bars and the use of a three-dimensional chart to convey two-dimensional information create chart junk and data confusion: do the colors suggest different categories?

A diagonal bar chart is almost never appropriate; it weakens the impact of the heights of the individual bars and distorts the overall picture.
Don’t hide the illustration

Though this bar chart usefully includes the quantities in the chart (trying to integrate text and graphics), it hides the tops of the bars, making it more difficult to make comparisons. Why use bars and then not show the part that actually communicates the quantity?

Smaller problems: use of 3-D when the data are only 2-D, and use of a bar chart when a line would make everything easier.

Here we completely redo the chart, and as part of that, guess at what one might want to communicate with this chart; probably the gap between budget and supporting revenues. If that’s the goal, then why not show it?

Because the original included data values, we include them here as well, but only in the data series relevant to the point we are trying to make: for the past five years, the gap has been between $3 and $4 billion dollars.
Several design flaws in this chart make it difficult to interpret the data.

- Most important, a line chart would be more appropriate for this data, because there are more than three categories.

- Vertical writing is always harder to read, but once the chart is converted to lines, the data labels can be dispensed with. (If the chart must double-function as a reference, put a data table below the chart.)

- The stripes in two of the bars are, at a minimum, distracting.

- The legend contains an abbreviation schedule that is not used in the chart. Better to simply label the data lines.

Redesigned in this way, the chart raises several useful questions, including “what happened in 1996, and, to a lesser extent, in 1999?”

This chart can enable questions—and answers—that the bar chart would not.
4.3.2 Effective bar chart design choices to consider

This chart clearly identifies South Carolina from the other Southeastern states by highlighting its ranking in a different color.

It would have been even more effective to put the whole South Carolina bar in the different color, and to put the US average in as a vertical line.
This bar chart shows yearly temperatures above average in red and below in blue, an intuitive color scheme that aids comprehension. Having the scale located on both the right and left sides of the chart makes it easier to determine the values of the bars, while the trend line is clearly distinguished from the average temperature in green.

By separating data points into categories, this graphic emphasizes the important variable in the trend; in this case, that primary law states tend to have higher rates of seat belt use than secondary ones. This data would have been extremely difficult to interpret if the states had been shown alphabetically. In addition the background color distinction makes it easy to see the two groupings.
Whenever possible, showing two sets of data on the same chart can help suggest (although not determine) causality. This combination bar chart and line chart shows how fatality rates have dropped as seat belt use has increased. Showing the data in two separate charts would not have facilitated (forced?) the comparison. And while it suggests some causality, the combination of the two variables one chart also makes also makes clear that the relationship is not direct, suggesting that other factors may also be at work.

Including a fair amount of data is important to helping the reader look for changes in the relationship between the two variables. If the chart included only the last five years of data, it would suggest a different story.
Horizontal bar charts such as this are particularly useful when the text is an important element of the chart. In this case, a vertical orientation would make the place names impossible to read.

Again, one might usefully emphasize the national average bar.
Explain in the chart what’s going on with the data

If the chart raises an obvious question, answer it so that decision-making can focus elsewhere.
4.4 Pie charts

A pie chart is a useful way of displaying a set of categorical data or displaying the different values of a variable (e.g., percentage distribution). This type of chart is a circle divided into a series of segments (slices) representing categories. The particular advantage of the pie chart is its ability to show the size of categories relative both to each other and to the whole.

**Projected Transportation Revenues (Except Transit)**

*(in 2002 dollars)*

2002-2005

- **State Maintenance**: $284 Million
- **Local Construction**: $556 Million
- **Powell Bill Maintenance**: $503 Million
- **Federal/State Construction**: $2.9 Billion

Design principles illustrated:

3. *Employs the size or scale of a display to communicate the data and data relationships.* The large federal share is clearly displayed, in addition to noting the figures represent 2002 dollars.

7. *Facilitates wise comparisons,* of each segment share to the total revenue.

9. *Use color judiciously.* The colors of the pie segments are simple and should reproduce in black and white.

10. *Integrates text and graphics,* and places the labels directly across from the segments, rather than using a key.
Sometimes a segment of the drawing will be separated from the rest of the pie in order to emphasize an important piece of information.

Public opinion: Should the DOT adopt Plan X?

However, pie charts present several difficulties and should be used sparingly and carefully to illustrate only particularly relevant data comparisons.

Do not:

1. Use pie charts when there are more than six to ten components. When there are too many slices in the pie, it becomes difficult to compare the sizes of the various slices and thus to draw meaningful conclusions.

2. Use pie charts when the values of all the components are too similar. Whether the implication is that the categories are in fact basically the same size or not, there are better ways to make that point, such as simply using a data table. Imagine a pie chart of three sections: 32%, 33%, 34%. The eye cannot tell whether they are all the same size or not.

Do:

1. Label segments with either percentage or absolute values to help readers quickly determine which segments are bigger when several slices look close to the same size.

2. Place the value and segment labels beside their corresponding area. As with bar charts, this prevents users from having to shift between the pie and the key to identify what category each segment represents.

3. Order the segments of a pie chart by size (largest to smallest) in a clockwise direction. A haphazard ordering can prevent the chart from creating a compelling and concise representation of the data.
4.5 Maps

Maps are perhaps the most versatile and effective means of displaying data that has a geographic component. In addition to their conventional purpose, showing location, relative size, topography, and built features, GIS technologies can link an enormous variety of data to geographic location. Examples of such data display commonly used by state DOTs include:

- Population and employment by county
- Level of service (LOS) by corridor
- Location of natural features (for example, endangered species habitat) relative to transportation facilities
- Distance from transportation facilities

Common map features which aid in the audience’s comprehension of the data are:

1. Always show north,
2. Include key identifiers like highways, jurisdictions, or natural features;
3. Maintain a consistent orientation for all maps within a document or presentation; and
4. Include a scale bar.

Using color in maps

The following maps effectively use color gradation to show minimum and maximum scenarios for fluctuations in employment growth. These two maps presented side-by-side, convey data both visually and numerically. The use of color makes it easy to see trends across the state, and where townships which are likely to gain or lose employment are be located. In addition, the map contains detailed figures showing the exact number of predicted employment losses or gains. In sum, it communicates quickly, but can also function as a reference without interfering with the communication.
Predicted employment changes

<table>
<thead>
<tr>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>-287</td>
<td>-368</td>
</tr>
<tr>
<td>-216</td>
<td>-72</td>
</tr>
<tr>
<td>-72</td>
<td>-358</td>
</tr>
</tbody>
</table>

The above example uses the following design principles effectively:

7. 8. Placing identical maps side by side, helps facilitate comparisons through a small multiple.

9. Judicious use of color, green and grey background outlines do not distract from the data.

10. Integrate text and graphics. The magnitude of gains or losses are noted within the county.

The following two maps from the same report use color somewhat less effectively. The map on the left displays data along a continuum, thus it stays within a single color family and reserves the darkest shade to indicate the highest intensity. This is intuitive to most readers and adds another level of reinforcement to the conclusions that can be drawn.
The map on the right, however, uses color to obscure the data and prevents an accurate interpretation of the trends. Here again the darker shade indicates more intense population change, but residual green from the other map is used for no growth areas. This mixing of color schemes and map scales (one uses population density, while the other is change in population density) renders the map useless and impossible to interpret. White would be a much more effective means of indicating areas with no change in population growth in the map on the left, or alternatively showing both maps with the green color scale.

Finally, the maps confuse the reader by putting 2025 on the right and 2040 on the left.

These two maps illustrate the following Design Principles:

3. By conducting the analysis at the smallest geographic level possible, the map employs size, scale, and units to maintain and maximize the integrity in communicating relationships, and does not aggregate or average the information.

4. The map on the left uses darker shades of green for denser areas, using design elements to focus attention on the data. The map on the right contains a less intuitive color scheme and is therefore less effective.

8. Use small multiples. By using otherwise identical map templates, the differences in the details are more obvious.
The map to the right is an example of a map containing too much information, the vast majority of which is not relevant to decision-making.

The implication of the map is that most of the state, geographically speaking, is served by an airport within a 30-minute drive. (Note that one always needs to be careful the quantity being referred to as “most” is clear. Unless population is explicitly shown, as above, maps generally show geographic quantities only.) Between the many overlapping circles, the dots representing the airports, the county boundaries, and the county names, the map layers on too much information. As a result, it neither communicates well nor works as a reference.

A cleaner version would eliminate the county lines and circle borders, leaving behind just the highlighted, exceptional areas. This modification would result in a quicker identification of areas not currently being served by a local airport and support a conclusion that much of the county currently is. A secondary conclusion could be that most parts of Indiana are served by multiple airports. A particularly useful version of this map might omit all of the county names and boundaries except those that do not meet particular criteria: not entirely served; not served by more than one airport, etc.

Maps need not incorporate color to be effective data displays. The map below uses simple line thickness to show freight tonnage along routes across the U.S. It effectively identifies where the largest flows occur nationwide, and highlights Ohio, whose DOT prepared the map.
Design elements illustrated in this map:

1. Use the simplest possible display format. The map builds on the intuitive concept that thicker lines represent more tonnage throughput.

5. By eliminating as many unnecessary elements from the graphic as possible, this map avoids confusing geographic lines and political boundaries in order to focus on the data.

### 4.6 Traffic Volume and Level of Service Maps

A specialized type of map often produced by state DOTs displays traffic volumes and/or level of service (LOS) for intersections and road segments. Displaying LOS as a map instead of a table makes it clear to the reader which intersections or road segments have more traffic or congestion than others, and directs a decision-maker to trouble spots.
The two graphics above demonstrate some problems with the use of bar charts to display LOS data. Most important, a stacked bar chart is most useful when displaying data that contains components contributing to a whole, as with the earlier example of how the population of the municipalities added up to the county population. With LOS, the important attribute is the performance of the highway at different geographic points. It is not useful to know that roughly 60 percent of a segment is LOS E; it would be useful to know which portions of that segment are LOS E. This would be more effectively conveyed with a map than a stacked bar chart, which does not include a geographic component.

(In addition to that fundamental problem, the two charts show several other mistakes to avoid. Although meant to be used together, they use an inconsistent scale. The chart on the right goes to 1,800 while the left is only 1,600. This makes comparisons between the two charts misleading. Close inspection reveals that while the charts appear to show a decrease in LOS for the first two segments because the bars are lower, traffic has actually increased with the modified build scenario depicted on the right. Confusing captions compound the problems because the chart on the left claims it represents “existing and no-build scenarios” but displays only one set of data. It is thus not clear to the reader whether the data corresponds to both sets of figures. At the same time, the additional trend lines do not clarify and in fact detract from the development of a clear message.)

Transportation agencies are, of course, particularly interested in facilities. Effective information design will often use maps of those facilities to organize and display data.

The following black-and-white map is an example of an effective display of LOS information as it clearly illustrates the road segments and associated LOS. The map organizes a great deal of relevant information on a single page, information which would otherwise take many tables and much text to convey.

There are several features included in this map which make it a particularly effective display of the information. The time ring key provides an unmistakable key to which ring corresponds to which time of day; similarly it would have been far less effective to say “inner ring,” etc. Meanwhile, the road segments are clearly shown on the map, along with small orientation features such as cross streets, a bridge, and a construction zone. Without these small design attributes, the map would not be nearly as effective at communicating the data.

In addition, arrows located both inside and outside the road segments help the reader stay oriented to the counter-clockwise direction of traffic and add a visual element to the text box reminding the reader “counter clockwise direction of flow.” Similarly, the direction of the letters indicating LOS remain oriented horizontally on the page instead of rotating around 360 degrees, for easier viewing by the reader.
The only potential element of confusion in this map comes from the inclusion of a number and LOS “F” in the rankings which is not explained in the key. Every other element of the map relies on relatively intuitive concepts which would help someone unfamiliar with the data comprehend it. It would be confusing to see a segment rated LOS F when the title of the map implies that LOS varies only from A through E. A quick solution to this issue would be to simply change the title of the map to include LOS F, or add a note at the bottom of the page with a description of the necessity for a numerical component in some instances.

In the map below, traffic volumes are illustrated by varying the thickness of the line, so that more heavily trafficked areas are more prominent. In order to successfully combine several types of information, a less detailed measure of LOS, congested vs. not congested, was used with categories of traffic volumes. In order to accommodate these two distinct types of information, one quantitative and one qualitative, in a single map the graphic uses both color and line thickness visualization techniques. The advantage of
designing the map with these visual elements is that readers unfamiliar with LOS or transportation issues can come away with more meaningful conclusions than would be possible with either text or tables alone. The map effectively uses intuitive associations to link more complicated concepts with visual indicators. For example, the color red is used for congested segments where traffic would be likely be stopped, and green in uncontested areas where traffic would be free flowing.

While the use of color is a positive feature in this map, the data is obscured somewhat by illustrating each town in a different color. As none of the municipalities share a border, it would have been just as effective to use the same grey color for all three, and eliminate an unnecessary processing step for the reader.

**Congestion and traffic volumes, Farmington, Aztec, and Bloomfield**
Another example of using cultural associations to effectively communicate information follows. Like the one above, this graphic also uses red and green to communicate various levels of LOS, this time at intersections. This map even effectively uses the immediately understandable symbol of a traffic light. Each traffic light is color coded to indicate signalized and non-signalized intersections, as well as interchanges for each of the 6 levels of service. While the map is not to shown to scale, it conveys relative distance and placement of intersections, in addition to those predicted in the future. This LOS map format is more suitable for use at the local level, such as a small area plan or project level analysis, than statewide.

Finally, the following example of a LOS map successfully combines several of the elements in the previous maps. By using several methods of data visualization and cognitive social associations, the map is readily understandable while maintaining data accuracy and consistency.

The primary information displayed in this graphic concerns north and southbound LOS for each road segment during AM peak, PM peak, and on weekends, both under current conditions and those predicted for 2020. Additional features of this map include: clearly marked elements such as cities, counties, intersecting roads, and the state border in order to situate the interstate study corridor in context; the number of lane miles along each segment; the length of each segment; notations when peak traffic flow occurs; and the dividing point at which flows shift from heavier on weekdays to heavier on weekends.

In addition, the color-coding of the LOS makes it easy to differentiate between current segments levels and their corresponding levels in 2020. This is greatly aided by cascading the three separate charts and maps in the graphic vertically, with visual elements such as the flow dividing line serving as an informative link. At the same time, varying the length of the LOS color bars in the table elements makes them more easily associated with the individual highway segments shown on the map.
4.7 Organizational and Flow Charts

Organizational charts show the relationships between data elements, while flow charts show similar relationships occurring between processes. These can be used to illustrate planning processes such as Transportation Improvement Plans (TIP), State Transportation Improvement Plans (STIP), or environmental documentation, in addition to processes external to the state DOT but which interact directly with one of the above processes.

Three examples of organizational and flow charts are included here in order to illustrate several elements important to consider in the construction of an effective graphic. This type of graphic is most suitable for use with data which is distinguished by a firm hierarchy or organizational stratification. The advantages of using this type of graphic are the ease with which an audience can locate specific information within the context of relevant information which may or not be relevant. Successful organizational and flow charts combine concise data displays with sometimes elaborate frameworks in order to emphasize the interconnectedness of each data point. This would be difficult to describe with text and would be lost entirely if presented in a table. The most common display tools used to facilitate the comprehension of each chart element are color, arrows, text, references, and causality.

The first flow chart displays a less successful flow chart detailing the two-year planning cycle for a STIP. There are a number of elements in this graphic which lead to confusion and ambiguous conclusions.

First, the box sizes vary according to the amount of text rather than importance, making it difficult to see at a glance whether some steps are more important than others. This problem is compounded by the addition of color-coding using outlines and shading, without a key to indicate what these distinctions are.
intended to indicate. This unclear emphasis on certain boxes hides the fact that certain steps of the STIP process could be more important than others. Readers are forced to read each of the 24 boxes of the chart in order to draw any meaningful conclusions about the process. An additional problem with the text in this graphic is the use of all capital letters and sans serif font, making it difficult to read the text quickly than would a lower case, serif font.

It is vital, particularly in organizational flow charts, to include references to external documents and define acronyms for readers who might be unfamiliar with the subject material. The STIP update uses quite a few acronyms, which are not defined either in the figure or the text immediately surrounding it. Finally, the STIP update chart uses a passive voice such as “MPO/RPO supplements developed” and “STIP reviewed with BOT” making it difficult to determine which department or agency is responsible for the step.
BIENNIAL STIP UPDATE PROCESS

YEAR ONE

CURRENT STIP

STATEWIDE STIP PUBLIC MEETINGS
October - November

GOVERNMENTAL AND
PUBLIC PRIORITIES

MONITOR SCHEDULES AND COST,
DEVELOP BRIDGE, INTERSTATE
REHABILITATION AND SAFETY
PROGRAMS AND FINALIZE
FEASIBILITY STUDIES

MPORPO PRIORITY SESSIONS
January - March

DRAFT STIP
DEVELOPMENT

BALANCE DRAFT STIP WITH ANTICIPATED
REVENUES AND EQUITY FORMULA

DRAFT PROGRAM REVIEWED WITH
BOT, SECRETARY AND GOVERNOR

ALTERNATE YEAR
LEGISLATIVE REPORT
SEPTEMBER

DRAFT STIP PRESENTED TO BOT
September

MPORPO SUPPLEMENTS
DEVELOPED

September

YEAR TWO

PUBLIC REVIEW OF DRAFT STIP

DRAFT STIP PUBLIC COMMENT MEETINGS
October - November

AIR QUALITY
CONFORMITY
ANALYSIS

DRAFT STIP DEVELOPED

MPORPO REVIEW SESSION
WITH NCDOT
January - March

MTIPS AND AIR QUALITY
DETERMINATIONS
APPROVED BY MPOS
AIR QUALITY DETERMINATIONS
FOR NON-MPO AREAS WILL
BE MADE

COST, BUDGET ESTIMATES AND
AND EQUITY BALANCE UPDATE

STIP DEVELOPMENT

PRESENTED TO LEGISLATIVE
TRANSPORTATION OVERSIGHT
COMMITTEE

STIP REVIEWED WITH
BOT, SECRETARY
AND GOVERNOR

BOT APPROVES
REVISED
STIP

REVISED STIP
TO
FHWA FOR
APPROVAL

PROGRAM DEVELOPMENT BRANCH

North Carolina's Rural Consultation Process
January, 2004
The following chart links a particular project development process with the Section 106 process in order to show the areas needing coordination. Although each of the project development processes undoubtedly contains more specific steps than those included here, editing irrelevant information from the chart focuses on the information on relevant steps. The three archeological phases are shown in appropriately muted colors with a key explaining the purpose of each phase. The individual steps of both processes are contained in consistent text boxes with clear explanations, while thick tan lines link concurrent steps in both processes.

This example uses the following Design Elements in order to make clear associations among diverse relationships:

1. By using the simplest display format possible, the reader is able to easily navigate through the steps. The flow chart also uses stop signs to add visual emphasis to the process outputs.

6. The smallest effective difference. The flow chart uses subtle color differences, predictable shapes, and distinct elements to link the steps.

7. Facilitate wise comparisons. The flow chart maintains each processes’ flow while linking concurrent steps in the center.
Information Design for Effective DOT Decision-making

**Iowa DOT’s Project Development**

**“CAN DO” PROCESS**

1. Send new project scope to regulatory/governmental agencies
2. Collect data about the project corridor
3. Develop location alternatives
4. Recommend one alternative

**PHASE 1**

**PHASE 2**

**“SECTION 106” REVIEW PROCESS**

1. Initiate project, notify tribes
2. “Identify historic property” (Does any historic property exist?)
   - Yes: “Evaluate property’s historical significance” (Determine if property is potentially eligible for National Register of Historic Places)
   - No: No NRHP-eligible property

3. “Assess adverse effects” (Is NRHP-eligible property likely to be adversely affected by project?)
   - Yes: “Resolve effects” (Develop Memorandum of Agreement to resolve/mitigate adverse effects)
   - No: 106 completed; end of consultation (unless site finding)

4. Acquire right of way

**PHASE 3**

**Legend for Phases of Archaeological Investigation**

PHASE 1 archaeological investigation: to determine if the site may contain historic property; includes visual survey, surface data collection and/or subsurface testing

PHASE 2 archaeological investigation: to determine if property qualifies for National Register of Historic Places; includes subsurface testing and research

PHASE 3 archaeological investigation: to determine methods by which Memorandum of Agreement will be implemented; may include archaeological excavation, data recovery
5 Working with Common Information Design Software

The discussion thus far has focused on information display options, particularly those most relevant to the work of state DOTs. This section more closely examines potential issues and concerns that can occur when editing graphics with some common software tools. The information design principles discussed continue to be relevant, particularly as the default settings for most programs are unlikely to be optimal for your particular data.

5.1 Working in Excel

For many people Excel is the standard program used to transform data and statistics into visual charts and graphs. Excel default settings are not necessarily consistent with the principles of good graphic design. This section highlights several tools that a chart designer can use to manipulate the chart options within Excel, in order to create more informative, interesting information displays.

5.1.1 Improving Excel output by choosing the right chart type

The example to the right was intended to show the effect of alcohol and drug use on driving. The Excel defaults allocated too much space to chart elements of less importance such as legends and axes labels, while relegating the actual data to the background. None of the data show much variation, and the third category is rendered too small to identify.

This distortion often occurs during the last phase of chart-making in Excel, when the chart is created in the existing worksheet, instead of a new one.

Choosing a line chart instead shows the variations in each category over time by allowing each an appropriate scale.

It is also easier to label and line chart with the full names of each variable.
5.1.2 Improving an Excel chart of the same kind

The following two bar charts illustrate several advantages to controlling Excel’s chart design capabilities. Both charts illustrate the identical data using the same chart type, but while the first uses Excel’s default modes, the second was created with a few simple adjustments to color, font size, and labeling.

**Crossover of TTF Revenues from Construction to the HMOF**

- 2002: First year of crossover
- 2014: No longer able to fully match federal funds
- 2018: All TTF transferred to HMOF

**Crossover of TTF Revenues from Construction to the HMOF**

- 2002: First year of crossover
- 2014: No longer able to fully match federal funds
- 2018: All TTF transferred to HMOF

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*ICF International*
The changes which were used in Excel to create the second chart include:

- Removing the gray background by selecting “no fill,”
- Changing the font to Times New Roman for increased readability; deleting the Excel legend and adding text boxes to the chart directly,
- Selecting two colors with a higher contrast than blue and maroon, while noting how they will look when reproduced in black and white,
- Changing the gridlines from “automatic” or black to light gray,
- Changing the X axis labels to a horizontal orientation from a 45-degree angle and eliminating every other year, and
- Creating a text box for the chart title in Times New Roman font.

5.1.3 Improving Excel output by starting over

As powerful as it is, sometimes Excel just won’t be the right tool with which to develop a chart.

The two charts to the right show the number of Type 2 NEPA Categorical Exclusions (CE) entries and average processing time. There are several design problems with these charts, problems common to Excel.

1. There is no need for three dimensions. A two-dimensional bar chart would have more clearly conveyed the data.
2. Including a key in each bar chart constitutes chartjunk when there is only one type of data in each, and the units are already given on the X axis.
3. The bars in both charts are too thin and do not fully use the area of the chart to display the data.
4. At the same time, the bars are different widths in each chart, although they contain the same number of samples along the X axis.

These problems stem from uncritically using Excel defaults. Even if these were fixed, however, it is difficult to extract much meaning from the two charts. The chart that a decision-maker really cares about is Figure 2, and the question she or he will ask of the chart is, how long do Categorical Exemptions tend to take? Most of the bars are below 30 months, but the two in the middle at 40 and 80 months certainly draw the eye, emphasizing those high values. One has to take a little time to read back to Figure 1 to learn that the outlier 80 month sample has only three entries, and that the samples with shorter average processing times have far more entries. What conclusion can be drawn from these
two charts? And if one is trying to make a decision, how would use the two charts to make it? There should be a way to paint a fuller, more informative, more useful picture for decision-makers in one chart.

**Suggested reworking**

Instead of using a bar chart to display this information, the entire graphic can be combined into a single, data-rich chart. The data plot below identifies the same Type 2 CE information by number of months required for processing, but much more effectively. By showing all the data, not just average processing times for each categorical exclusion, the chart allows patterns to be identified.

**Processing Time in Months of Type 2 Categorical Exclusions (by Sample Type)**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Years</th>
<th>Processing Time in Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>12 14 16 17 20 23 24</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>19 22 25 18 19 23 26</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>36 38 40 42 44 37 42</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>79 80 83 79 80 83 79</td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>8 13 16 17 36 37 42 46</td>
</tr>
<tr>
<td>F</td>
<td>6</td>
<td>23 31 28 25 28 25</td>
</tr>
<tr>
<td>G</td>
<td>7</td>
<td>40 42 44 36 37 42 46</td>
</tr>
</tbody>
</table>

Cluster from 1-2 years (n = 25)
Cluster from 3-4 years (n = 12)

**Total N = 41**

**Discussion: designing for audiences**

Because Excel makes the bar chart approach so easy, it is common. The second approach, or any new approach to showing data, will be unfamiliar, and so most such approaches will require some discussion. Is that helpful or not to decision-making? It depends on the purpose of the data presentation. Is the chart intended primarily to communicate a point in support of decision-making? Or is the chart intended to support decision-making by supporting an exploration of data and what lessons it might hold? An information designer like Tufte, whose many works in the field were discussed in Chapter 1, would argue strenuously that all charts should support decision-making, rather than simply support a decision already made. But a state DOT employee needs to take into account her or his audience. Will the chart be used in fast-paced executive briefing, or will it be used at the staff level to explore and develop conclusions?

Ideally, a chart will serve in both purposes, making a point without too much discussion, but containing enough information to support deeper discussion should it be necessary. Although the reworked chart is unlikely to be used in an executive briefing, it shows how a chart can make both a straightforward point and support deeper discussion if desired. A presentation using this chart might proceed as follows:

- You asked “How long do Categorical Exemptions take to process?” This chart shows 41 CEs, in five samples. Each CE is shown in the chart by the number of months it took to process it. Each of the samples cover different conditions, so we haven’t taken a simple average, as that might be misleading.

However, you can see some clear patterns. 25 of the 41, or about 60%, are processed in 2 years or less. Another 12, or 30%, are processed in 3 to 4 years.
Q: So, 90% of our CEs are processed in less than 4 years?
- Yes.

Q: Do we know why some CEs take 1-2 years, and others take 3-4 years? And what happened with those 3 that took 7 years?

If the decision-maker wants to stop at “90% of all CEs are processed in less than 4 years,” he can. But if he wants to go deeper, the data to support a deeper discussion is right there. The new, single chart enables both the fast conclusion and the deeper discussion. The two original Excel charts neither reached any kind of conclusion, nor enabled any kind of useful discussion.

The Design Principles in the reworked chart include:

1. Use the simplest display format possible. This display may not look simpler at first, but it combines two less effective charts into one effective chart.

3. Employ appropriate size, scale, and units. If the question is, how long does CE take?, then the chart should help answer that question. As a start to answering it, the chart shows time in an intuitive left to right direction, and locates the data on that time scale.

4. Use design elements that focus attention on the data. This chart allows one to see clusters of processing times.

7. Facilitate wise comparisons. If comparing two or more data variables, put them on the same chart. Show the actual data, rather than aggregations.

This chart was developed in Word, and took just under 20 minutes.

This extended discussion of how to design a chart—both to communicate effectively and to support discussion—is in the “Excel” section of this primer because it illustrates so effectively that sometimes Excel will simply not be the right tool for an information design job. Excel and similar programs are simply tools, and should be chosen and used with care, not as defaults whenever data are involved.

5.2 Working in PowerPoint

The primer has thus far been focused both on the creation and presentation of graphics for use in documents and reports. Many state DOTs use Microsoft PowerPoint to give presentations. Principles for using graphics in presentations are similar to those for printed reports, but warrant additional discussion as well, as graphics must be modified to fit the screen, be especially clear and concise, and fit the themes and characteristics of the presentation as a whole.

A common practice used by government agencies to convey information both internally and externally is the slide presentation, in which points and evidence critical to the topic at hand are packaged into slides and projected onto a screen.

There is growing awareness among presenters and audiences about the limitations of this medium for conveying information. One of the most articulate critics of software-created slide presentations is Edward Tufte, who levels several criticisms at the format.5 While PowerPoint does much to enable

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presenters to combine words, numbers, and images (which is a hallmark of good information design), as well as to help presenters organize their thoughts, critics like Tufte argue that its shortcomings have actually led to a decrease in the quality of many presentations in which it is used.

Tufte suggests that PowerPoint has three chief weaknesses.

**Low spatial resolution**

Low resolution refers to the fact that compared with sheets of printed paper; the slide format can display orders of magnitude less data density. In other words, slides can accommodate many fewer characters for describing information, and the images projected are much more limited in detail than the images that can be printed on paper.

**A hierarchical, single-path format**

The single-path format refers to the linearity of ordering one slide after another, imposing a rigid order to the presentation that does not support the flexibility that effective information exchange and discussion sometimes demands.

**A focus on decoration instead of content**

Finally, the many standard templates packaged with PowerPoint software are focused on making a presentation look professional, but feature little attention to ensuring that it conveys information clearly. An obvious example is the busy “slide master” background that is often used on every slide.

If not handled properly, these three weaknesses lead to the over-simplification of the important points and information that a presentation means to convey, the loss of nuances in complex data and messages, and the obscuring of data by decoration.

The low spatial resolution of computer slide presentations precludes complex charts, allowing only the simplest displays to be projected with any clarity. Complex points are also precluded by the limited character density that this format can sustain, leaving only the most general and boiled-down text on the actual slides.

The relationships among the important points are often lost, making it difficult for an audience to see how one concept or finding may affect another. The analysis of data and information calls for examining data side-by-side, within eyesight, but slides do not have the capacity to carry the necessary amount of information required to make such comparisons simultaneously.

Tufte makes a distinction between teaching – characterized by explanation, reasoning, and questioning – and marketing – characterized by persuading, building support, and influencing. While academicians such as Tufte are primarily interested in teaching, it is sometimes the charge of transportation agencies to market ideas successfully, whether those ideas concern securing more funding or building consensus about how investments should be prioritized or convincing travelers to change behavior. Furthermore, the focus of the audience of scientific and academic talks is often decidedly different than the audience of transportation agency presentations. While academicians may need more open-ended discourse and debate about the meaning of scientific evidence, executive managers, decision-makers, and the general public may be more interested in quickly understanding ‘take-away’ messages.
Slide presentations such as PowerPoint have major limitations as tools for conveying information meant for teaching and discourse. But slide presentations do have major strengths as a means to convey information to persuade and influence.

Even its critics allow that PowerPoint is useful as an organizer of low-resolution color images, graphics, and videos. PowerPoint can be used to quickly and easily generate visual diagrams to show relationships among distinct entities or concepts, including directional relationships that show cause and effect. Points are often bolstered by inclusion of low-resolution, color images as examples to the subject being discussed, and PowerPoint serves as an easy way to organize and display such visual information. Finally, moving images may also be the best choice to illustrate certain points, and PowerPoint can be used to link instantly to such videos during a presentation.

Agencies still confront the question of whether or not to use slide software as a method of presenting. As Tufte notes, people can grasp visual information much faster than they can absorb it from talks. And yet, live presentation of information can be more engaging and interactive to audiences than a paper. Effective information design, then, may lie not in avoiding certain channels of information transmission, but in selecting the most effective channels, and then capitalizing on the strengths of those channels while avoiding the pitfalls associated with their weaknesses.

Should a transportation agency seek an alternative to PowerPoint, there are ways in which talks can be given without it. Instead of printouts of slide presentations, presenters can distribute paper handouts, formatted with a word processor or other tool rather than PowerPoint, that show the important text, numbers, data graphics, and images the presenter is interested in conveying. The previous sections of this Primer have been dedicated to producing easy-to-read information displays. But easy-to-read is not the same as simple, which is what PowerPoint compels because of its low-resolution capacity. Printed material, with much higher resolution, is preferable for information displays of almost any complexity. Tufte recommends using an 11” x 17” paper, folded in half to make 4 pages, which can convey up to 250 slides’ worth of information. Such a handout, on which various text and graphics can be arranged in various ways, can be a very effective accompaniment to a presentation that also serves as a take-home reference.

There are many ways to use the strengths of PowerPoint and avoid the pitfalls caused by its weaknesses. Thanks to Tufte and other critics of PowerPoint, some of these pitfalls are clear.

- For reasons discussed above in terms of adding distracting decoration without clarifying the information being presented, the packaged PowerPoint templates may very well do more harm than good, and are best avoided.

- The low-resolution of PowerPoint makes it a poor tool for producing information displays of any complexity. These graphics are best created and printed for display rather than imported into PowerPoint for projection or for creating slide handouts. Bullet lists are another area of potential pitfall.

- Tufte advises against using elaborate hierarchies of bullet lists, as such hierarchies can artificially and detrimentally compartmentalize pieces of information that may be more enlightening if allowed to mingle freely.
6 Case study

No one case study can capture all the recommendations or design principles. This case illustrates most of the principles discussed above.

**South Weymouth Naval Air Station Redevelopment**

South Weymouth Naval Air Station in Massachusetts is a 1300-acre Base Realignment and Closure (BRAC) site, 20 minutes south of Boston on a heavy rail commuter line. The three communities around it developed two rounds of base redevelopment plans that they believed would serve their goals. These plans encountered a variety of barriers, including concern about the traffic that would be generated. As a result, no plan could move forward.

For the third round of planning, a broad set of community performance indicators was introduced to help the community and the many local, state, and federal stakeholders, including the state DOT and the commuter rail agency, and others concerned about transportation implications, better understand the implications of different base redevelopment options.

The current preferred plan, produced with the help of this process, has very high scores on performance measures established by the stakeholder process, and as a result has widespread support among stakeholders. The graphics used in this case are exemplary for a number of reasons.

From a transportation agency perspective, the redesign addresses several concerns affecting the number of new trips generated by each new job and household. (Although the total amount of travel generated by the site increased as growth was added, that growth now also does not go elsewhere in the region, reducing the burden on the transportation system elsewhere. This aspect is unfortunately not captured in these graphics.) However, transportation was only one of the stakeholders’ concerns, so the project graphics addressed all of the performance measures of concern.
Smart Growth INDEX Case Study
South Weymouth, Massachusetts

- 1,450-acre military base reuse plan.
- Designed by ICF International for the U.S. EPA.
- Key design objectives: wetlands preservation and transit orientation.

September 2004
This graphic illustrates the following design principles:

1. *Use the simplest display format possible.* Here, the bracketing of cases 0 through 5 visually reinforces the idea that they have led to the development of case 6.

2. Including the data table with the geographic display *shows all the data in context.*

8. *Use small multiples.* Putting the seven site plans next to each other helps the reader compare them.

9. *Use color judiciously.* The color scheme distinguishes land uses while allowing differences between each map to come into focus.

The data table in the graphic above, while an important element in the overall information display, does not communicate for a decision-maker data as effectively as it could. A reader will ask: Why is the preferred case preferred? Why is its performance judged to be superior? That question is answered in the table below.
<table>
<thead>
<tr>
<th>Indicators</th>
<th>Units</th>
<th>Mills</th>
<th>Post Mills</th>
<th>Main Street</th>
<th>Compact</th>
<th>Villages</th>
<th>Dover Kohl</th>
<th>Preferred</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
<td>residents</td>
<td>1,540</td>
<td>1,540</td>
<td>10,211</td>
<td>9,468</td>
<td>8,924</td>
<td>6,955</td>
<td>5,958</td>
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<tr>
<td><strong>Employment</strong></td>
<td>employees</td>
<td>7,078</td>
<td>7,214</td>
<td>4,372</td>
<td>4,825</td>
<td>4,988</td>
<td>2,137</td>
<td>2,438</td>
</tr>
<tr>
<td><strong>Population Density</strong></td>
<td>res/net ac</td>
<td>41.62</td>
<td>21.42</td>
<td>50.73</td>
<td>79.84</td>
<td>80.58</td>
<td>41.27</td>
<td>56.09</td>
</tr>
<tr>
<td><strong>Land Use</strong></td>
<td>Use Mix</td>
<td>0-1 scale</td>
<td>0.04</td>
<td>0.3</td>
<td>0.14</td>
<td>0.15</td>
<td>0.15</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Use Balance</td>
<td>0-1 scale</td>
<td>0.51</td>
<td>0.71</td>
<td>0.70</td>
<td>0.80</td>
<td>0.81</td>
<td>0.91</td>
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<tr>
<td><strong>Housing</strong></td>
<td>Single-Family Dwelling Density</td>
<td>DU/net ac</td>
<td>--</td>
<td>--</td>
<td>7.78</td>
<td>9.13</td>
<td>4.57</td>
<td>7.72</td>
</tr>
<tr>
<td></td>
<td>Multi-Family Dwelling Density</td>
<td>DU/net ac</td>
<td>18.92</td>
<td>9.74</td>
<td>27.54</td>
<td>36.32</td>
<td>33.67</td>
<td>22.86</td>
</tr>
<tr>
<td></td>
<td>% total</td>
<td>0.0</td>
<td>0.0</td>
<td>8.7</td>
<td>0.0</td>
<td>9.4</td>
<td>6.0</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>Multi-Family Dwelling Share</td>
<td>% total</td>
<td>100.0</td>
<td>100.0</td>
<td>91.3</td>
<td>100.0</td>
<td>90.6</td>
<td>94.0</td>
</tr>
<tr>
<td></td>
<td>Amenities Proximity</td>
<td>avg walk ft</td>
<td>1,732</td>
<td>5,021</td>
<td>2,083</td>
<td>1,244</td>
<td>1,081</td>
<td>556</td>
</tr>
<tr>
<td></td>
<td>Transit Proximity to Housing</td>
<td>feet</td>
<td>5,298</td>
<td>5,702</td>
<td>910</td>
<td>884</td>
<td>849</td>
<td>743</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>Jobs to Housing Balance</td>
<td>jobs/DU</td>
<td>10.11</td>
<td>10.31</td>
<td>0.96</td>
<td>1.12</td>
<td>1.26</td>
<td>0.69</td>
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<tr>
<td></td>
<td>Employment Density</td>
<td>emps/net ac</td>
<td>24.12</td>
<td>24.46</td>
<td>55.40</td>
<td>45.78</td>
<td>40.85</td>
<td>19.77</td>
</tr>
<tr>
<td></td>
<td>Transit Proximity to Employment</td>
<td>feet</td>
<td>8,171</td>
<td>5,579</td>
<td>758</td>
<td>781</td>
<td>1,339</td>
<td>768</td>
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<tr>
<td><strong>Recreation</strong></td>
<td>Park Space Supply</td>
<td>ac/1000 pers</td>
<td>114.9</td>
<td>45.0</td>
<td>4.3</td>
<td>6.5</td>
<td>0.6</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>avg walk ft</td>
<td>8,173</td>
<td>4,382</td>
<td>1,239</td>
<td>991</td>
<td>2,121</td>
<td>677</td>
<td>810</td>
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<tr>
<td><strong>Environment</strong></td>
<td>Open Space Share</td>
<td>% total area</td>
<td>53.5</td>
<td>64.7</td>
<td>69.9</td>
<td>75.4</td>
<td>74.2</td>
<td>71.1</td>
</tr>
<tr>
<td></td>
<td>Open Space Connectivity</td>
<td>0-1 scale</td>
<td>0.90</td>
<td>0.93</td>
<td>0.95</td>
<td>0.96</td>
<td>0.94</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Stormwater Runoff</td>
<td>cubic ft/ac/year</td>
<td>27.713</td>
<td>30.937</td>
<td>20.204</td>
<td>16,984</td>
<td>20,385</td>
<td>22,262</td>
</tr>
<tr>
<td></td>
<td>Nonpoint Pollution</td>
<td>kilograms/ac/year</td>
<td>50.9</td>
<td>54.5</td>
<td>36.8</td>
<td>30.7</td>
<td>38.1</td>
<td>42.3</td>
</tr>
<tr>
<td></td>
<td>Imperviousness</td>
<td>%</td>
<td>28.49</td>
<td>35.40</td>
<td>17.30</td>
<td>16.12</td>
<td>17.62</td>
<td>18.63</td>
</tr>
<tr>
<td><strong>Transportation and travel</strong></td>
<td>Internal Street Connectivity</td>
<td>ratio</td>
<td>0.43</td>
<td>0.71</td>
<td>0.97</td>
<td>0.95</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>External Street Connectivity</td>
<td>feet</td>
<td>9,047</td>
<td>11,309</td>
<td>5,654</td>
<td>9,047</td>
<td>5,654</td>
<td>4,523</td>
</tr>
<tr>
<td></td>
<td>Street Segment Length</td>
<td>ft</td>
<td>3,619</td>
<td>854</td>
<td>378</td>
<td>544</td>
<td>431</td>
<td>408</td>
</tr>
<tr>
<td></td>
<td>Street Centerline Distance</td>
<td>total ft</td>
<td>32,301</td>
<td>64,317</td>
<td>93,428</td>
<td>69,035</td>
<td>96,719</td>
<td>117,111</td>
</tr>
<tr>
<td></td>
<td>Street Network Density</td>
<td>st mi/sq mi</td>
<td>2.7</td>
<td>5.4</td>
<td>7.9</td>
<td>5.8</td>
<td>8.3</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>Pedestrian Network Coverage</td>
<td>% of streets</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Pedestrian Crossing Distance</td>
<td>feet</td>
<td>68</td>
<td>47</td>
<td>41</td>
<td>45</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Street Route Directness</td>
<td>walk/air ratio</td>
<td>1.71</td>
<td>1.43</td>
<td>1.50</td>
<td>1.44</td>
<td>1.52</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>Pedestrian Accessibilities</td>
<td>% w/15 min</td>
<td>91.5</td>
<td>99.2</td>
<td>98.9</td>
<td>99.9</td>
<td>97.3</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Home Based Vehicle Mi. Traveled</td>
<td>mi/day/capita</td>
<td>19.8</td>
<td>20.0</td>
<td>18.8</td>
<td>18.5</td>
<td>18.4</td>
<td>19.7</td>
</tr>
</tbody>
</table>

### Best practice ratings

- **Favorable**
  - 6
  - 7
  - 16
  - 16
  - 14
  - 15
  - 19

- **Fair**
  - 5
  - 3
  - 5
  - 4
  - 6
  - 6
  - 3

- **Unfavorable**
  - 13
  - 14
  - 4
  - 4
  - 5
  - 4
  - 3
This table illustrates the following design principles:

4. *Design elements focus attention on the data.* Which performance indicators improved? Which ones still need improvement? The color coding quickly answers these questions. The accompanying data then answer “by how much?” if one wants to delve deeper.

9. *A judicious use of color.* The chart uses color to tell a story, and not to decorate.

Although this table rewards a close read, for many audiences it will be too dense. One can condense it, and replace the color ratings with simple changes.

### PERFORMANCE INDICATORS: SOUTH WEYMOUTH NAVAL AIR STATION REDEVELOPMENT

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Original plan</th>
<th>Approved plan</th>
<th>Change from original plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>residents</td>
<td>1,540</td>
<td>7,218</td>
<td>+369%</td>
</tr>
<tr>
<td>Population Density</td>
<td>residents/gross acre</td>
<td>21.4</td>
<td>82.4</td>
<td>+285%</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>employees</td>
<td>7,214</td>
<td>4,720</td>
<td>-35%</td>
</tr>
<tr>
<td>Employment Density</td>
<td>employees/net acre in jobs</td>
<td>24.5</td>
<td>148.2</td>
<td>+506%</td>
</tr>
<tr>
<td>Commercial Building Density</td>
<td>commercial floor area/net acre</td>
<td>0.3</td>
<td>.4</td>
<td>+43%</td>
</tr>
<tr>
<td>Jobs to Housing Balance</td>
<td>jobs/DU</td>
<td>10.3</td>
<td>1.4</td>
<td>-87%</td>
</tr>
<tr>
<td><strong>Recreation and Amenities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amenities Proximity</td>
<td>average walk ft</td>
<td>5,021</td>
<td>1,525</td>
<td>-70%</td>
</tr>
<tr>
<td>Park Proximity</td>
<td></td>
<td>4,382</td>
<td>568</td>
<td>-87%</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stormwater Runoff</td>
<td>cubic ft per acre per year</td>
<td>23,206</td>
<td>17,383</td>
<td>-25%</td>
</tr>
<tr>
<td>- per person</td>
<td></td>
<td>15.1</td>
<td>2.4</td>
<td>-84%</td>
</tr>
<tr>
<td>Nonpoint Pollution</td>
<td>kilograms per acre per year</td>
<td>54.5</td>
<td>31</td>
<td>-43%</td>
</tr>
<tr>
<td>- per person</td>
<td></td>
<td>0.04</td>
<td>0.004</td>
<td>-88%</td>
</tr>
<tr>
<td>Imperviousness</td>
<td>% of total land</td>
<td>35.6</td>
<td>13.9</td>
<td>-61%</td>
</tr>
<tr>
<td><strong>Travel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing Proximity to Transit</td>
<td>Average feet to rail station</td>
<td>5,702</td>
<td>448</td>
<td>-92%</td>
</tr>
<tr>
<td>Employment Proximity to Transit</td>
<td></td>
<td>5,579</td>
<td>673</td>
<td>-88%</td>
</tr>
</tbody>
</table>

The single color, green, highlights unambiguously positive changes.
Finally, this case study helps illustrate some of the themes in Section 5.2 about the limitations of working with PowerPoint.

These pages would not project well. They are too dense with information to be read from a distance. However, they are easily read on paper, and detailed, successful meetings on the very complex question “What is the best land use plan for the re-use of South Weymouth Naval Air Station?” have been supported entirely with these charts, printed and distributed.

- For executive decision-making briefing, one can make just a single point: the “Final” plan is preferred because it has the highest total Favorable + Fair scores, including all of the transportation performance indicators.

- For those who wish to delve into why the different plans produce different performance, that detail is available as well, without overwhelming the basic point.
Appendix: A brief selection of terms

*Axis, axes.* X and Y axes in chart with two variables are labeled in the chart below.

If the items on the X axis refer to individual things, like individual states, then the X axis is generally called the “Category axis”.

*Chart, Graph.* According to most dictionaries, may be used interchangeably to refer to any visual representation of numbers. In some organizations, “graph” may have a narrower connotation of displaying data on X and Y (or more) axes (as shown below), and “chart” is used for everything else, such as a “pie chart”. This primer uses “chart” as a general, all-inclusive term.
**Data dimensions.** The number of different types of information in a chart. For example, a chart of VMT by year has two types of information in it; VMT, and year. The chart should thus have only two dimensions, the X and Y axis, as shown above in *Axis*.

A “3-D” chart should be used only when the data have three dimensions. For example:

---

**Graphic.** Strictly speaking, anything written or drawn, but in common use in information design, anything other than the text. A chart is a graphic; so are a picture, and a map.

**Serif, San serif fonts.**

*Serif; San serif*

Serifs are the additional material on the letters in the word on the left, like the “foot” on the “f”. These make text easier to read in most cases. Of fonts available in most common computer programs, Times New Roman is serif, and Arial is san serif—without serifs. Serif fonts make for good text, and san serif make for good captions.