Data Visualization for Business Intelligence

Jack G Zheng
Kennesaw State University

6
Data Visualization in Business Intelligence

Jack G. Zheng

Introduction

Business Intelligence (BI) is a set of methods, processes, architectures, applications, and technologies that gather and transform raw data into meaningful and useful information used to enable more effective strategic, tactical, and operational insights and decision-making to drive business performance (Evelson and Nicolson, 2008). A general BI process covers a number of sub-processes or phases including data gathering, data cleanse, data storage, data analysis, data presentation and delivery (Zheng, Zhang, and Li, 2014). In the phase of data presentation, query or analysis results are presented and delivered in various human comprehendible formats (such as tables and charts) which directly supports sense-making and decision-making. Data presentation also includes interactive queries and data explorations that help users find useful information. Correspondingly in the technology stack, BI systems include various data visualization and interaction forms and techniques through reports (static and interactive reports), digital dashboards, and more complex analytical visual tools (Chiang, 2011).

Data visualization has been rising rapidly for the past a few years in the BI and analytics industry, as part of the modern BI movement which emphasizes on self-service (Parenteau et al., 2016). It is also a big part of data science which has gained wide popularity recently. There have a been a plethora of tools and systems that feature their data visualization solutions. As an interdisciplinary field, data visualization brings together psychology, technology, art, and decision science to deliver the last mile of the complete BI and analytics capability to users. Compared to other types and applications of visualization, business data visualization, particularly concerns about the visualization of business data, is mainly for the purpose of communication, information seeking, analysis, and decision support.

One of the key questions in business data visualization is how, and in what form, data visualization contributes to the overall business intelligence process and system. This chapter provides a comprehensive high-level view of different types of data visualizations that can be used in the business environment, and to provide a guidance of technology and system selection. The chapter starts with defining business data visualization and comparing it to other common types of visualizations and their applications, then provides a comprehensive review and analysis of common tools and applications of business data visualizations used in business intelligence, and concludes with a brief overview of recent trends and prospects.

Background

What Is Business Data Visualization?

The term "business" in "business data visualization," as well as in "business intelligence," has a broader meaning than just commercial activities. It generally refers to many human and organizational activities and operations that keep a system running. This can include commerce, education, sports, entertainment, government, and many others. In these business activities and processes, data are produced and recorded to reflect all aspects of the business (human or organizational activities), and then it is analyzed and reported at various levels. Business intelligence is about transforming raw data into meaningful and useful information that is consumed by humans. Business data or information is different from other types of data (Tegarden, 1999). In the context of business intelligence, business data has the following features:

- Abstract: most business data describes abstract activities and processes (e.g. product sales, member registration, product or user movement, etc.). The data does not describe or is not directly used to create real-life entities (objects, models) or phenomenon. The visual representation of this kind of data is also abstract by using metaphors.
- Quantitative: although qualitative data also offers great insights and has a lot of values today especially in the artificial intelligence discipline, quantitative data is the focus of business data. In many cases, qualitative data is quantified in business intelligence analysis and business data visualization.
- Structured or semi-structured: most data is structured and shares common attributes with clearly defined metadata.
- Multidimensional: facts or measures can be viewed and analyzed through different perspectives and levels. This is particularly common in business analysis.
- Atomic: most business activities are based on business transactions; each raw data record represents a transaction and can be viewed and understood independently.

- Comprehendible: data and results can be directly understood by human users (assuming with domain knowledge) in a short time.

The BI process typically consists of data management (also including data gathering, cleanse, storage), data analysis, and data presentation. The term data presentation describes the interfacing layer between data and human. In this layer, data (can be raw, aggregated, or any types of analysis results) are presented to users in their desired forms and formats. In the statistics discipline, the three basic categories of data presentation are commonly summarized as textual, tabular, and graphical. These categories can also apply to BI data presentation methods. Data visualization is the graphical or visual method of presenting data. In the context of business intelligence, it can also be called business data visualization or business information visualization to distinguish other types of visualization.

In general, visualization is the process of forming a concrete and direct vision-perceivable image in a human mind by utilizing a combination of visual elements (shapes) and variables like color, positions, etc. Things that can be visualized include visible reality that people can see (person, world, nature), hidden reality that normally be hidden (earth core, blood, universe), invisible reality (wind, air, heat, electron, sound, smell), and abstract things (data, idea, hierarchy, process, relationship).

Data visualization is the visual and interactive exploration and graphic representation of data of any size, type (structured and unstructured) or origin. The purposes of visualizing data are multifold, ranging from general comprehension and understanding of ideas, supporting information behaviors (analysis and decision support, information seeking, browsing, navigation), to artistic (beauty) expression and appreciation (Viégas and Wattenberg, 2007), and even just for fun or storytelling. In contrast, the goals of visualizing business data are focused on human information seeking and decision-making behaviors, particularly in two broad goals: (a) visualizing key metrics for easy and fast comprehension which directly facilitates decision-making; (b) providing a visual and interactive way to explore data. Such visualizations often use simple, standard, and abstract charts or diagrams, and utilize data binding techniques at the back end.

Both research and practices have shown data visualization's value and contribution to the decision process (Vessey, 1991) and information-seeking process (Shneiderman, 1996). Visualization generally helps data comprehension and enhances problem-solving capabilities. More specifically:

- Visualization eases the cognitive load of information processing, and it helps one recall or memorize data easily because of the perceivable image (Borkin et al., 2013).

- Data visualization techniques provide a visual overview of complex data sets to identify patterns, structures, relationships, and trends at a high level.
- Visualizations provide visual cues that draw people's attention to quickly focus on areas of interest or areas of difference (can be an anomaly). This allows decision makers to use their natural spatial/visual abilities to determine where further exploration should be done (Tegarden, 1999).
- Visualization exploits the human visual system to extract additional (implicit) information and meaning, sometimes referred to as intuition.

Business Data Visualization vs. Other Types of Visualization

Business data visualization has some unique features compared to some related fields or methods that also utilize general visualization techniques. These related fields or methods mainly include: information visualization, illustration, scientific visualization (discussed together with computer graphics and VR), and simulation. Their differences can be best illustrated in their content (what is to be visualized), visual forms/tools (how they are visualized), and purposes. The comparison is summarized in Table 6.1.

Table 6.1 Comparison of Related Visualization Fields

	Content	*Visual Forms/Tools*	*Purpose*
Business data visualization	Quantitative data, metrics, key performance indicators (KPIs)	Charts, diagrams, dashboards	Data exploration, analysis, decision-making
Information visualization	All kinds of information, quantitative and qualitative	Infographics, illustrational diagrams	Information seeking, artistic illustration, casual communication, storytelling
Illustration	Processes, structures concepts, ideas	Diagram, image, graphics	Making the content more vivid and engaging, easier to understand the complexity
Scientific visualization	Real-world object or phenomenon, mathematical functions and formulas	Computer-generated graphics, 3D virtual reality	Recreate or simulate the real-world object or phenomenon, or visualize an algorithm effect
Simulation	Calculated data based on formulas or rules	Animated diagram or virtual reality	Demonstrate the effect of scenarios under certain rules

Information visualization is a very close field to data visualization. In fact, the term is often used as the synonym to data visualization if data is used in a more general sense (in contrast to business data). They share many common features, principles, and methods. However, information can be generally more qualitative and less structured, for example, information about workflows, structures, concepts, and ideas. The visualization of information utilizes more free forms of visual diagrams or illustrations (illustrational diagrams) that are not specifically for quantitative data, for example, network graphs and workflow charts.

Information graphics or infographics are a common tool for information visualization especially in a more casual context. An infographic is commonly a mixture of different forms of information (text and numbers) and multiple visual forms (charts, diagrams, images, tables, maps, lists, etc.) to quickly and vividly communicate a good amount of information in an engaging manner (Harrison, Reinecke, and Chang, 2015). Many infographics have a typical format characterized by large typography and long vertical orientation (Lankow, Ritchie, and Crooks, 2012). They are gaining popularity in online marketing over the years and their use has expanded in many occasions where communication to the public is important. Some examples can be found at dailyinfographic.com and cooldailyinfographics.com.

Information visualization is more casual (Pousman, Stasko, and Mateas, 2007), general, and subjective than business data visualization whose purpose is more for decision support or data exploration. It is intended for a wider and casual audience with a focus on storytelling or narrative visualization (Segel and Heer, 2010). Because of this, information is presented with stronger artistic expression than that found in typical business data visualizations (Hagley, n.d.), sometimes with overuse of artistic design, often referred to as visual embellishment (Bateman et al., 2010).

Illustration, as a term, is a little different than visualization. Illustration often is used to explain ideas or concepts with the help of diagrams or even general pictures and graphs. It materializes abstract ideas using more concrete and directly perceivable images for explanation, or uses simplified diagrams for explaining more complex situations (processes or structures). Most importantly in the context of business, illustrations are not necessarily data driven.

Scientific visualization, commonly used in science, is "primarily concern[ed] with the visualization of three-dimensional phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth" (Friendly and Denis, 2006). Examples include physical science visualization, visualization (simulation) of reality (universe, sun, explosion, atom, climate, etc.), and mathematical model/algorithm visualization. The visual output can be a virtual replica creation based on real data, or computer-generated data based on algorithms and imaginary creation. Scientific visualizations often make use of computer graphics and virtual reality technologies to recreate the visual scene.

Simulation is somewhat related to scientific visualization and is specifically used to demonstrate motion-based visuals. It can utilize complex computer graphics to generate realistic scenarios. On the other hand, it also can create simple scenarios using animated diagrams or simple graphics (e.g. http://setosa.io/bus/).

Business Data Visualization Forms

With the increasing recognition of data visualization's roles and values in a business intelligence system, tools and applications that specifically target business data visualization solutions have become widely available. This section will review some most common types of data visualization forms and tools used in BI.

Categorizing Business Data Visualization Forms

Typically, BI results are presented in the form of reports, dashboards, and analytical tools. Among these, dashboards are mostly data visualization driven. Reports are traditionally static and non-interactive, and they present more detailed data. Modern reports add a lot of elements of visualization (either embedded visuals or charts/diagrams) and interaction, which enhance reports' readability. Analytical tools are also becoming more visually oriented. Some analytical tools, labeled as visual analytical tools (or analytical dashboards), are also driven by visualizations.

There are several commonly used visualization forms and tools in BI reporting and analytics. There are three basic categories of visual forms based on how visualizations are presented on screen: embedded visuals, block visuals, and standalone visuals. Table 6.2 summarizes features and examples of each one.

Table 6.2 Common Forms of Business Data Visualization

Form/Style	*Description*	*Typical Types and Examples*
Embedded visual	It is embedded in, or directly on top of, texts and other forms of data presentation (tables, graphics, etc.).	• Conditional formatting • Inline chart (Sparkline)
Block visual	It is displayed as an independent visual unit and occupies a larger space. It is often a part of a report or dashboard, appearing together with other content. But sometimes it can become a standalone visual with many data points or enough complexity.	• Chart • Illustrational diagram • Map (smaller) • Data table (usually with embedded visuals)
Standalone visual	It is a standalone application and is not mixed with other types of content or tools. Most interactions are within the visual. It may consist of a combination of different types of visuals.	• Dashboard • Visual analysis tool (or an analytical dashboard) • Map (bigger or full screen)

Embedded Visuals

Embedded visuals are visual effects embedded in another form of presentation. They are not independently presented but always used on top of other presentation forms. Embedded visuals include two major forms: conditional formatting and inline mini charts (or Sparkline).

Conditional formatting refers to the direct formatting or styling of text, numbers, shapes, and other contents utilizing visual variables like color, size, etc. (Bertin, 2010). Conditional formatting does not significantly change the layout and flow of contents, thus it is less intrusive to the content. Instead, it provides a decorative effect that reveals more meaning or highlights selected content from the data or text.

A Sparkline is a small minimized chart embedded in the context of text paragraphs, tables, images, or other type of information. It presents the general data pattern (variation, trends, differentiations, etc.) in a simple and highly condensed way (Tufte, 2006). Interpretive and supporting information like title, label, data point, legend, are omitted from the chart. A miniature line chart (hence called Sparkline) is most commonly used, but it can be of other chart types, including bar charts, bullet graphs, etc.

Charts and Diagrams

A block visual occupies a larger space but still part of a report or dashboard, appearing together with other content. It is a more independent and self-contained visual unit. Sometimes it can become a standalone visual if there are many data points or enough visual and interaction complexity. Charts and diagrams are the two most common forms of block visuals.

Charts are a visual combination of symbols (visual elements of point, line, and area) and visual variables (color, shape, size, etc.) which are directly associated with data. The terms of chart and diagram can sometimes be used interchangeably without any explicit differences. More often, diagrams are considered to include charts. In the context of business data visualization, a chart is more abstract and focuses on visualizing quantitative values (e.g. business performance measures and indicators), while a diagram can also visualize qualitative information as well to illustrate structures, relationships, sequences, etc. Charts and diagrams are the major forms of business data visualizations used in BI. They are the fundamental piece to present data in many reports and presentations.

Basic types of charts include line charts, bar charts, pie charts, etc., and examples of diagrams include organization structure diagrams, tree diagrams, network diagrams, workflows diagrams, etc. Abela (2008) provides a basic categorization of charts by purpose; the visual guide has been widely used for guiding chart choices (Table 6.3). Another purpose, profiling, is also added to the table for a more complete comparison. Profiling can be seen as a special case of comparison among multiple data items.

Table 6.3 Chart Chooser by Abela (2008)

Purpose	*Meaning*	*Example Charts*
Comparison	Comparing and sorting data points	Bar/column chart, line chart, radar chart
Composition	Showing part-to-whole comparisons	Stacked column/area chart, pie chart
Distribution	Aggregated value (usually count) of data points placed in categories; the category can be value ranges or time (trend).	Histogram, scatter plot, bubble chart
Relationship	How things (data items) are related or positioned in a bigger context.	Scatter plot, bubble chart
Profiling*	Comprehending things through visual shapes and patterns.	Radar chart, parallel coordinates

* Added by the author to enhance Abela's version.

Other more specific types of charts are used in different business contexts for more specific purposes. These charts are based on the more generic chart types like bar charts and line charts, and add more specific visual elements, or arrange the elements in a specific way to represent domain-specific meanings. For example, bullet charts (based on bar charts) are used in performance measuring; perceptual maps (based on scatter plots) are used in marketing; waterfall or bridge charts (based on column charts) are used in driving factor analysis; Gantt charts (based on data tables and bar charts) are used in project management; funnel charts are used in sales; candlestick charts are used in stock technical analysis.

Location-Based Visuals

Location as a dimension plays an important role in many areas of business data analysis and decision-making. Many business activities are associated with locations. It has been gaining increased attention especially with the wide adoption of location sensors (like GPS and other location capture technologies) which generate location data. Location-based visuals, commonly based on a map, provide a background or a context that is familiar to the users and make the location-related data more comprehendible and perceivable. A 2015 yearly survey (Dresner, 2015) finds

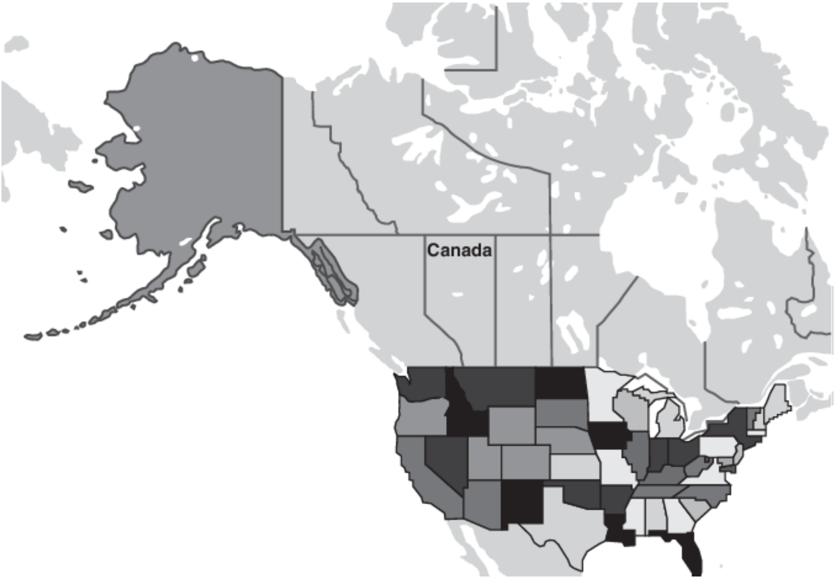
> map-based visualization of information as the top priority, and more than 95 percent of respondents rank it as at least somewhat important. More than 60 percent report that the functionality for layered visualizations is "very important" or "critical" for their organization.

The location-based visuals involve three basic factors: type of location data, visual forms, data points representation on the map.

The types of location data are directly associated with a business and its analysis. One major type of location data is geo locations that come with real-world maps. Many places and regions are based on geospatial mapping, such as political regions (country, state, city, etc.), various types of real estate properties or areas (park, campus, road), or any other arbitrary locations determined by businesses (postal ZIP area, sales region, service district). A second type of location data is local contextual locations which do not directly rely on geo coordinates. These locations are relative locations within in a confined area, such as inside a park, campus, building, room, court, bus/subway line, or even as small region such as a shelf, body, etc. For example, many sports-related analytics analyze the data related to locations on playing fields; stadium and airlines analyze seating data which relates to locations; mall, hospitals, universities, and apartments analyze room/facility usages which are also related to locations. The last type of locations is associated with more abstract ideas like processes, computer networks, organization structures, etc. These abstract locations can also be visualized on an abstract map (or more like an illustration diagram).

The visualization forms for location data is how the background layer of the map is presented. There are two broad categories: (a) real-world maps are used as the background layer, then points, paths, and areas are displayed accurately or closely proximate to the background (Figure 6.1a); (b) a more abstract map (either geo location or non-geo location), sometimes just an illustrational diagram, is used as the background layer, and positioning of objects are based on relative position (e.g. X/Y coordinates) in the map context. The positions or areas on the map are for illustration purpose only, and not corresponding to their real-world positions or sizes (Figure 6.1b).

[Insert Figure 6.1a Here]



[Insert Figure 6.1b Here]

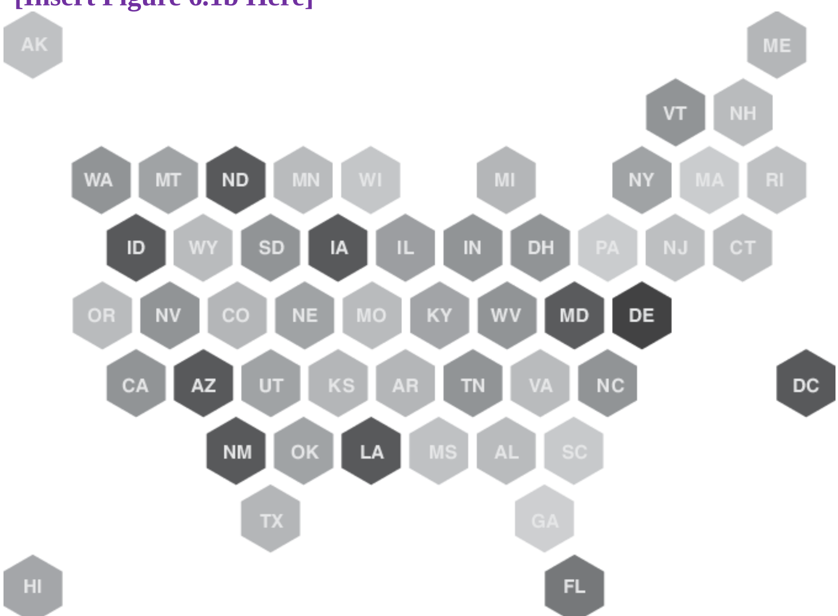


Figure 6.1 Business Measures Visualized on Maps—Created Following (Taylor, 2017)

Figure 6.1b shows a type of abstract map called tile grid map (Shaw, 2016). Tile grid maps abstractly use similar-sized tiles to represent geo regions with irregular sizes. It has several visual advantages in some cases when location precision is not important:

- Eliminate map distortions on some real-world map projections. For example, avoid the Alaska effect on US maps (Taylor, 2017).
- Provide a more consistent view of places of irregular shape and different sizes. In some cases, it makes smaller areas more visible.
- Provide a more modern and consistent look and feel.

Dashboards

Standalone visuals are more like applications than visualizations. They occupy even larger space or even full screens. They also contain multiple types of content as well as interaction controls. A digital dashboard is a major type of standalone visual. A dashboard is “a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance” (Few, 2004). The term dashboard originally came from operational status monitoring on machines which provides visual display for quick reading. Its use has been expanded to visualization of digital data associated with business performance on screens. A dashboard (at the front end) is basically an integrated application of data (content), visual views, and user interface/interaction (UI).

Dashboard = Data + Visualization + UI

The data on the dashboards primarily consists of metrics, Key Performance Indicators (KPIs), and textual information. Metrics (or measures, indicators) are numerical values that measure various aspects of the business activities. A KPI is a metric that compares to its target (goal) and other comparable benchmarks (performance intervals, historical periods, or industry averages) (Barr, 2009). KPIs are used intensively in performance-focused dashboards. Other common data on a dashboard include a set of values to reflect history, trends, distributions, breakdowns, forecasts, or other kinds of comparisons and relationships. Textual information is not typically on many dashboards but it can be included depending on the purpose of the dashboard.

The data on the dashboard are presented via a variety of views or visualization forms discussed earlier, including charts, diagrams, tables (with conditional formatting or other embedded visuals), and styled standalone numbers (usually KPIs).

Last, a dashboard is a business application with a rich user interface for users to interact with data. The key UI elements considered in dashboard include layout (arrangements of data and visualizations, following human information behavior best practices), overall formatting/styling components (which can be visuals themselves) such as title and background, and user interaction controls such as command buttons and navigational controls (menus, tabs).

Traditional BI reports contain detailed data in a tabular format (or pivot tables) and typically display numbers and text only. The two main purposes of reports are printing (with styling) and exporting (raw data). It is geared towards people who need detailed data rather than direct analysis and understanding of data. Modern BI reports can be interactive and visual, but the focus is still on presenting detailed data. The distinction is a bit blurred between reports and dashboards in some practical cases. For example, the IT spending dashboard (www.itdashboard.gov/drupal/summary/006i) is more like a report (a visual-intensive interactive report).

Compare to reports, dashboards are more focused on data visualizations arranged in a single screen, or with limited scrolling and panning. Textual information and detailed data tables can be part of a dashboard only if they are necessary and important to user needs. Even so, it is better to present detailed data through interactive means like pop-ups, tooltips, or in separate screens via details-on-demand designs (Shneiderman, 1996).

A well-designed dashboard allows decision makers to see the most relevant data that reflects business status and supports decisions. It is a highly summarized and centralized snapshot that saves a user's time by eliminating the need to run multiple reports or get data through different sources. It should allow the user to quickly understand data and respond promptly at one place (bidashboard.org, n.d.).

As the use of dashboards grew, they have expanded into three basic types of dashboard: overview, operational, and analytical. Each of them share common attributes of dashboards (data + visualization + UI), but each of them has some different purpose, data, and design best practices. Operational dashboards display data that facilitate the operational side of a business, monitoring operational activities and statuses as they are happening. They provide views of important operational indicators, often based on real-time or near real-time data; they focus on current performance and are action-oriented. Summary/overview dashboards provide high-level summary of business performance represented by KPIs. A strategic dashboard is a typical example of a summary/overview dashboard at the strategic or executive level, which specifically concerns the state of the overall business against strategy goals.

Analytical dashboards, or visual analysis tools, focus on interactive exploration or analysis (visual analysis) of a large amount of data. They allow users to investigate trends, predict outcomes, and discover insights. This kind of use is a bit different from traditional dashboards, which are primarily used for quick scanning and understating of key metrics. Some people specifically categorizes them as "visual analysis tools" (Chiang, 2011) rather than a type of dashboard. Nonetheless, the design of analytical dashboards is similar to general dashboards with a focus on data, visualization, and UI design. Analytical dashboards usually visualize patterns, trends, and other complex relationships among a large amount of data, without a significant focus on a few metrics. The purpose is to explore data and analyze patterns through an interactive process. They contain abundant parameter settings, selections, filters, and other controls to manipulate the main visualization. The main visualization is usually a single (or very few) visual component that occupies a big portion of the screen as the main UI component, with a large number of data points displayed on it. Users' major activity will be repeatedly setting parameters and examining the generated visuals. This type of dashboard often supports ad hoc querying, dynamic visualization generation, common OLAP operations like drill down. It is primarily used for intensive data exploration or analysis, used by data analysts and researchers.

Trends and Prospects

Data visualization has been one of the growing forces driving the BI industry. As an important part of modern BI systems and platforms, business data visualization closely follows or even impacts the general BI and analytics trends. Some of the notable trends are presented below.

Personal or self-service BI: Self-service BI features control in the hands of users, especially power users. This group of people is highly skilled in using technology applications in business tasks, and they often need instant results. They are able to use computer tools and languages to get what they want with little assistance from their IT departments. Some of the tools like Tableau and Power BI have quickly risen to satisfy this need using a visualization-driven approach and gained wide recognition (Sallam, 2017).

Embedded BI: Personal BI tools are usually standalone tools which need a separate data connection or import process. Embedded BI emphasizes the analytics and data presentation as an integral part of an application, instead of using an independent tool or system. Embedded BI or visualization has an advantage in local data modeling and integration, thus delivers standard reports and dashboards in a more efficient way to satisfy the most common needs. The analytics component has become a competitive component of many business systems. However, in many systems, the module is often seen as a separate module which requires businesses to pay separately (for example, Brightspace Insights).

Mobile BI: Mobile computing also drives the evolvement of BI and data visualization to be more accessible and usable on multiple devices with different screen sizes and interaction techniques. Although not typically for mobile phones, access to dashboards though tablets or tablet-like devices is increasing in many business environments where people move around regularly, such as sales, field support, sports, and hospitals. The major influence from mobile computing is the interaction method of touch-oriented interfaces, which requires some new design principles and best practices on dashboard interactions.

The job market and career development related to data analysis and visualization have seen an increasing demand over recent years. Preferably, data visualization development requires skills from a number of fields, including information design, UI design, human information behavior and cognition, interaction design, artistic design, programming, data processing, and business domain knowledge. The demand for multi-skill and interdisciplinary experience will continue to grow.

Conclusion

The shifting focus on end users with better and more effective data presentation and visualization is a global phenomenon. Business data visualization has an increasing importance in the complete BI process and is becoming an integral part of any BI system. Various forms of data visualization, each with their unique features, help BI users and decision makers at different levels from different perspectives. BI managers and developers should understand their features, strengths and weakness, and use them together to create a good mix that satisfies different types of users with different needs. This chapter provides a comprehensive review of these visualization forms and tools, which will help BI managers, decision makers, analysts, and developers better select and utilize them. The perception of visualization is common across all cultures and business environment, but the meaning delivered through visualizations may be affected by a number of factors like color and orientation. Adapting data visualization solutions in local culture is also important in the global business environment.

References

Abela, A. (2008). *Advanced Presentations By Design: Creating Communication that Drives Action* (1st ed.). San Francisco: Pfeiffer. Available from: https://extremepresentation.com/design/7-charts/

Barr, S. (2009, November 23). *What Does "KPI" Really Mean*? Dashboard Insight. Available from: www.dashboardinsight.com/articles/digital-dashboards/fundamentals/what-does-kpi-really-mean.aspx

Bateman, S., Mandryk, R. L., Gutwin, C., Genest, A., McDine, D., and Brooks, C. (2010). Useful junk? The effects of visual embellishment on comprehension and memorability of charts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2573–2582). New York, NY: ACM. Available from: https://doi.org/10.1145/1753326.1753716

Bertin, J. (2010). *Semiology of Graphics: Diagrams, Networks, Maps* (1st ed.). Redlands, CA: Esri Press.

bidashboard.org. (n.d.). *Dashboards Benefits*. Accessed July 10, 2017. Available from: www.bidashboard.org/benefits.html

Borkin, M. A., Vo, A. A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., and Pfister, H. (2013). What makes a visualization memorable? *IEEE Transactions on Visualization and Computer Graphics*, 19(12), 2306–2315. Available from: https://doi.org/10.1109/TVCG.2013.234

Chiang, A. (2011, November 28). *What Is a Dashboard*? Accessed July 10, 2017. Available from: www.dashboardinsight.com/articles/digital-dashboards/fundamentals/what-is-a-dashboard.aspx

Dresner, H. (2015, May 25). *IoT and the Growing Use of Location Features in Business Intelligence Software*. Sand Hill. Available from: http://sandhill.com/article/iot-and-the-growing-use-of-location-features-in-business-intelligence-software/

Evelson, B. and Nicolson, N. (2008). *Topic Overview: Business Intelligence—An Information Workplace Report*. Forrester. Available from: www.forrester.com/report/Topic+Overview+Business+Intelligence/-/E-RES39218

Few, S. (2004, March 20). *Dashboard Confusion*. Retrieved July 10, 2017, from www.perceptualedge.com/articles/ie/dashboard_confusion.pdf

Friendly, M. and Denis, D. (2006). *Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization*.

Hagley, J. (n.d.). *What's the Difference Between an Infographic and a Data Visualization*. Accessed July 10, 2017. Available from: www.jackhagley.com/What-s-the-difference-between-an-Infographic-and-a-Data-Visualisation

Harrison, L., Reinecke, K., and Chang, R. (2015). Infographic aesthetics: Designing for the first impression. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 1187–1190). New York, NY: ACM. Available from: https://doi.org/10.1145/2702123.2702545

Lankow, J., Ritchie, J., and Crooks, R. (2012). *Infographics: The Power of Visual Storytelling*. Wiley.

Parenteau, J., Sallam, R.L., Howson, C., Tapadinhas, J., Schlegel, K., and Oestreich, T. W. (2016). *Magic Quadrant for Business Intelligence and Analytics Platforms*. Available from: http://get.tableau.com/gartner-magic-quadrant-2016.html

Pousman, Z., Stasko, J., and Mateas, M. (2007). Casual information visualization: Depictions of data in everyday life. *IEEE Transactions on Visualization and Computer Graphics*, 13(6), 1145–1152. Available from: https://doi.org/10.1109/TVCG.2007.70541

Sallam, R. (2017, February 16). *Magic Quadrant for Business Intelligence and Analytics Platforms*. Accessed July 10, 2017. Available from: www.gartner.com/doc/3611117/magic-quadrant-business-intelligence-analytics

Segel, E. and Heer, J. (2010). Narrative visualization: Telling stories with data. *IEEE Transactions on Visualization and Computer Graphics*, 16(6), 1139–1148. Available from: https://doi.org/10.1109/TVCG.2010.179

Shaw, T. (2016, April 27). *Good Data Visualization Practice: Tile Grid Maps*. Accessed July 10, 2017. Available from: /ideas/good-data-visualization-practice-tile-grid-maps-0

Shneiderman, B. (1996). The eyes have it: A task by data type taxonomy for information visualizations. In *IEEE Symposium on Visual Languages* (pp. 336–343).

Taylor, K. (2017, January 13). *Viz Variety Show: Use Hex-Tile Maps to Eliminate the Alaska Effect*. Accessed July 11, 2017. Available from: www.tableau.com/about/blog/2017/1/viz-whiz-hex-tile-maps-64713

Tegarden, D. P. (1999). Business information visualization. *Communications of the AIS*, 1(4).

Tufte, E. R. (2006). *Beautiful Evidence* (1st ed.). Cheshire, CT: Graphics Press.

Vessey, I. (1991). Cognitive fit: A theory-based analysis of the graphs versus tables literature. *Decision Sciences*, 22(2), 219–241.

Viégas, F. B. and Wattenberg, M. (2007). Artistic data visualization: Beyond visual analytics. In *Proceedings of the 2nd International Conference on Online Communities and Social Computing* (pp. 182–191). Berlin, Heidelberg: Springer-Verlag. Available from http://dl.acm.org/citation.cfm?id=1784297.1784319

Zheng, G., Zhang, C., and Li, L. (2014). Bringing business intelligence to health information technology curriculum. *Journal of Information Systems Education*, 25(4).