One-Factor RSM Tutorial

(Part 1 – The basics)

Introduction

In this tutorial you will get an introduction to response surface methods (RSM) at its most elementary level – only one factor. If you are in a hurry, skip the sidebars. These are intended only for those who want to spend more time and explore things.

☒ ***Explore basic features of the software***: It will be assumed that at this stage you've mastered many Design-Expert® software basic features by completing the preceding tutorials. At the very least you ought to first do the General One-Factor tutorials, basic and advanced, before starting this one.

The data for this one-factor tutorial, shown below, comes from *RSM Simplified* (Mark J. Anderson and Patrick J. Whitcomb, 2005, Productivity, Inc., New York: Chapter 1).

x: Departure (minutes)	y: Drive time (minutes)
0	30
2	38
7	40.4
13	38
20	40.4
20	37.2
33	36
40	37.2
40	38.8
47.3	53.2

Commuting times as a function of when the driver leaves home

The independent (x) variable (factor) is the departure time for Mark's morning commute to work at Stat-Ease, Inc. Time zero (x=0) represents a 6:30 A.M. start, so for example, at time 40, the actual departure is 7:10 A.M. Mark wants to quantify the relationship between time of departure and the length in minutes of his commute – the response "y."

Let's begin by setting up this one-factor RSM experiment in Design-Expert. Be forewarned, we must do some editing of the design to deal with some unplanned events in the actual execution. Fortunately, the software allows for such revising in the experimental design layout and deals with any repercussions in the subsequent analysis.

Design the Experiment

Start Design-Expert. You will see our handy new quick-start page, which includes the main menu and icon bar. Using your mouse, click **New Design**.

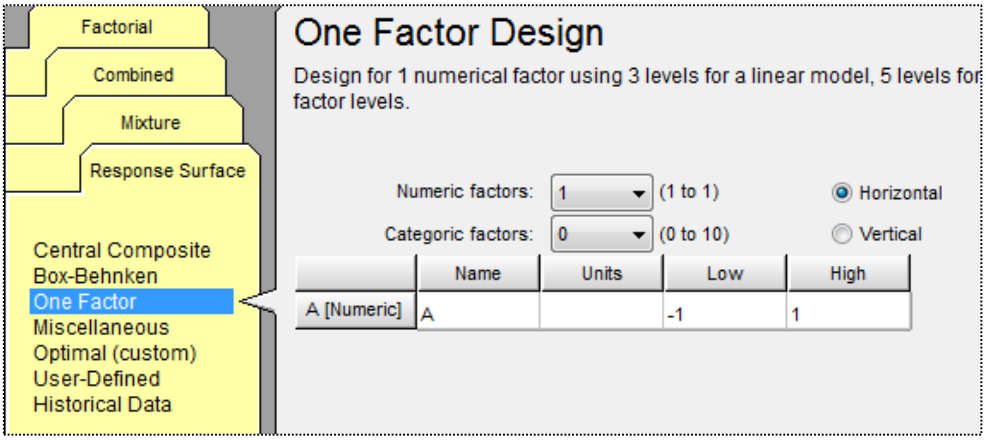


Quick-start page – New Design Button at Top

You now see four tabs at the left of your screen. Click the tab labeled **Response Surface**. Then select **One Factor** design

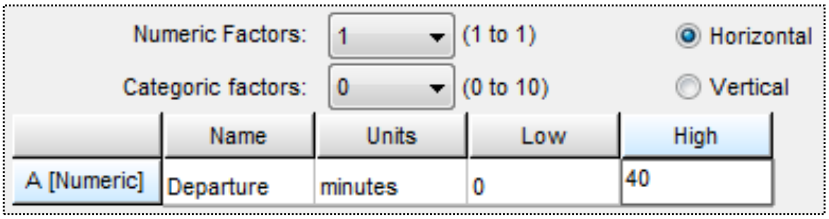
☒ ***Explore other response surface design options***: Note that the first two designs on this tab — the Central Composite and Box-Behnken – do not support experiments on only one factor. Work through the Multifactor RSM Tutorial to explore program tools from multiple-factor response surface methods.

Your screen should now look like the one shown below.



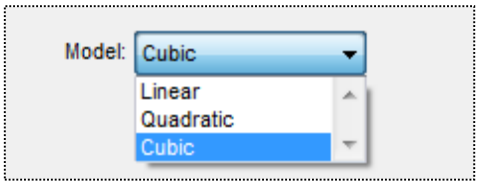
One factor response surface design

Now enter for factor A the **Name, Units, Low**, and **High** inputs as shown below.



Entering factor name, units, and low/high experimental range levels

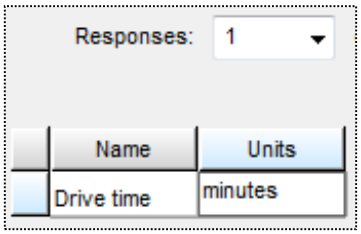
Mark's initial theory was that traffic comes in waves. In other words, traffic does not simply increase in a linear fashion as rush hour progresses. Instead, he hypothesized that traffic builds up, backs off a bit, and then peaks in terms of density of cars on the roads into town. Standard RSM designs, such as central composite (CCD) and Box-Behnken, are geared to fit quadratic models (refer to *RSM Simplified* for math details). Generally this degree of polynomial proves more than adequate for approximating the true response. But in this case, where the response may be 'wavy,' we will notch up to the third-order **Model** labeled **Cubic.** The model droplist is located near the bottom of your screen.



After selecting a cubic model (center points increased by default to 2)

Notice that the number of runs increases from 7 to 10 after upgrading your model from its default of quadratic. This upgrade includes 2 center points added in by default (versus 1 for linear). Thus it takes only 3 more runs to design for the cubic model.

Press **Continue** to move on to the response entries. Now enter the **Name** and **Units** inputs as shown below.



Response data entry

Press **Finish** to see the resulting design displayed in randomized run order.

Modify the Design As Actually Performed

Normally you'd now print your screen and use it as a procedure (recipe) sheet. However, to reproduce Mark's experiment it is helpful to right-click the **Factor** column header, and from the pop-up menu select **Sort Ascending**.

To account for Mark's mistake of awakening very, very late one morning, replace the first **Factor** entry of **0.00** with his actual departure time of **47.3**.

Factor 1 A:Departure minutes	Response 1 Drive time minutes
47.3	
0.00	
6.68	
13.34	
20.00	

First run re-entered at actual value of 47.3

That tardy start was not Mark's only mistake. (Evidently Mark is not a morning person!) He also got mixed up somehow on another specified departure – so you must also replace the **Factor** entry of **26.66** with the actual value of **2**. (Strange but true: Mark didn't adhere to his recipe sheet and left too early that morning.)

Factor 1 A:Departure minutes	Response 1 Drive time minutes
47.30	
0.00	
6.68	
13.34	
20.00	
20.00	
2	
33.32	

Changing the second botched factor level

Let's sort again , so we can better see how times now line up in this design. This time, just double-click the **Factor** column and it will be quickly sorted in descending order. Double-click again and it will be back in ascending order (arrow pointing down).

OK, notice how this design specifies some departure times to the one-hundredth decimal place, for example 6.68. This is impractical, so let's round to the nearest minute: Replace **Factor** levels 6.68 with **7**, 13.34 with **13**, and 33.32 with **33** as shown below.

Factor 1 A:Departure minutes	Response 1 Drive time minutes
0.00	
2.00	
7	
13.34	
20.00	
20.00	
33.32	

Factor 1 A:Departure minutes	Response 1 Drive time minutes
0.00	
2.00	
7.00	
13	
20.00	
20.00	
33.32	

Factor 1 A:Departure minutes	Response 1 Drive time minutes
0.00	
2.00	
7.00	
13.00	
20.00	
20.00	
33	

Rounding inconvenient factor levels

That was a lot of work, so now is a very good time to preserve it by selecting **File**, **Save As**. Type in the name of your choice (such as **Drive time**) for your data file, which will be saved as a *.dxpx type.

Click **Save**. Now you're protected in case of a system crash. Next, enter the response values as shown below.

Factor 1 A:Departure minutes	Response 1 Drive time minutes
0.00	30
2.00	38
7.00	40.4
13.00	38
20.00	40.4
20.00	37.2
33.00	36
40.00	37.2
40.00	38.8
47.30	53.2

Entering response data

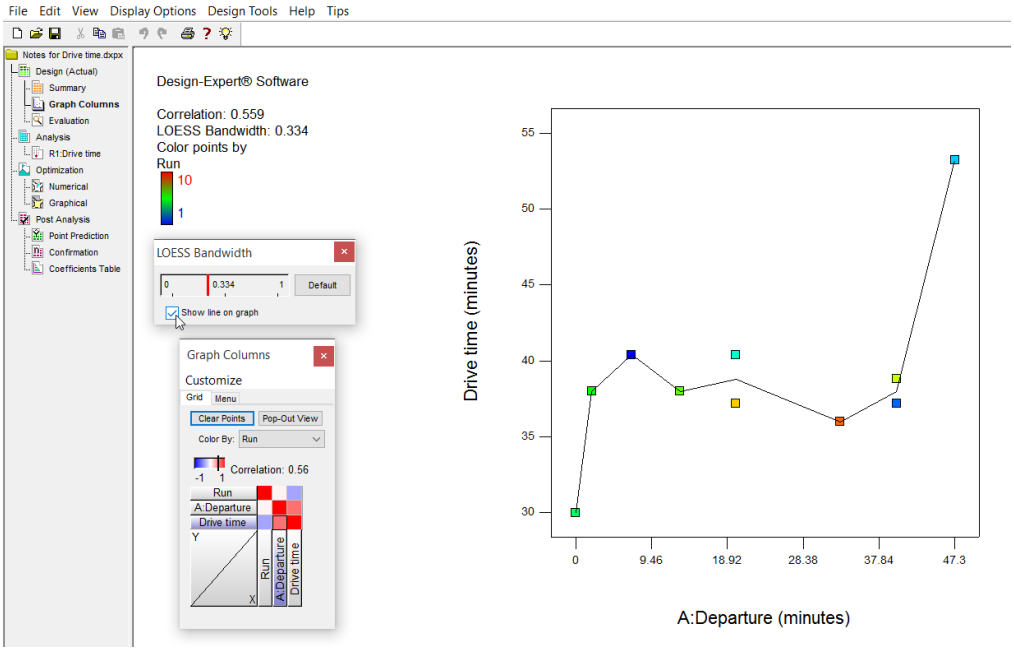
This is another good time to preserve your work, so click the Save icon 🖫 on the toolbar.



Saving the response data you've entered

The design is done and the experiment completed – not quite as Mark originally planned, but perhaps well enough. We will see.

☒ ***Explore LOESS fit***: Click the **Graph Columns** node to see a scatter plot of drive times. Then click on the checkbox in the LESS Bandwidth box to "show line on graph" to see a locally weighted smoothing.



LOESS fit

To change the bandwidth, move your mouse over the line just above the checkbox. When it changes to a double-arrow then click and drag it to another setting. Play around with this to see how bandwidth affects the fit (or click the "light bulb" help icon for tips on how this works). However, keep in mind that this is more for visualization purposes—it is completely speculative at this stage. Therefore you had best press on from here for a more conventional regression modeling.

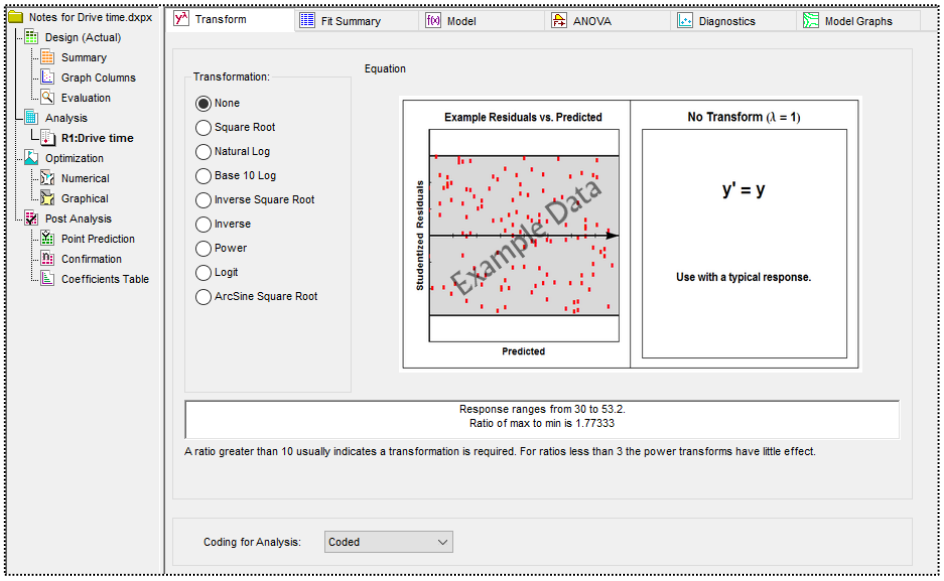
P.S. This really ought to be called LOWESS (locally weighted scatterplot smoothing). However, the inventor, William Cleveland, liked "loess" (pronounced 'low is') because of its "semantic substance"* being this relates to a deposit of fine clay or silt that in a cut through the earth appears as smooth curve.

*(Cleveland, William S.; Devlin, Susan J. (1988). "Locally-Weighted Regression: An Approach to Regression Analysis by Local Fitting," *Journal of the American Statistical Association* 83 (403): 596–610.

Analyze the Results

Before we start the analysis, be forewarned that you will now get exposed to quite a number of statistics related to least-squares regression and analysis of variance (ANOVA). If you are coming into this cold, pick up a copy of *RSM Simplified* and keep it handy. For a good guided tour of these RSM analysis statistics, attend the Stat-Ease workshop titled RSM for Process Optimization. Details on this computer-intensive and hands-on class, including what's needed as a prerequisite, can be found at www.statease.com. Or simply visit our website to see valuable tips and case studies.

Under the **Analysis** branch click the node labeled **Drive time**. Design-Expert displays a screen for transforming the response.

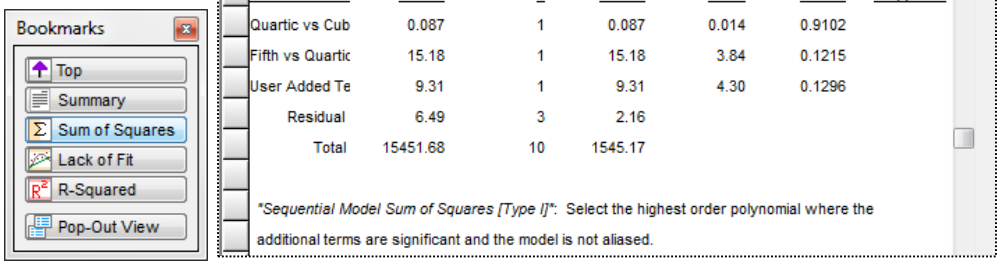


Transformation options

As noted at the bottom of the above screen, in this case the response range is not that great (less than three-fold), so do not bother trying any transformation – it can remain at the default of none.

☒ ***Explore details on transformations***: Before moving on, press the screen tips button (or select **Tips**, **Screen Tips**). This is a very handy help system that tells you about any screen you are viewing. As you travel from one screen to the next for the first time, keep pressing screen tips to get a brief overview on a just-in-time basis. For more detail, go to program Help and search on a specific topic.

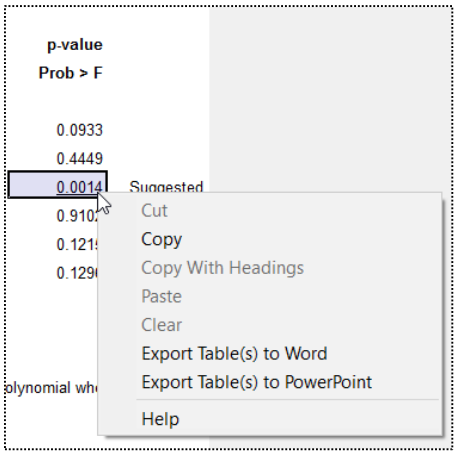
Now press **Fit Summary**. Design-Expert provides a summary to start. Let's look at the underlying tables – start by pressing the **Sum of Squares** on the floating **Bookmarks** tool. You then see a table that evaluates each degree of the model from the mean on up.



Fit Summary – table of sequential model sum of squares

See *RSM Simplified* Chapter 4 if you are interested in the details. The program suggests the cubic model and underlines that line in this table of sequential sum of squares. The extremely low p-value indicates a highly significant advantage when adding this level to what's already been built (mean, linear, and quadratic).

☒ ***Explore options for help***: Remember to try the screen tips on this screen. Also, try right-clicking on a given cell to see if the program offers context-sensitive Help, as it does below.



Accessing context-sensitive Help by right-clicking a report cell

Also, consider referring to program Help via the main menu.

P.S. Notice the options to export output into Word or PowerPoint. This would be a good time to give this a try.

Scroll down to the next section of output, which displays tests for lack of fit.

Lack of Fit Tests

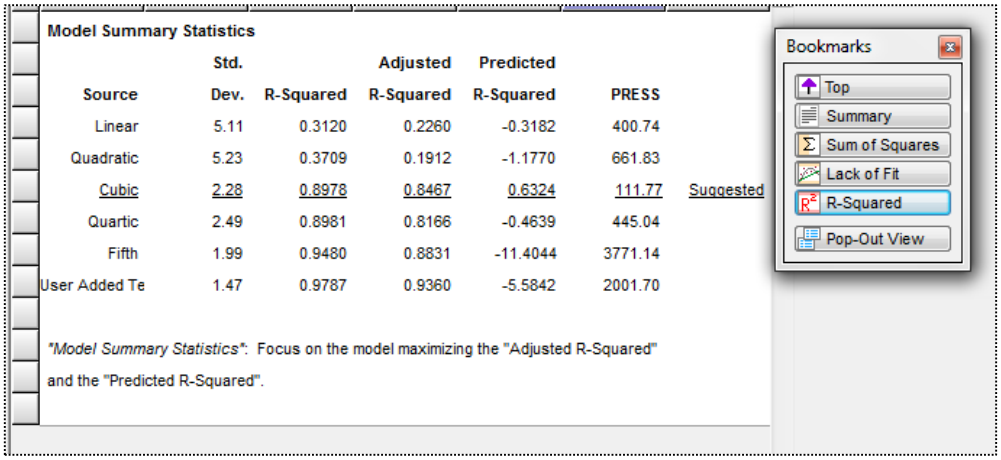
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Linear	202.76	6	33.79	10.56	0.0890	
Quadratic	184.86	5	36.97	11.55	0.0816	
Cubic	24.66	4	6.17	1.93	0.3696	Suggested
Quartic	24.57	3	8.19	2.56	0.2933	
Fifth	9.40	2	4.70	1.47	0.4051	
User Added Te	0.088	1	0.088	0.027	0.8837	
Pure Error	6.40	2	3.20			

*"Lack of Fit Tests": Want the selected model to have insignificant lack-of-fit.

Lack of fit tests

The cubic model produces insignificant lack of fit – that's good!

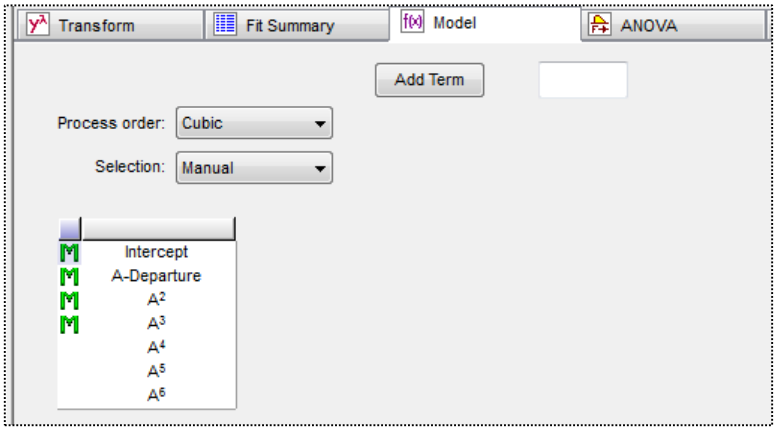
On the floating **Bookmark** press the **R-Squared** button to jump down to the last section of the fit summary report – model summary statistics.



Model summary statistics

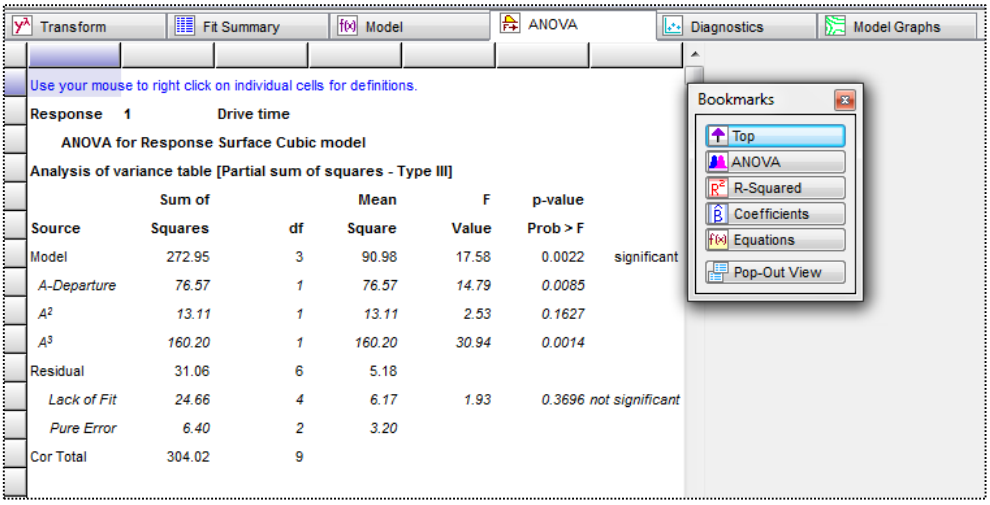
It should be no wonder that Design-Expert suggests cubic. Look how much lower the standard deviation is from this model and how much better it is compared with lower-order models for R-squared – raw, adjusted, and predicted. Also the cubic model produces the least PRESS (predicted residual sum of squares) – a good measure of its relative precision for forecasting future outcomes.

Move on by pressing the **Model** tab.



The cubic model chosen

It's pre-set the way the software suggested, so without further ado, press **ANOVA** for the analysis of variance. Design-Expert reports that the outcome for the model is statistically significant. It also tells you that the lack-of-fit is not significant.



Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	272.95	3	90.98	17.58	0.0022	significant
A-Departure	*76.57*	*1*	*76.57*	*14.79*	*0.0085*	
A²	*13.11*	*1*	*13.11*	*2.53*	*0.1627*	
A³	*160.20*	*1*	*160.20*	*30.94*	*0.0014*	
Residual	31.06	6	5.18			
Lack of Fit	*24.66*	*4*	*6.17*	*1.93*	*0.3696*	*not significant*
Pure Error	*6.40*	*2*	*3.20*			
Cor Total	304.02	9				

Analysis of variance (ANOVA)

Press **R-Squared** on the floating **Bookmarks** palette and move on to the next section of output, which displays various model statistics.

Std. Dev.	2.28	R-Squared	0.8978
Mean	38.92	Adj R-Squared	0.8467
C.V. %	5.85	Pred R-Square	0.6324
PRESS	111.77	Adeq Precisior	14.274

Post-ANOVA statistics

☒ ***Explore annotations***: Most of these measures have already appeared in the Fit Summary report, but a few are newly reported. Read the annotations and, if you need more detail, get Help by right-clicking on any particular statistic.

Click **Coefficients** on the floating Bookmark palette to see details on the model coefficients, including confidence intervals (CI) and the variance inflation factors (VIF) – a measure of factor collinearity. A simple rule-of-thumb is that VIFs less than 10 can be safely disregarded, so perhaps Mark did not botch things too badly by missing some of his scheduled times for departure.

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	38.29	1	1.20	35.36	41.22	
A-Departure	-9.34	1	2.43	-15.29	-3.40	7.43
A^2	-2.79	1	1.76	-7.09	1.50	1.84
A^3	12.71	1	2.29	7.12	18.31	9.47

Details on model coefficients

After this you see the predictive equations in terms of coded factor levels and the actuals.

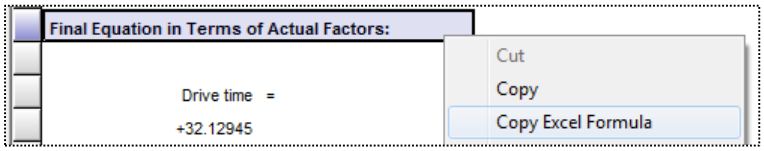
Final Equation in Terms of Actual Factors:

Drive time =
+32.12945
+1.71926 * Departure
-0.10234 * Departure^2
+1.58923E-003 * Departure^3

Final equations for predicting drive time

This last formula will be most useful for Mark, because he can simply plug in his departure time in minutes (remember that zero represents 6:30 a. m.) and get an estimate of how long it will take to drive into town for work at Stat-Ease. However, it pays to do some checking before making use of predictive models generated via RSM.

☒ ***Explore a tool that exports the formula into a spreadsheet***: Right click any part of equation to pull up the option for **Copy Excel Formula**.



Copying the formula to Excel spreadsheet

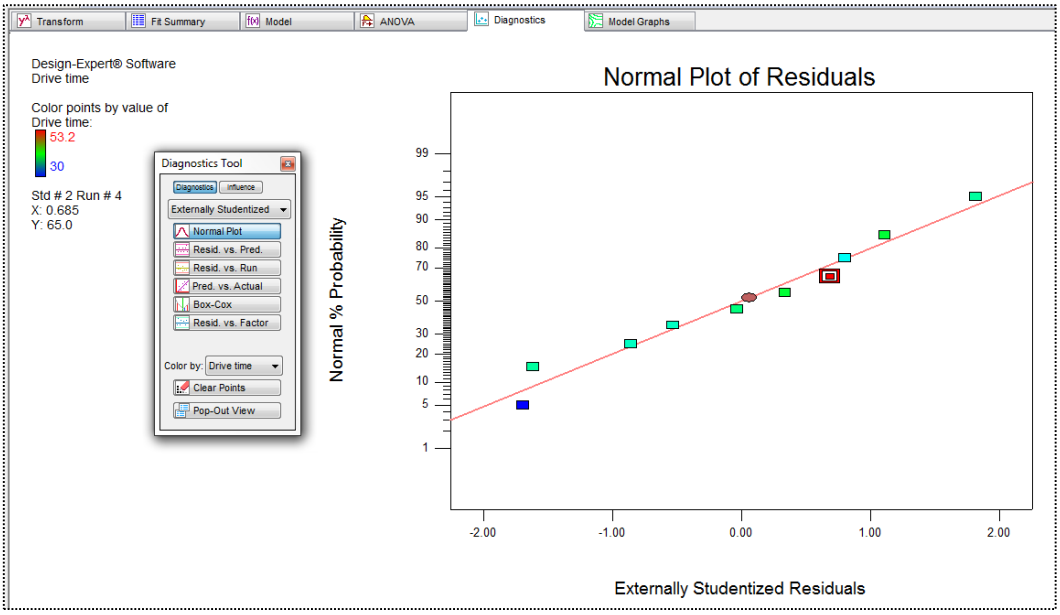
Now, if you have this program installed, open Microsoft Excel and **Paste**. Enter in a departure time and see what's predicted. In this example, the equation predicts a 38 minute commute if Mark leaves home 5 minutes beyond his target time of 6:30 in the morning.

	A	B	C
1	Final Equation in Terms of Actu		
2			
3	Factor entry sheet:		
4	A - Depart	5	
5			
6		F(...)=	38.36595

Plug and chug predicts commute time

Analyze Residuals

Press the ***Diagnostics*** button to see a normal plot of the residuals.



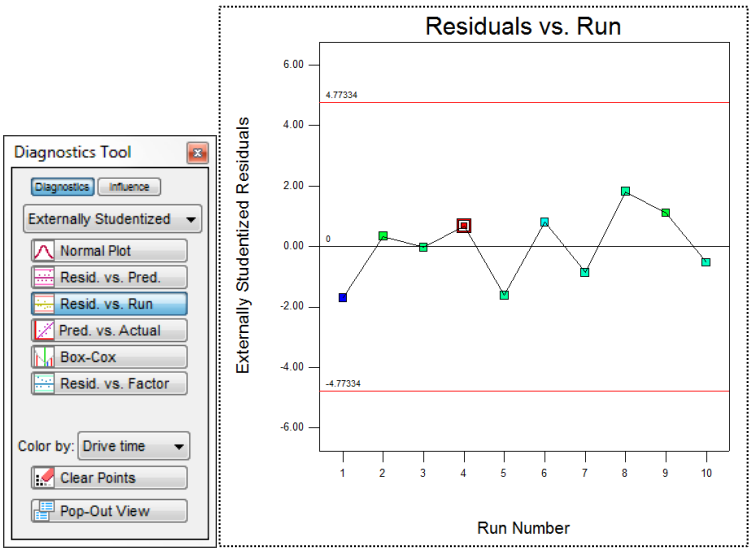
Normal plot of residuals (longest drive time highlighted)

Notice they are colored by drive time. Click the red one – this is the longest commute resulting from Mark oversleeping one day when the design said he ought to have left at the earliest time.

We could say a lot more about this plot, but let's just call it good, because all the points line up nicely and the test for departure from normality is insignificant.

☒ ***Explore how to interpret the normal plot of residuals (and other diagnostics)***: For more details, press Tips. Also, refer to preceding tutorial General One-Factor, which delves into the Diagnostic tools of Design-Expert software.

On the floating **Diagnostics Tool**, press the **Resid. vs Run** button



Residuals by run (your order may differ due to randomization)

Notice that the highlighted residual — the one stemming from the highest response — falls well within the red lines, that is, it varies only due to common-cause

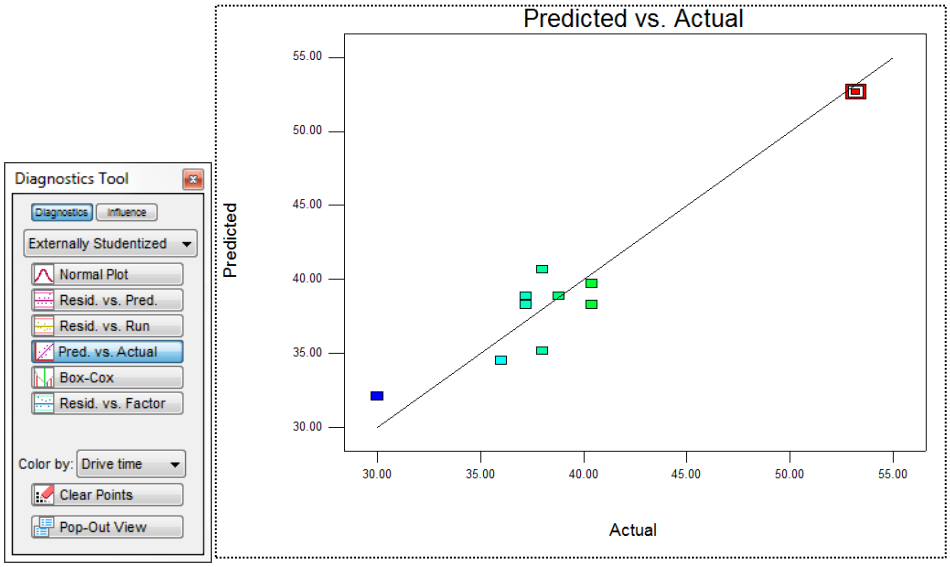
variations. Thus there is no reason to remove this result, albeit unplanned experimentally, from the analysis.

☒ ***Explore further thoughts on the residuals versus run plot***: The first thing to watch for, obviously, would be a single point falling outside the red line, that is, an outlier. In any case, the decision on whether to keep data or not ultimately depends on the judgment of the subject-matter expert. In this case, based on a decade of experience commuting daily into work and confirmation runs after his experiment, Mark chose to keep the point in question (the one highlighted). It's simple really: If one leaves so late that one gets caught in rush hour, one will spend more time driving!

Another thing to look for in the run plot is trends or shifts. For example, if the winter came midway through a driving experiment like this, it would probably create a shift. Randomization is vital for protecting against time-related changes like this that otherwise would bias the outcome. Always randomize your experimental run order.

P.S. We will not explain here why (for good statistical reasons) residuals are "externally studentized." Other tutorials might say a few things about this. However, your best resource will be Screen Tips and program Help. If you need enlightenment, now is a good time to seek out information 'under the covers' of Design-Expert.

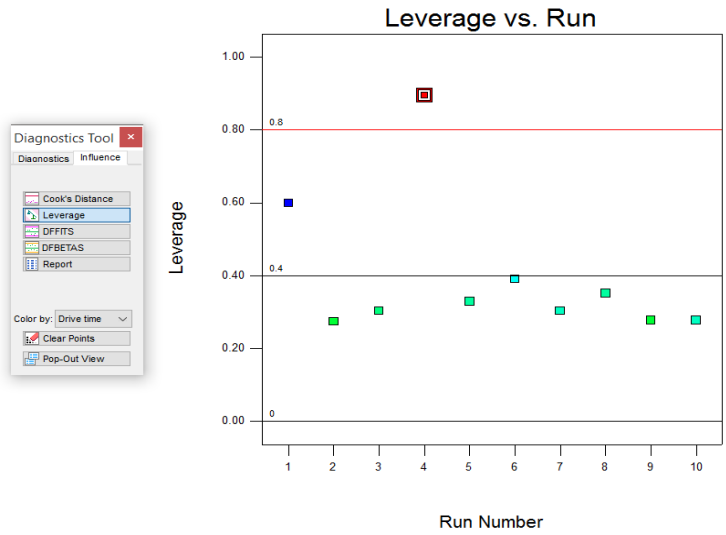
Now press the **Pred. vs Actual** button to see a plot showing how precisely the drive time is modeled.



Predicted versus actual response

The points show some scatter around the 45 degree line in the times below 40, but it hits the high point directly. That's good!

☒ ***Explore leverage***: Not to belabor this, but recall that Mark never intended to leave so late that he'd get into the rush hour that precipitated such a long drive time. By including the result, he degraded the quality of the original design laid out by Design-Expert. In particular, the added point is very influential in the fitting. To assess the impact, click the button labeled **Influence** to see the second plot on this side of the list — the one for **Leverage**. (Note: your plot may differ due to the randomization of run order that Design-Expert changes whenever it rebuilds a design.) You should now see that the leverage for the longest drive-time point falls above the red-line threshold for this statistic — twice the average leverage. (A statistical detail: The average leverage (0.4) is simply calculated by dividing the number of model coefficients (4 including the intercept) by the number of runs (10).)

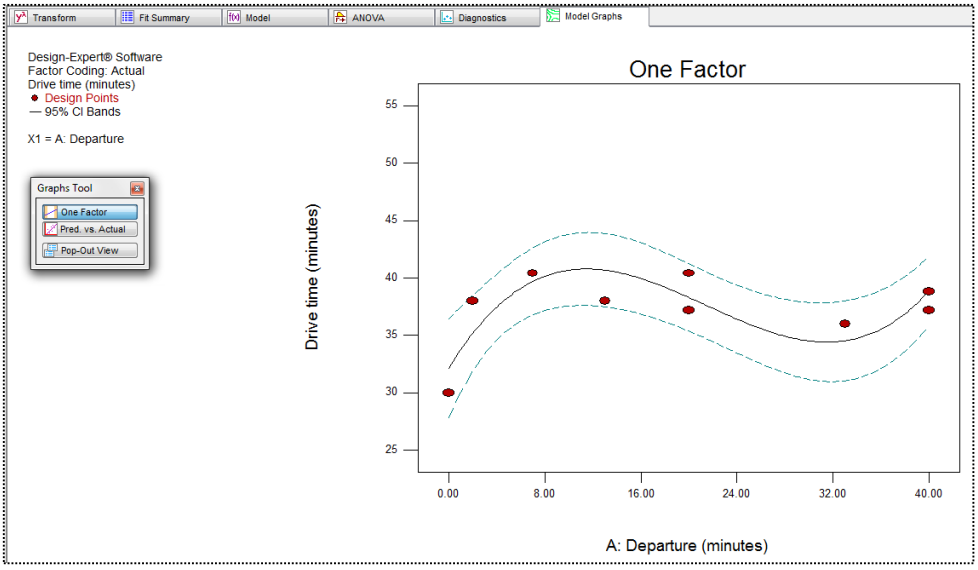


Leverage (your pattern may differ due to randomization of run order)

This highlighted point is not a statistical outlier — it fell within the limits on the run chart. In fact, Mark (to his chagrin) observes similarly long drive times whenever he departs late from home. However, this particular set of experimental data relies heavily on this one high leverage point for fitting one or more of the model terms. That's good to know.

View the Effects Plot

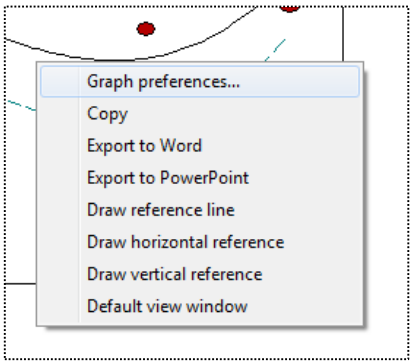
OK, we are finally at the stage where we can generate the response surface plot and see how drive time varies as a function of the time of departure: Press **Model Graphs** to produce the response surface plot. The dotted lines represent the 95% confidence band on the mean prediction at any given departure time.



One factor model graph (response surface plot)

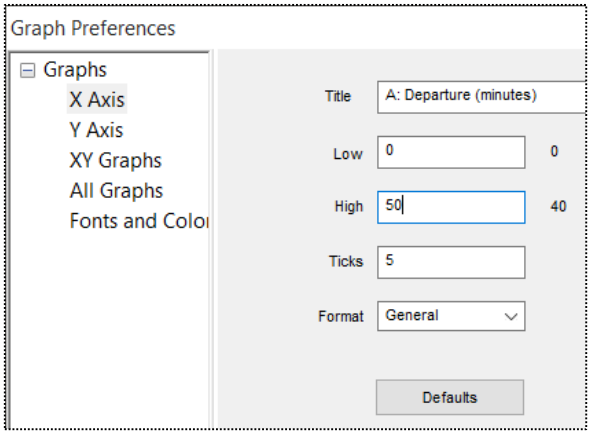
Oops! The program still thinks Mark will never leave more than 40 minutes later than the earliest time (6:30 A.M.). But as you know, he goofed up one morning and left later. With your mouse over the plot, right-click and select **Graph**

Preferences to remedy this discrepancy between planned and actual maximum factor level.



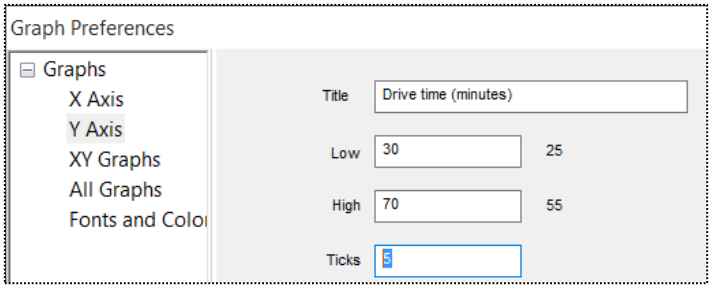
Graph preferences menu

On the **X Axis** dialog box, which comes up by default, change the **High** level to **50**.



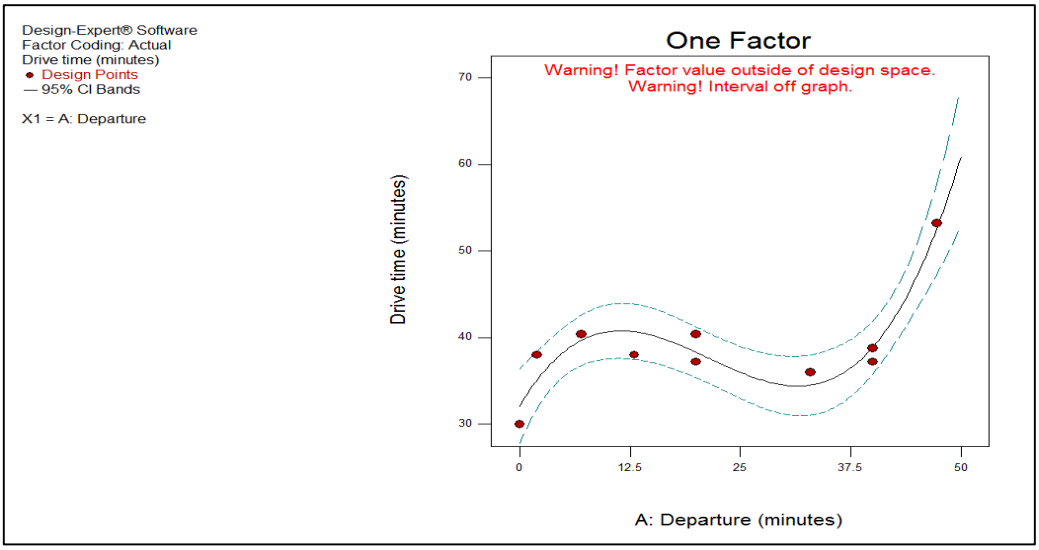
Graph preference options (via right-click on plot)

Finally, select the **Y Axis** tab and enter for the **Low** end a value of **30** and for the **High** side the level of **70**. Also change **Ticks** to **5** (it will look better this way).



Changing the Y axis range and ticks to 5

Click **OK** to see how this changes the plot. (The warning about the factor value being outside of the design space is a helpful reminder that Mark overslept that one morning and left much later than planned.)



Response plot with X-axis expanded to include highest actual level

Ah ha! It appears that Mark might be seeing a 'hole' in the traffic, that is, a trough in the drive time that opens up 25 minutes or more after the earliest departure time. Therefore, he might get a bit more sleep without paying too harsh of a penalty in the form of a longer commute. However, he'd better be careful, further delays from this point could cause him to be very tardy for work at Stat-Ease.

☒ ***Explore options for exporting graphs***: The figure above was produced via Edit, Copy from Design-Expert and then Edit, Paste to Microsoft Word. As you saw on the Graph Preferences menu, Design-Expert also provides tools for direct export to Word or PowerPoint. If you have these Microsoft Office applications installed, now is a good time to try these export options. Also, via Design-Expert's File menu option you can Export Graph to file. Design-Expert offers many Save as options, including encapsulated postscript ("eps") – popular with publishers of journals and textbooks.

That's it for now. Save the results by going to **File**, **Save**. You can now **Exit** Design-Expert if you like, or keep it open and go on to the next tutorial – part two for one-factor RSM design and analysis, which delves into advanced features via further adventures in driving.

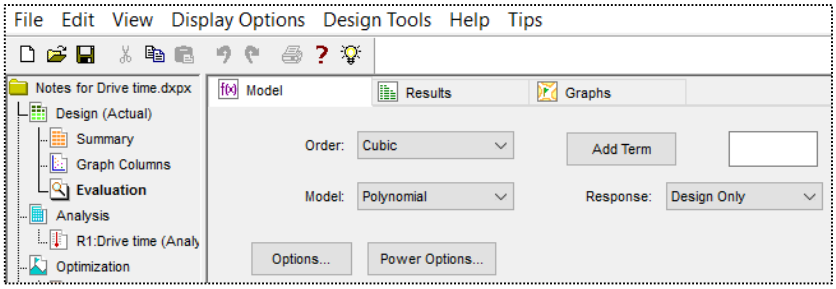


One-Factor RSM Tutorial
(Part 2 – Advanced topics)

Adding Higher-Order Model Terms

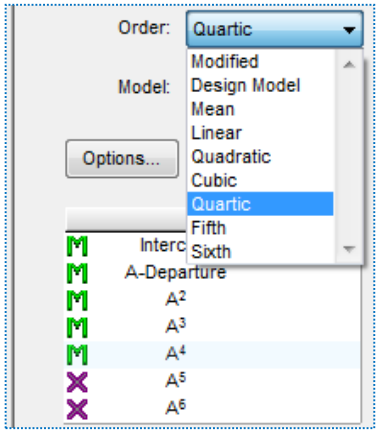


If you still have the driving data active in Design-Expert® software from Part 1 of this tutorial, continue on. If you exited the program, re-start it using our new opening screen (click the **Open Design** button) or use **File**, **Open Design** to open data file **Drive time.dxpx**. Otherwise, go back and set it up as instructed in One-Factor RSM Tutorial (Part 1 – The Basics). The wavy curve you see on the response surface plot for drive time is characteristic of a third-order (cubic) polynomial model. Could an even higher-order model be applied to the data from this case? If so, would it improve the fit? Under the **Design** branch click the **Evaluation** node.



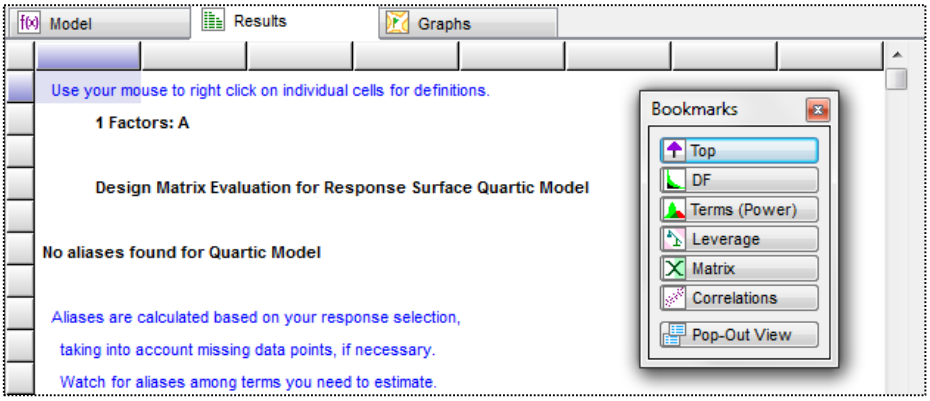
Design evaluation

Change the **Order** to **Quartic** or double-click the term A^4 to put it in the model ("M").



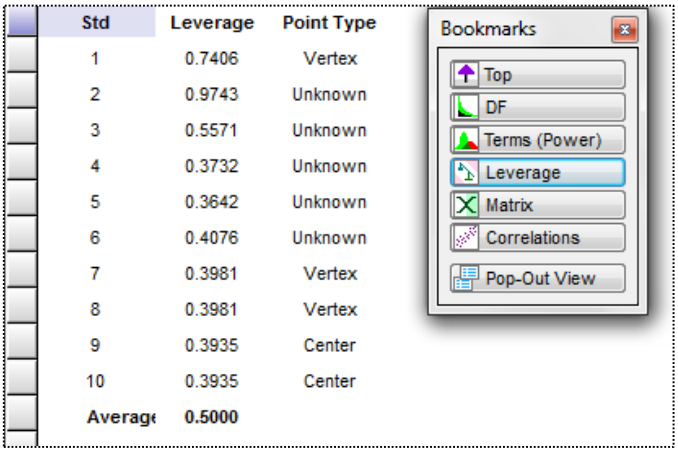
Model changed to quartic (4^{th} order)

Click **Results** to see the evaluation of this higher-order model.



Evaluation finds no aliases for quartic model

No aliases are found, but other aspects of the evaluation fall short of the ideal. Scroll down the output (or use the Bookmarks) and pay close attention to the annotations. On the floating **Bookmarks** click the button for **Leverage**.

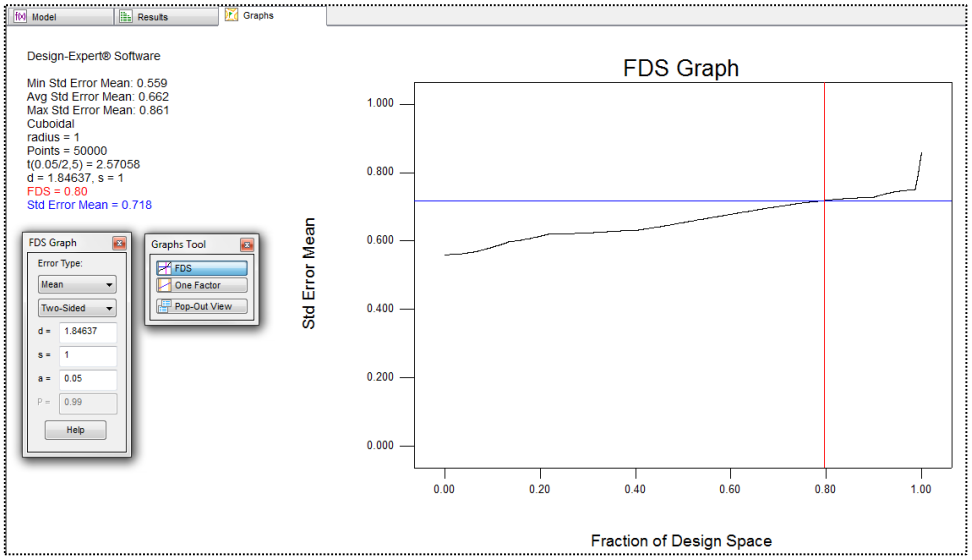


Std	Leverage	Point Type
1	0.7406	Vertex
2	0.9743	Unknown
3	0.5571	Unknown
4	0.3732	Unknown
5	0.3642	Unknown
6	0.4076	Unknown
7	0.3981	Vertex
8	0.3981	Vertex
9	0.3935	Center
10	0.3935	Center
Average	0.5000	

Note the design point with the unusually high leverage of 0.9743. This is the late departure time near 50 minutes that occurred due to Mark oversleeping, causing a 'botched' factor setting. It should not be surprising to see this stand out so poorly for leverage.

☒ ***Explore more advanced design evaluation statistics***: Many more evaluation statistics can be generated from Design-Expert – the ones shown by default are the most important ones. To enable additional measures and modify defaults, click Options under the Model screen.

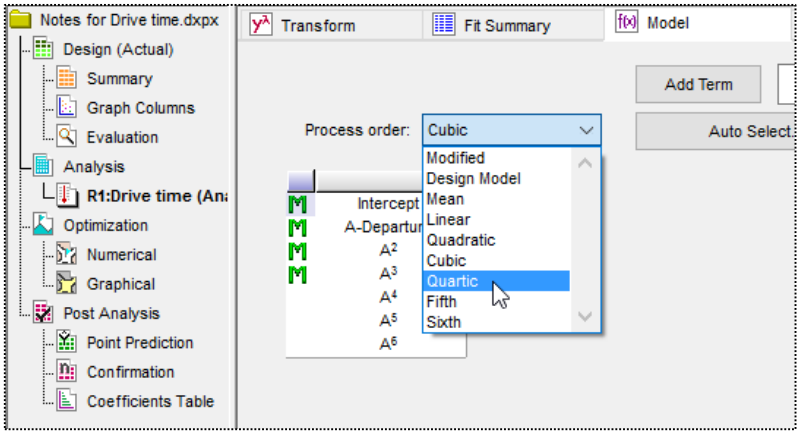
Press ahead to the Graphs to see the plot of FDS – fraction of design space. Click the curve of standard error at a fraction near 0.8 (80 percent) to generate cross-reference lines like those shown in the screen shot below.



FDS graph

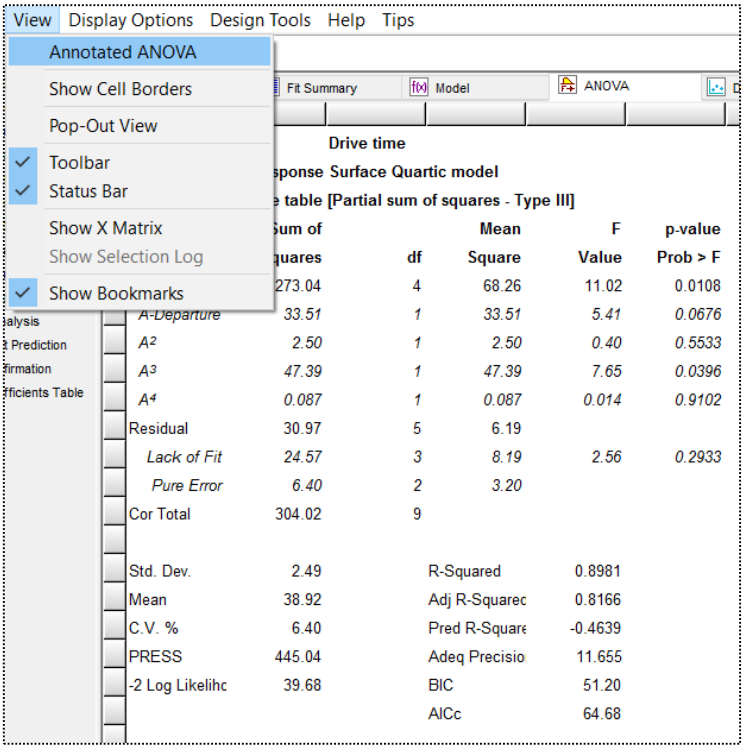
☒ ***Explore FDS graph***: As noted in Screen Tips (hint: press the light-bulb icon), this is a line graph showing the relationship between the "volume" of the design space (area of interest) and amount of prediction error. The curve indicates what fraction (percentage) of the design space has a given prediction error or lower. In general, a lower and flatter FDS curve is better. The FDS graph provides very helpful information on scaled prediction variance (SPV) for comparing alternative test matrices – simple enough that even non-statisticians can see differences at a glance, and versatile for any type of experiment – mixture, process, or combined. For example, one could rerun the FDS graph for the cubic model and compare results and/or try some other experiment designs.

Let's not belabor the evaluation: Go back to the **Analysis** branch and click the **Drive time** node. Then press ahead to the **Model** and change **Process order** to **Quartic**.



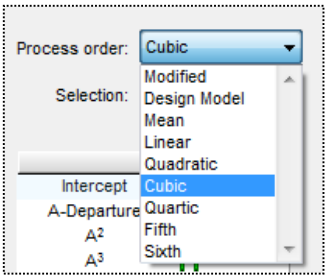
Changing model to quartic for analysis

Now click the ***ANOVA*** tab. Notice that not only does the A^4 term come out insignificant (p-value of 0.91), but the Pred R-Squared goes negative – not a good sign!



ANOVA for quartic model (annotations turned off via View menu)

Before moving on to the next topic, return to the **Model** tab and re-set the **Process order** to **Cubic**, which we recommend for this case.



Back to the cubic model

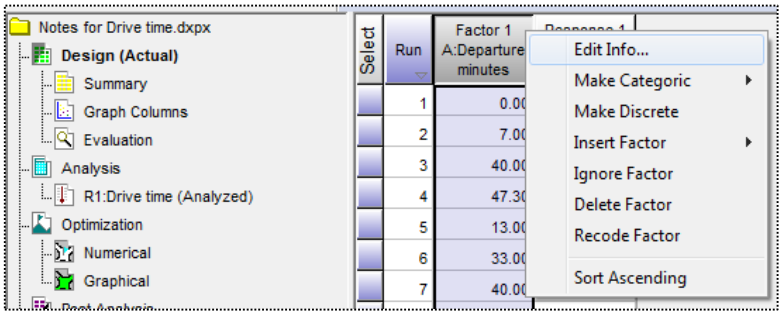
By the way, Design-Expert distinguishes enough in this simplistic one-factor case to add up to sixth-order terms to the model list. However, in some cases, you may need to use the Add Term entry field. For example, in a two-factor RSM you can add terms such as A^2B^4 or A^3B^2.

Propagation of Error (POE)

Seeing such a rapid increase in drive time predicted for late departures makes Mark more aware of how much the response depends on what time he leaves home. He realizes that a 5-minute deviation one way or the other would not be an unreasonable expectation. How will this cause the drive time to vary? Perhaps by aiming for a specific departure time, Mark might reduce drive-time variation caused by day-to-day differences when he leaves for work. Via its capability to

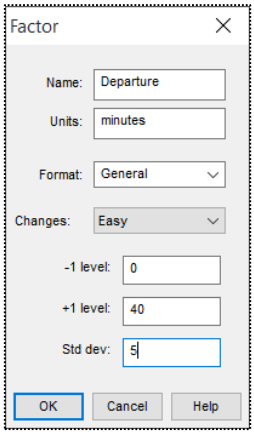
calculate and plot propagation of error (POE), Design-Expert can provide enlightenment on these issues.

Click the **Design** branch to bring up the run-sheet (recipe procedure) for the experiment. Then right-click the column-header for **Factor 1 (**A:Departure) and select **Edit Info**.



Editing info for the input factor

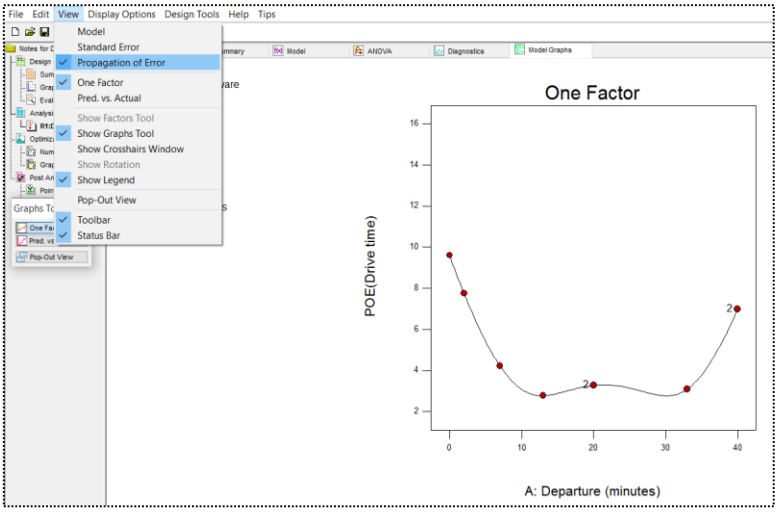
For **Std Dev** enter **5**.



Entering standard deviation for factor

Press **OK** and go back to the **Analysis** branch, click the **Drive time** node and go to **Model Graphs**.

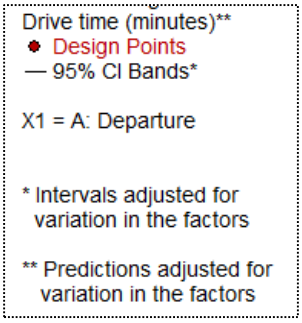
Then from the **View** menu select **Propagation of Error**.



Plot for POE

Notice that POE is minimized at two times for departure, which correspond with flats on the wavy response plot you looked at earlier.

☒ ***Explore how Design-Expert accounts for factor deviation***: As you may have noticed by the legend on the model graph, Design-Expert makes use of the knowledge on standard deviation of the factor(s) to adjust the confidence intervals.



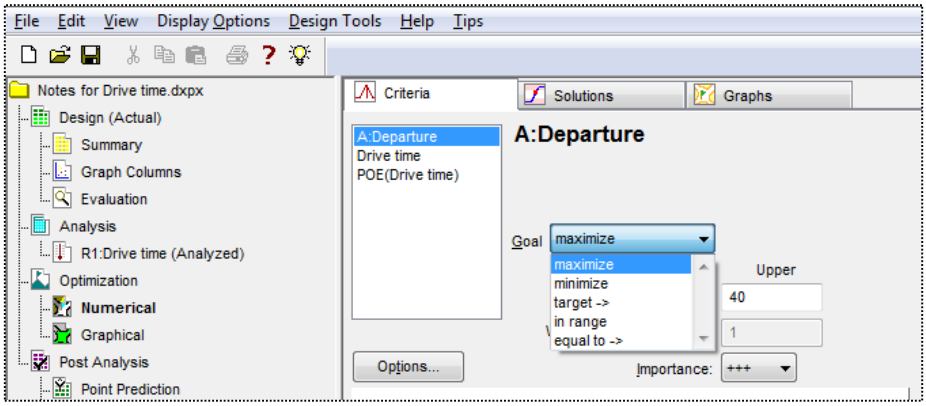
Variation in factor level now accounted for

For details on how this is done, contact Stat-Ease statisticians via stathelp@statease.com.

Multiple Response Optimization

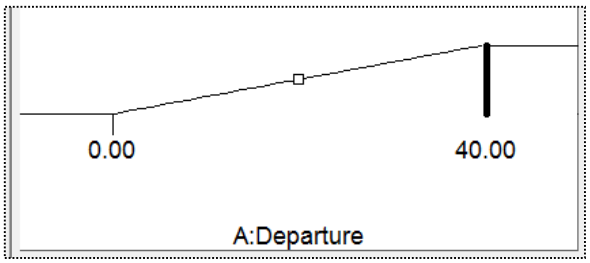
Ideally, Mark would like to leave as late as possible (to get more sleep every morning!) while minimizing his drive time – but making it the least variable. These goals can be established in Design-Expert software so it can look for the most desirable outcomes.

Under the **Optimization** branch, choose the **Numerical** node. For Departure, which comes up by default, click **Goal** and select **maximize**.



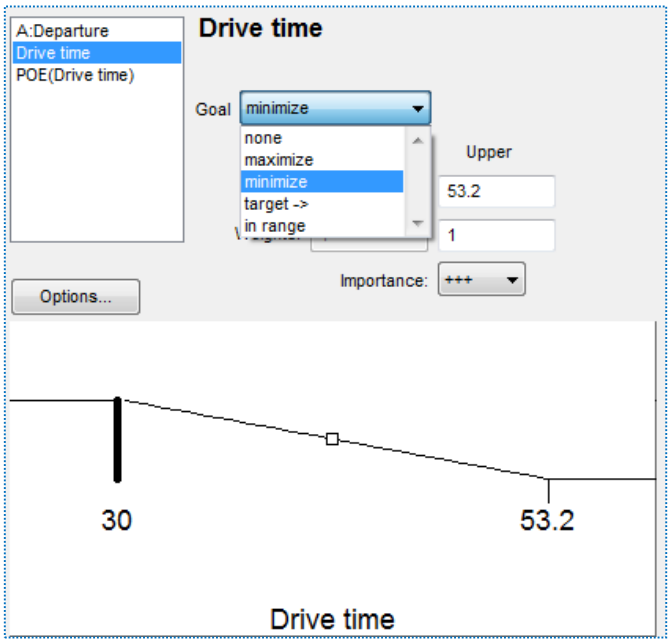
Setting goal for departure

The program pictures this goal as an upward ramp (/) to indicate that the higher this variable goes the more desirable it becomes.



Desirability ramp for departure – later the better (maximize)

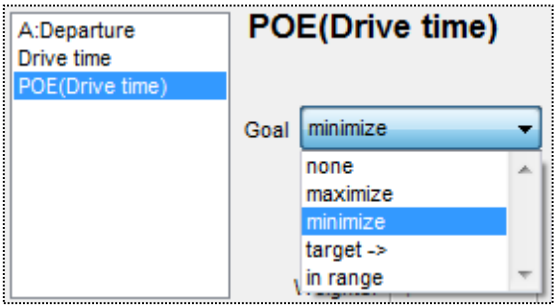
Next, click the response for **Drive time.** For its **Goal** select **minimize**.



Drive time minimized

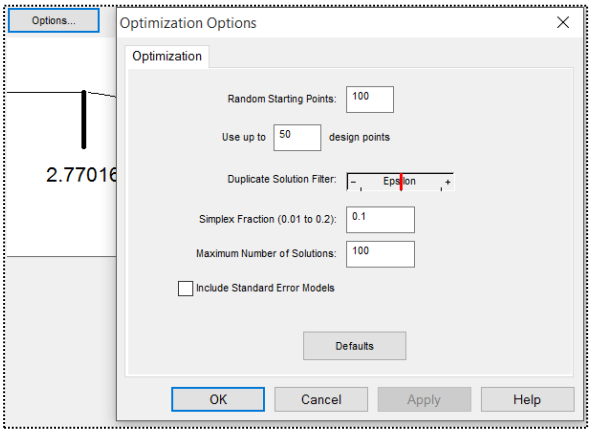
Notice the ramp now goes downward (\) to show that for this variable, lesser is better, that is, more desirable.

Lastly, to reduce variation in drive time caused by deviation in departure, click **POE (Drive Time)** and set its **Goal** to **minimize**.



Minimizing POE

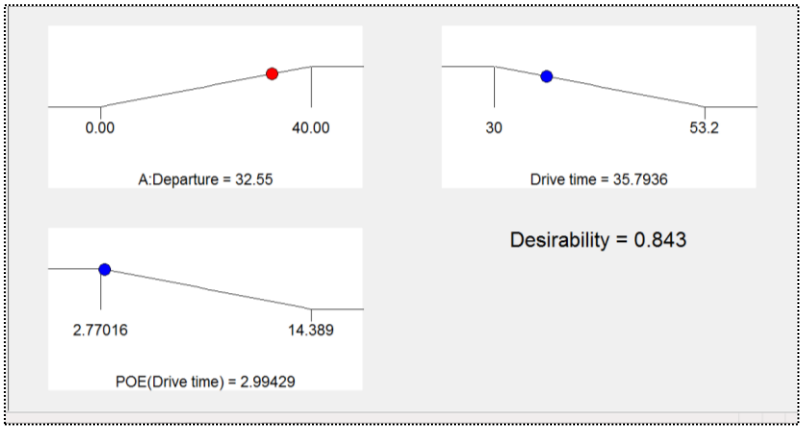
☒ ***Explore options for numeric optimization***: Before pressing ahead, click the **Options** button.



Options for numeric optimization

The settings here will affect the hill-climbing algorithm that Design-Expert uses to find the most desirable combination of variables. For details, check Help. Click **OK** to accept the defaults.

Press the **Solutions** tab to see in "ramps" view what Design-Expert recommends for the most desirable departure. The program now chooses a departure time at random and climbs up the desirability response surface. It repeats this process over and over, but in this case, the same point (within a value "epsilon" for the duplicate solution filter – see Optimization Options above) is found every time – a departure around 33 minutes beyond the earliest start acceptable by Mark for his morning commute. (Your result may vary somewhat due to the random starting points of the hill-climbing algorithm.)



Ramps view of most desirable solution (your results may vary from this)

Now Mark knows when it's best to leave for work while simultaneously maximizing the departure (and gaining more 'shut-eye'), minimizing his drive time, and minimizing propagation of error. The only thing that could possibly go wrong would be if all the other commuters learn how to use RSM and make use of Design-Expert. Mark hopes that none of you who are reading this tutorial live in his suburban neighborhood and work downtown.

