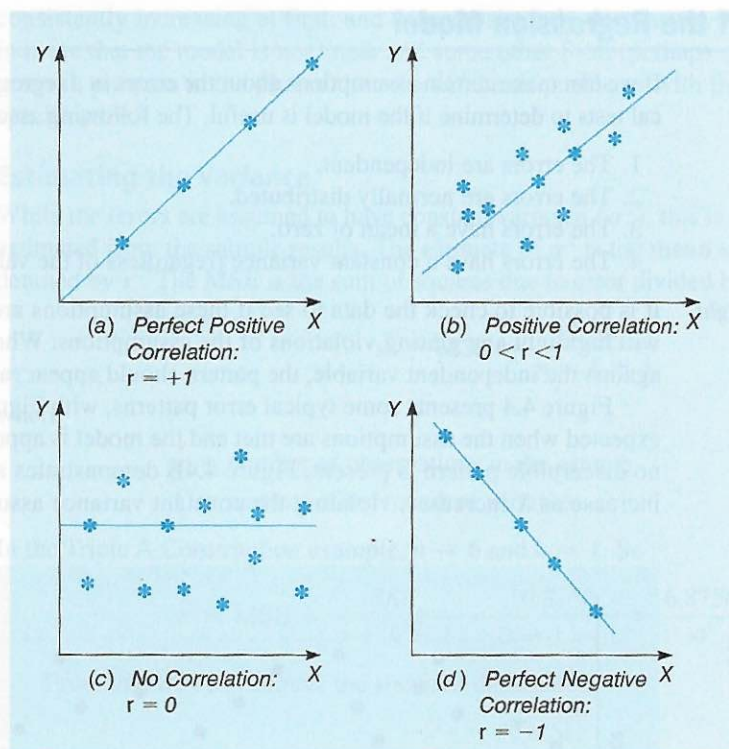


FIGURE 4.3
Four Values of the
Correlation Coefficient



possible scatter diagrams for different values of r . The value of r is the square root of r^2 . It is negative if the slope is negative, and it is positive if the slope is positive. Thus,

$$r = \pm\sqrt{r^2} \quad (4-11)$$

For the Triple A Construction example with $r^2 = 0.6944$,

$$r = \sqrt{0.6944} = 0.8333$$

We know it is positive because the slope is $+1.25$.



IN ACTION

Using Regression as Part of Improvement Initiative at Trane/Ingersoll Rand

Trane U.S. Inc. is a brand of Ingersoll Rand and is a leader in both home and commercial air conditioning. In an effort to improve quality and efficiency, the company consolidated its manufacturing of evaporator and condenser coils into one location in South Carolina. A key part of the coil unit is a header, which controls the flow of water or refrigerant through the coil. With about 120 unique headers produced on each shift, with increased demand for their air conditioners due to federal refrigerant standards, and with growing pressure to reduce costs, Trane began an improvement initiative in 2010.

Value stream mapping, a lean manufacturing technique, was used to visualize the entire process and identify waste in the system. A new layout was suggested to improve processing and reduce the overall time of production. To predict how well the new layout would perform in the manufacture of the headers, data was collected about the time to move materials into position, time to set up a job, time to set up a machine, and time to process a job. Several regression models were developed to

determine which job characteristics were most significant in the various times involved in processing, and to measure the variability in times. These were used in simulation models that were developed to determine the overall impact of the new layout and to determine where bottlenecks might occur. One of the bottlenecks, at a robotic machine for welding, was eliminated by retooling the robot to allow the machine operator to operate both sides of the robot. This enables the robot to process two headers simultaneously.

The improvement initiatives from this project are estimated to save over \$700,000 per year. This project highlighted the importance of data-based analytics and lean manufacturing tools in identifying the improvement tactics for complex value streams. The company plans similar improvement initiatives for other value streams in the future.

Source: Based on John B. Jensen, Sanjay L. Ahire, and Manoj K. Malhotra. "Trane/Ingersoll Rand Combines Lean and Operations Research Tools to Redesign Feeder Manufacturing Operations," *Interfaces* 43, 4 (July–August 2013): 325–340.

4.5 Assumptions of the Regression Model

If we can make certain assumptions about the errors in a regression model, we can perform statistical tests to determine if the model is useful. The following assumptions are made about the errors:

1. The errors are independent.
2. The errors are normally distributed.
3. The errors have a mean of zero.
4. The errors have a constant variance (regardless of the value of X).

A plot of the errors may highlight problems with the model.

It is possible to check the data to see if these assumptions are met. Often a plot of the residuals will highlight any glaring violations of the assumptions. When the errors (residuals) are plotted against the independent variable, the pattern should appear random.

Figure 4.4 presents some typical error patterns, with Figure 4.4A displaying a pattern that is expected when the assumptions are met and the model is appropriate. The errors are random and no discernible pattern is present. Figure 4.4B demonstrates an error pattern in which the errors increase as X increases, violating the constant variance assumption. Figure 4.4C shows errors

FIGURE 4.4A
Pattern of Errors
Indicating Randomness

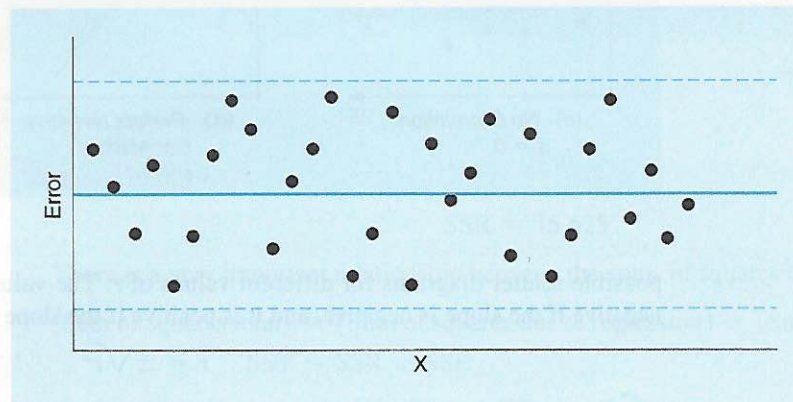


FIGURE 4.4B
Nonconstant Error
Variance

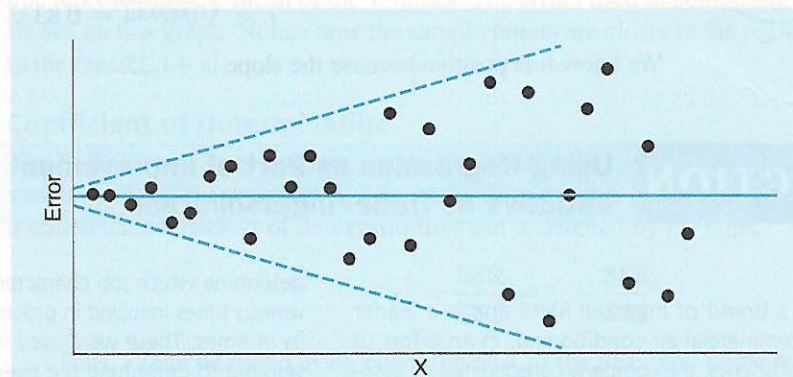


FIGURE 4.4C
Errors Indicate
Relationship Is Not Linear

