stat teaser

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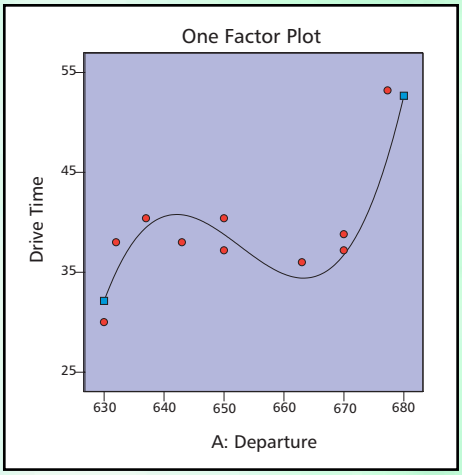
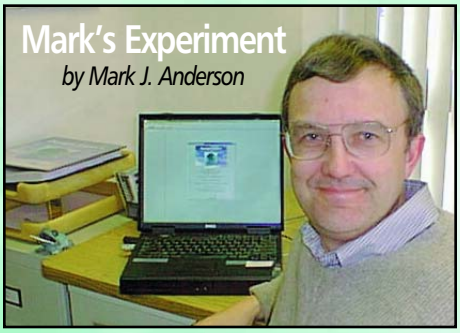
Six Sigma for the Road

In Minnesota, we've enjoyed a remarkably mild winter this year compared to last, which was hell on wheels. Snow combined with the Minnesota Department of Transportation's (MN DOT) experimentation on ramp metering made traffic jams the rule rather than the exception*. It's a great relief to now be driving with my steel-belted radial tires rubbing rubber on road, not ice.

Now that I am encountering the normal ebb and flow of rush hour, I again see the peculiar waviness described in my February 1996 Stat-Teaser column, "Using DOE to Spend Less Time in Traffic: Part Two." Let's see what gold nuggets can be gleaned from this data by using Design-Expert® software's tools for Six Sigma, including propagation of error (POE) and multiple response optimization. *(In the limited space available for this column, I can't go into details on these powerful*



Departure Time vs Drive Time



DOE tools. If you want hands-on knowledge, attend our "Response Surface Methods for Process Optimization" workshop.)

For the sake of discussion, assume that an employee named Joe must choose a starting time between 7 and 8 AM. Assume the following desires on the part of company and worker:
- Boss prizes punctuality
- Employee seeks sleep.

Experimentation reveals the following pattern of driving time versus the time Joe leaves home (expressed in minutes starting at 6:30 AM - for example, a value of 670 translates to 7:10 in the morning). I realize that my data only weakly supports the waviness in the mid-range of the time window, but I am convinced from over 10 years of commuting (~2000 drives!) that this is accurate, so please bear with me.

Looking at this curve, Joe sees that he can leave at 6:30 and get to work at 7, but he must then get up early. ☹ At the other end of the scale, the graph shows

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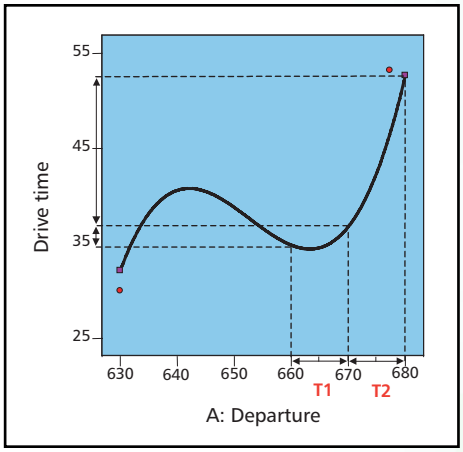
that a 7:20 AM departure (680 on the scale) puts Joe in the thick of rush hour, which lengthens his drive time beyond 50 minutes. The boss, who watches the clock like a hawk, would not be happy because Joe would not get in to work until after 8. ☹ What if Joe leaves a bit earlier at 7:14 (674 on the scale)? According to Design-Expert, the drive will take 45 minutes, so he'd get into work at 7:59 - just in time! But hold on, the actual arrival time will obviously vary due to differences in day-by-day traffic, etc. Analysis of variance (ANOVA) reveals that the standard deviation in drive time is 2.3 minutes. Furthermore, whatever time Joe targets for his departure from home will also vary - let's assume with a standard deviation of 5 minutes.

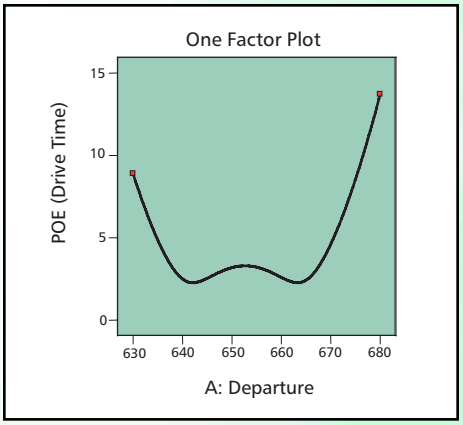
Joe now reconsiders his idea of leaving as late as possible. Five minutes deviation one way or the other in his departure, just as rush hour revs up (see T2 on the plot below), makes his arrival



The Variance Transmitted from Factors (X-Axis) to Response (Y-Axis)

very uncertain. Notice how the lines on either side of T2 (on the x-axis) hit the response curve and transmit an amplified difference over to the drive time response (the y-axis). The boss won't like this! On the other hand, the same deviation at a somewhat earlier departure (T1) causes very little change in drive time (the narrow band on the y-axis).

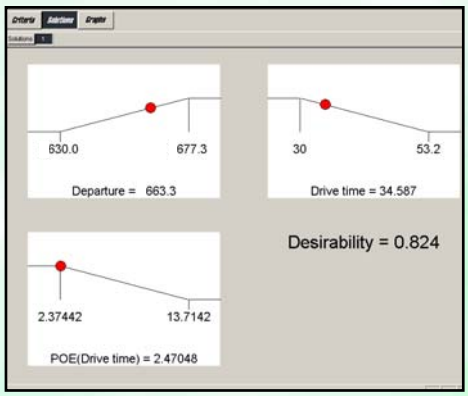
Fortunately, by making use of a statistical tool called propagation of error (POE), Design-Expert software can account for the variation transmitted from input factors - such as the time Joe leaves for work. In essence, the POE method involves application of partial derivatives to local flat areas on the response surface, preferably the broad valleys or high plateaus.** Design-Expert does all the calculus and mathematical computations and it even plots the results for you!



Look for Minimums on the POE Graph

The graph above shows that transmitted variance (POE) can be minimized at two different times - the deflection points in the original drive time curve where it flattens out temporarily. (The POE incorporates the 2.3 minute underlying variation from the ANOVA, so it cannot fall below this level.)

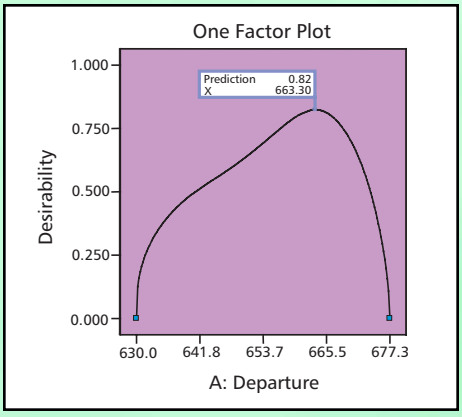
Now, with the aid of Design-Expert, let's see how Joe can minimize POE (variation) while maximizing his sleep and minimizing drive time (and hopefully getting to work on time, consistently). I entered these goals in the software's numerical optimization node, thus establishing desirability scales for each input and output variable on a scale of 0 (low) to 1 (high).



Optimal Solution

Design-Expert then searched for a departure time that best met all the goals. It came up with a solution at a departure time of 663.3 minutes (approximately 7:03 AM), which produces a predicted drive time of 34.6 minutes.

The overall desirability curve from numerical optimization, with a flag set at the peak, can be seen below.



Set the Flag at Maximum Desirability

By leaving a bit after 7 AM, Joe will enjoy an extra half-hour of sleep beyond the earliest time (6:30 AM) considered in this analysis. ☺ The drive time at this point, according to the original

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Case Study Reprints Available

Three case studies illustrating the use of designed experiments in industry are now available as reprints free of charge (see the order form on page 4). In addition, a new review of Design-Expert 6.0 is available.

#56: "Engineering Software Quickens Product Launch", reprinted from *Packaging World*, January 2001. Mary Kay, Inc. used Design-Expert to help avoid product launch delays and unnecessary rework costs.

Reprint #56 Engineering Software Quickens Product Launch

#57: "Design-Expert 6.0" by John Wass, reprinted from *Biotech Software and Internet Report*. This review of Design-Expert 6.0 concentrates on the software updates from version 5.0. John says, *"The Stat-Ease staff has added many new features that are not merely cosmetic while retaining the analytic rigor and extreme user-friendliness which characterized previous versions."*

Get a copy of the complete review by ordering **Reprint #57** on page 4.

If you have not yet upgraded to Design-Expert version 6.0, use the form on page 4 to order it today!

#58: "Enhancing Solid-Phase Disk Extraction Performance with Design of Experiments" by Craig A. Perman, reprinted from *American Laboratory*, November 2001. (Also published in the September 2001 Stat-Teaser.) 3M uses fractional factorial designs to improve product performance.

#59: "Achieving Six Sigma Objectives for Variability Reduction in Coating Formulation and Processing" by Mark Anderson and Pat Whitcomb, reprinted from *Paint & Coatings Industry*, November 2001. This article illustrates the use of the robust design tool, propagation of error (POE), to make a coating system more robust to variations in component levels and processing factors.

--Continued from page 2.

graph, is 34.6 minutes, with a prediction interval from 28 to 41 minutes. Even if his drive lasts 41 minutes, Joe will get to work early enough (7:44 AM) to keep his Boss happy. ☺

- Mark

* See "Mad Mark and the Meter Gnomes" from the March 2001 Stat-Teaser, viewable at **www.statease.com.**

** For mathematical details, see "Robust Design - Reducing Transmitted Variation" by Pat Whitcomb and myself, presented at the 50th Annual Quality Congress in 1996.

Order a free reprint of the above paper **(Reprint #48)** by filling out and faxing back the order form on page 4.

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May 3 — FOCUS Conference
Troy, MI
Talk by Larry Scott (Consultant):
An Overview of DOE as a Process

May 22 — IIE Solutions Conference
Orlando, FL
Talk by Shari Kraber:
How to Match Information Objectives to Optimal Fractional Factorial Designs

May 20-22 — 56th Annual Quality Congress, Denver, CO
See us at Booth 725.
Talk by Mark Anderson:
Part of session titled, "Proactive Techniques to Design Robust Products"

June 5-7 — ASA Q&P's Spring Research Conference, Tempe, AZ
Session Moderated by Pat Whitcomb: *Non-Manufacturing Applications of DOE*

June 11-13 — Quality Expo Detroit, Novi, MI
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03/02

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