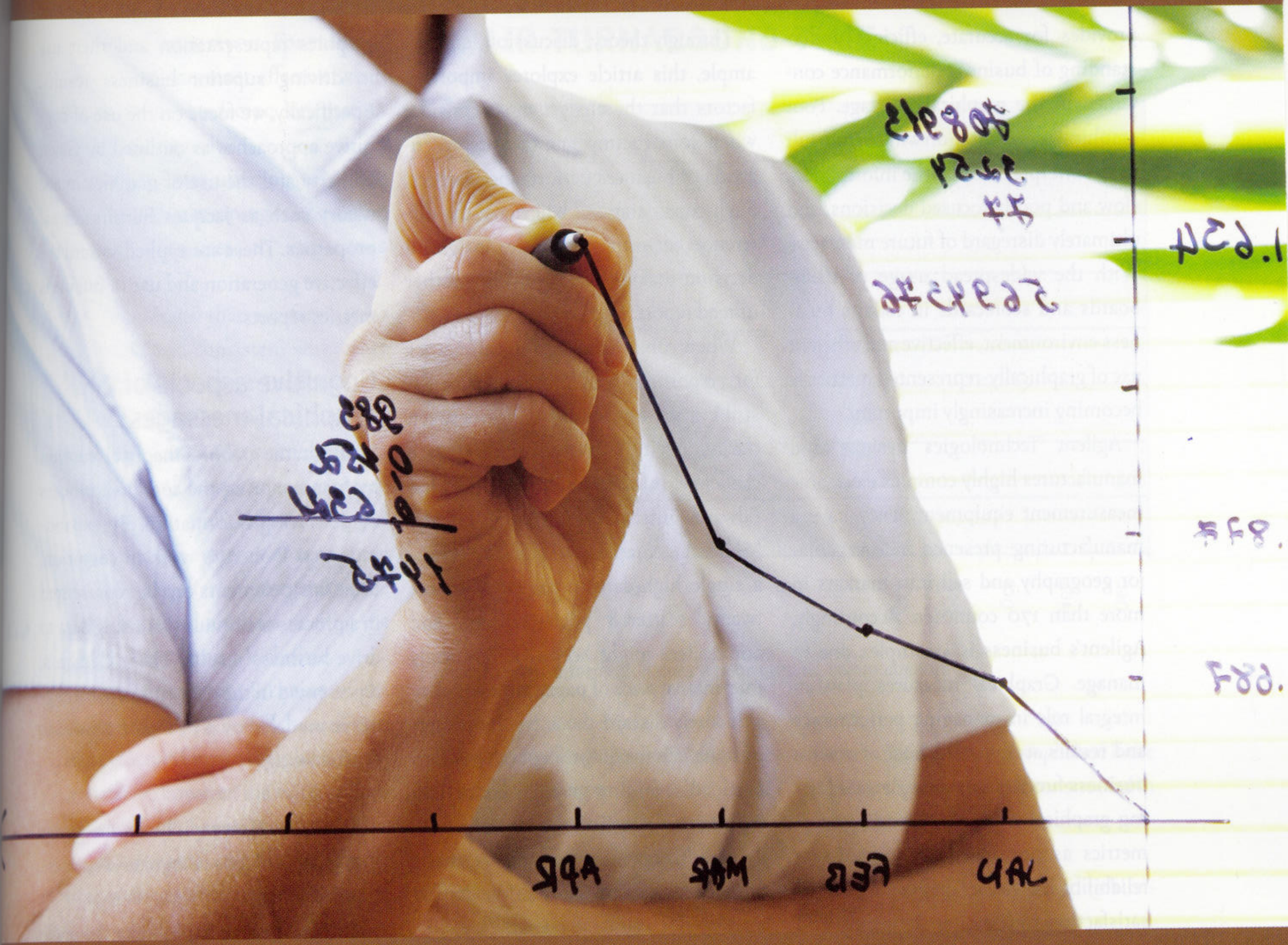

ON DISPLAY

Effective graphical representation of data drives results

BY JOHN HERNIMAN AND BILL LYCETTE

BUSINESS MANAGERS FACE A SEEMINGLY ENDLESS stream of data. Charged with making complex decisions based on incomplete and imperfect information, today's managers must quickly sift through vast arrays of complex facts and figures, separating the trivial many from the vital few. In this case, the vital few can mean the difference between a decision that delights customers or drives them away, builds shareholder value or destroys it, fosters outstanding business decisions or only average ones.

Graphical representation of complex information can be a powerful tool, but only if it is constructed in a fashion that provides for accurate, efficient understanding of business performance contained in the graphical message. Poor graphical representation will likely result in misinterpretation of the information, slow and poorly focused decisions, and ultimately disregard of future messages. With the widespread usage of dashboards and scorecards in today's business environment, effective and efficient use of graphically-represented metrics is becoming increasingly important.

Agilent Technologies designs and manufactures highly complex electronic measurement equipment. They have a manufacturing presence in every major geography and sell into markets in more than 170 countries. Accordingly, Agilent's business is a complex one to manage. Graphical measures play an integral role in managing performance and results at Agilent. A host of diverse business fundamentals are depicted using graphical methods, including such metrics as on-time delivery, hardware reliability, software quality, customer satisfaction indices, repair turnaround time, and cost of non-quality.

Through theory, discussion, and example, this article explores important factors that the analyst must consider when constructing graphical representation of business performance metrics. Such considerations will make the difference between a valuable, insightful decision-making tool and yet another unread report.

When constructing graphical metrics for reporting business performance, striking the optimum balance between clarity, brevity, and level of detail is a challenge. Information design specialist Edward Tufte elegantly sums it up: "Showing complexity is hard work... a single high-density page can replace twenty scattered posterizations ... and our readers might keep that one really informative piece of paper, although they will surely discard those twenty posterizations." To the question of information overload regarding graphics containing high data density, Tufte counters the critics with "Simpleness is another aesthetic preference, not an information display strategy, not a guide to clarity."

There are many elements to effective graphics representation and their use in driving superior business results. Specifically, we focus on the use of cognitive approaches as outlined by Gavin Doherty and the use of graphics image theory such as Jacques Bertin's retinal properties. These are applied toward the effective generation and use of business metrics reports.

DATA-TO-DECISION COGNITIVE MODEL

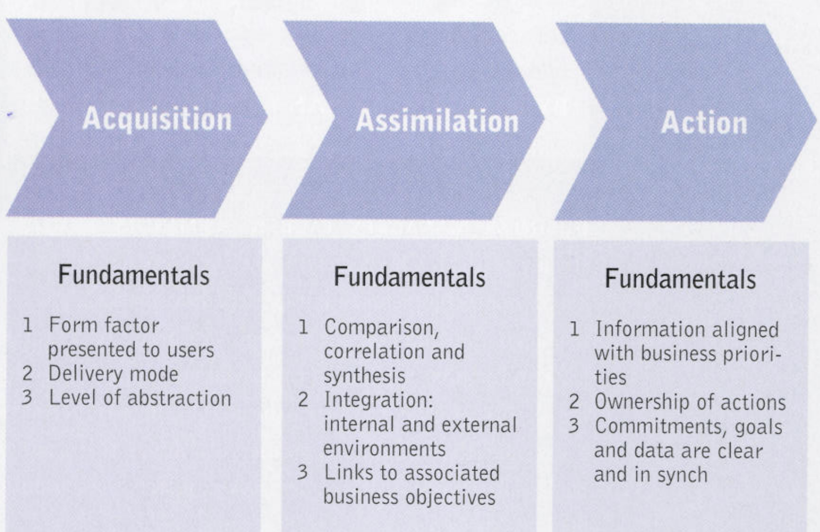

Figure 1. The fundamentals of acquisition, assimilation, and action lead to decisions.

Cognitive aspects of graphical messages

We begin the graphics theory discussion by first exploring the cognitive process of perceiving information. By expanding upon Doherty's work in cognition, three basic elements can be represented in a process continuum for using data to drive business results. These elements, represented in the data-to-decision cognitive model shown in Figure 1, include the following:

1. *Acquisition*. How rapidly can the reader of graphical data recognize and interpret the data?
2. *Assimilation*. How rapidly can the reader convert the graphically-represented data into a construct that matches his real world business goals?
3. *Action*. How rapidly can the reader determine what business actions need to be taken based on the assimilated message?

Most managers experience an excessive amount of visual data in a work day. Speed of determining the basics of the information are vital in deriving understanding from any data set.

Proper application of graphic image theory is required for achieving success in minimizing speed to acquisition. From a cognitive perspective, special consideration should be given to:

- Physical form factor that matches reader expectations and efficiently utilizes space in the report. For example, trend charts are most effective when presented in landscape orientation rather than portrait.

- Representations utilizing adequate labeling so that meaning can be drawn without references to extraneous codes.
- Use of formats that are familiar to the reader and consistent with other business metric representations.
- Delivery of the message by a vehicle that considers reader's requirements and the local business environment (push versus pull techniques). For instance, push systems such as email may be more effective in ensuring the message is read vis-à-vis posting the graphical image on a Web site.
- Level of abstraction. Richness of the image may be increased by utilizing more abstract forms of graphical representations; however, the value of such richness must be weighed against the increased mental cost of data acquisition as discussed in the next section.

The reader must rapidly assimilate the data and transform it into an accurate understanding that is relevant to her sphere of operation. This is accomplished through:

- Ensuring the graphical representation supports the businesses' analysis practices, i.e. comparison, correlation, and synthesis methods. For example, does the message directly link with the operation's performance dashboards?
- Consistency of the graphical message with the reader's internal environment, e.g. business goals and operational metrics.
- Consistency of the graphical message with the reader's external environment, e.g. customer expectations, regulatory directives, and financial reporting requirements.

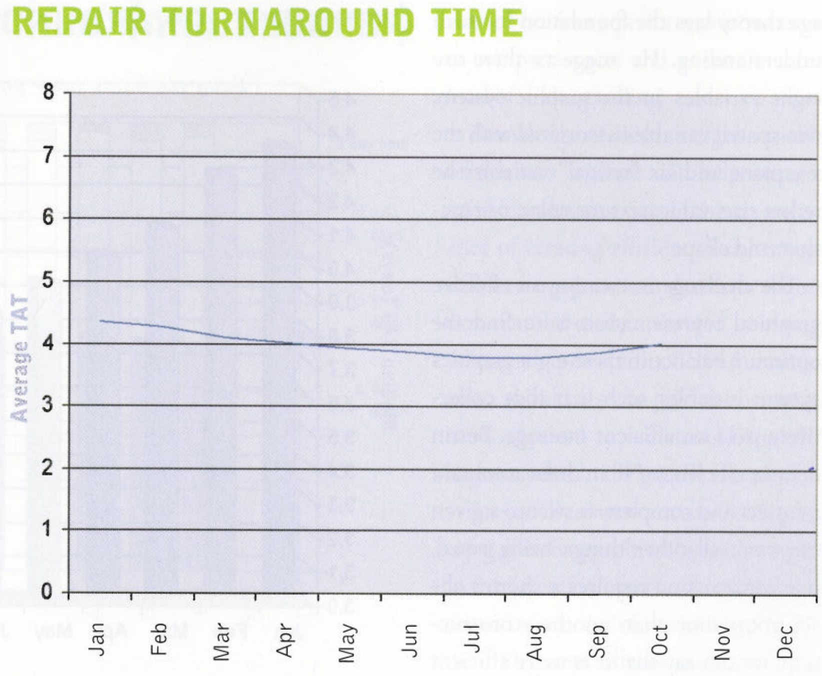

Figure 2. What information does a poor graphic communicate?

Truly compelling representations are successful at integrating both internal and external environmental requirements into a single image.Tufte describes medical detective work conducted by John Snow where he investigated the cause of a cholera epidemic that broke out in central London in 1854. Time-series graphs are initially presented which quantify the severity of this outbreak but shed no real causal understanding. However, when the same data was transformed from a one-dimensional temporal format into a two-dimensional spatial mapping, the likely source of the epidemic became clear in an instant. By plotting incidents of death onto a city street map, Snow showed a clear connection between high death rate and proximity to a public water pump on Broad Street. (Ironically, one of the quality tools widely employed today is the "measles chart" which is used to plot locational defect data on a two-dimensional spatial map!)

Finally, the reader must take the assimilated message and use it to quickly make a decision that effectively serves the business. This is best accomplished if the graphical representation is constructed in such a fashion that:

- The message is clearly linked to business priorities and goals.
- There is stability in representation of the metric.
- Ownership of the action is clear.
- There is clear relevance between graphical data and impact of actions on customers and financial stakeholders.
- Commitments match goals, and goals match data type.
- Goals and actual performance delivered by the business are clearly depicted.

Turning concepts into business performance

Taking the graphical representation discussion one step further, we now move into the realm of image theory. Creating effective graphical metrics must include an understanding of how people perceive graphical information and transform it into decisions and actions. Bertin's work in the area of graphics system and image theory lays the foundation for such understanding. He suggests there are eight variables in the graphic system: two spatial variables associated with the x-y plane and six "retinal" variables he terms size, value, texture, color, orientation, and shape.

The challenge in creating an effective graphical representation is to find the optimum balance in these eight graphics system variables such that they collectively yield an efficient message. Bertin defines efficiency: "If, in order to obtain a correct and complete answer to a given question, all other things being equal, one construction requires a shorter observation time than another construction, we can say that it is more efficient for this question." He goes on to say that the most efficient constructions are those in which any question can be answered in a "single instant of perception, that is, in a single image."

The notion of an efficient visual message has also been termed "mental cost" by linguist George Kinglsey Zipf as it relates to visual perception. Business managers face a myriad of information stimuli that compete for their precious time and energy, and by minimizing the mental cost associated with processing graphical messages their businesses stand to benefit from improved decision making.

Image theory concerns itself with the efficiency by which the reader is able to comprehend the message coded within the graphic. It is the responsibility of the graphic's creator to architect a visual image whose code can be easily broken down and understood. The creator has a number of options at her disposal to achieve this objective, including the thoughtful use of shape, scale, color, contrast, symbology, labeling, and texture.

Consider, for example, the metric taken from a hypothetical business performance report shown in Figure 2. Here, we have a time series plot showing the average time it takes to repair a product at a customer service center (turnaround time or TAT). We have all seen graphical metrics such as this, and the number of visual problems associated with the plot is many. The trend line is difficult to discern because the choice of background color provides insufficient contrast. Furthermore, use of solid background colors promotes wasted ink for those who desire to print a hard copy. Utilization of space is poor given that a single metric occupies a fairly large area, where the data density is low. The notion of texture is somewhat subjective, but this graphic is spartan and void of texture to any significant degree. The selection of the y-axis range is poor because it results in metric compression to the extent that trends are difficult to perceive.

In looking at the graphic's labeling, the nature of the data plotted on the y-axis is unclear. What is meant by average TAT? The reader is left to guess if the author meant mean, median or mode. An equally annoying error is the omission of the metric's unit of measure.

How quickly can the reader infer that customer satisfaction is improving or degrading? What action should the management team ask of the organization? This graphic is not efficient in answering these questions, and the mental cost is high compared to value derived from the graphic.

A much improved graphic using the same data is shown in Figure 3. Use of columns better fills the space and yields superior texture. Contrast between background and metric is much improved. Rotation of the x-axis labels results in an orientation with better readability. A modification to the y-axis scale provides greater sensitivity for detecting changes in trend. A change to the y-axis label (median TAT: days) results in a higher level of clarity. Finally, a target line was added to provide a reference point for gauging business performance results.

Applying concepts from Bertin's eight graphics system variables yielded substantial improvement of the metric as shown in Figure 3. However, with some

REPAIR TURNAROUND TIME (IMPROVED)

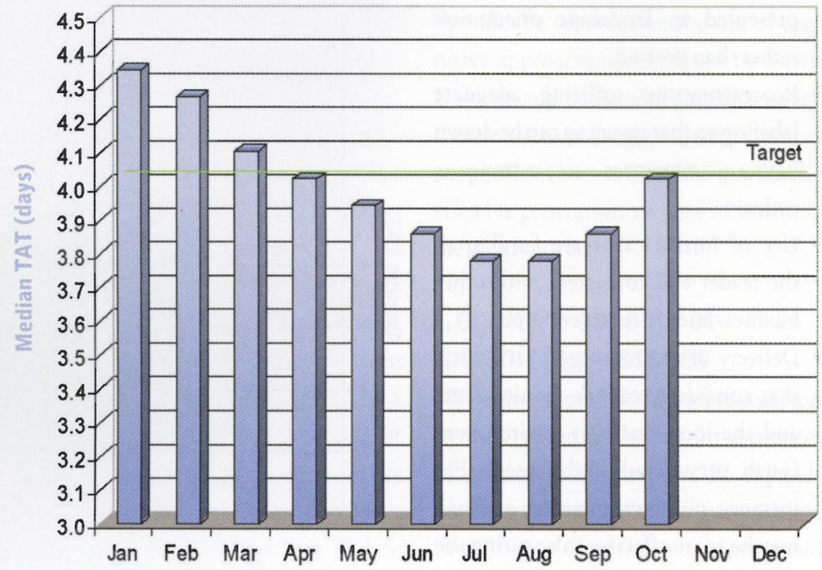

Figure 3. A better graphic communicates essential information.

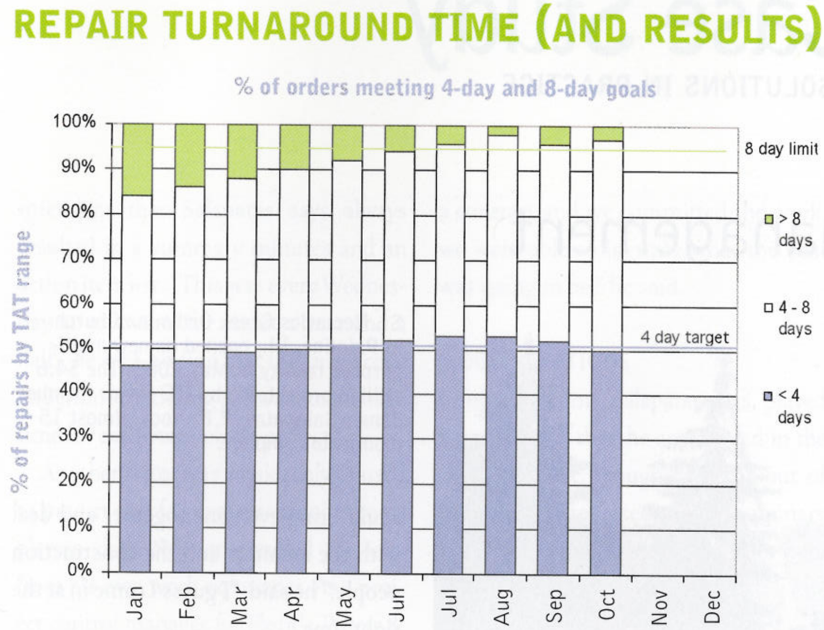

Figure 4. Efficient and rich understanding of process results.

further changes, even greater data density can be achieved. Additionally, application of Zipf's efficient visual image notion can help reduce the "mental cost" of interpreting the image. For instance, Figures 2 and 3 show only the median TAT thereby providing no insights into the right-sided tail of the TAT distribution. This is the region of the TAT distribution where customer satisfaction is lowest, and it is unclear from the graphic if solid operational performance has been achieved. Furthermore, the shade patterns and three-dimensional view of the bars in Figure 3 burdens the reader with a mental cost that yields no incremental value.

The data behind Figures 2 and 3 has been re-represented in Figure 4. We now see much richer use of texture and space. Whereas in the previous two representations the focus was on the "average" customer experience (median TAT shown against a four-day target), the focus of management attention is now moved to the right tail of the TAT distribution. Drivers of highest customer dissatisfaction, i.e. repairs taking longer than eight days, become clear in an instant as depicted by the red bar section. While the number of repair orders requiring four days or less has been fairly constant at roughly 50 percent (green bar), the percentage of repairs taking longer than eight days has been decreasing in recent months. As a result of much deeper process understanding, a second goal was added to the chart to monitor progress made towards further reductions in the percentage of repairs taking longer than eight days.

By application of image theory concepts and careful construction of graphical images, efficient understanding of multifaceted business results can be crisply communicated in compact spaces.

Visions of success

Well-managed businesses often rely on graphical representations of complex information to drive sound decision making. The objective when creating such graphical metrics is to provide "clarity in an instant," to present crisp communication of business performance measures in compact spaces and to ensure a deep level of understanding.

Knowledge of Bertin's eight variables of graphics systems will help ensure a solid foundation exists in the art and science of creating efficient visual images. Efficient images mean that critical questions can be easily answered in a single moment of perception. Careful consideration should also be paid to the mental costs required to understand the message encoded in the graphical image.

An equally important aspect of generating effective graphical business metrics is the attention paid to supporting the cognitive process of perceiving information. Elements of this data-to-decision cognitive process include information acquisition, data assimilation, and decision-making action. Effective application of graphics image theory and cognitive approaches will help assure that graphical metrics drive fast, intelligent business decisions.

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