Design of Experiments (DOE) Using JMP® and SAS®

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ABSTRACT

JMP has provided some of the best design of experiment software for years. The JMP team continues the tradition of providing state-of-the-art DOE support. In addition to the full range of classical and modern design of experiment approaches, JMP provides a template for Custom Design for specific requirements. The other choices include: Screening Design; Response Surface Design; Choice Design; Accelerated Life Test Design; Nonlinear Design; Space Filling Design; Full Factorial Design; Taguchi Arrays; Mixture Design; and Augmented Design. Further, sample size and power plots are available. We give an introduction to these methods followed by an example using measurement factors.

BRIEF HISTORY AND BACKGROUND

From early times, there has been a desire to improve processes with controlled experimentation. A famous early experiment cured scurvy with seamen taking citrus fruit. Lives were saved. Thomas Edison invented the light bulb with many experiments. These experiments depended on trial and error with no software to guide, measure, and refine experimentation.

Japan led the way with improving manufacturing—Genichi Taguchi wanted to create repeatable and robust quality in manufacturing. He had been taught management and statistical methods by William Edwards Deming.

Deming taught “Plan, Do, Check, and Act”: PLAN (design) the experiment; DO the experiment by performing the steps; CHECK the results by testing information; and ACT on the decisions based on those results.

In America, other pioneers brought us “Total Quality” and “Six Sigma” with “Design of Experiments” being an advanced methodology.

COMPUTERIZED DOE

With the advent of computer science in the 1960s, many aspects of experimentation were enhanced, from tracking planning, recording quality control of manufacturing, fitting data, and even running advanced computer models to precede manufacturing experiments. The science is not limited to manufacturing but goes to IT, information technology, survey technology, and management. Early design of experiments improved crop yield in agriculture—many disciplines could benefit from the science of design of experiments.

JMP LEADS THE WAY

SAS Institute JMP software was a leader in the field—a major boost to JMP sales. Did you know this? You should follow the JMP website and their blog to keep up. With the robustness of SAS and JMP software, companies and government agencies such as the FDA know to trust JMP and SAS software, now accepting design of experiment data as part of clinical trial validation.

A MOST COMMON APPROACH USING JMP METHODOLOGIES

Remember two things: computer aids help but wisdom in usage is paramount. Secondly, different scenarios require different approaches, and there are hundreds of approaches documented. JMP covers all aspects when you consider extending the most common approaches with custom design.

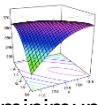
You may be using JMP design of experiments to begin and find the best set up for optimum manufacturing, or you may be refining your methods and demonstrating to management and customers that you have reached the best. The scientific approach in design of experiments helps you in both.

If your scenario is that of just beginning, you could start with full factorial design for a small number of factors, or a screening design when you have too many factors. A screening design will initially use from five to seven factors. **The best initial approach for most cases is to use the Custom Design**.

PRESENTING THE PLATFORMS — JMP/DOE EXPERIMENTAL DESIGN

Full Factorial Design
The basis of the science is to choose ranges for the n factors and assign a top value and low value for each factor. The factors can be varied and optimum results calculated. The icon picture represents an n-dimensional cube and if a middle dot is shown, it means a middle value can also be used.

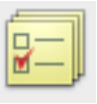
Screening Design
By cutting down, in a patterned manner, the number of experiments to conduct, the most important and dominant factors can be found first.



Response Surface Design
At this point, you may want to do some auxiliary statistical graphics, visualization, and optimization exploration. You can do this with JMP to look for local and global maximum or minimum points on the factor surface.

Custom Design
The JMP Custom Design allows you to tailor your plan of experiments to meet specific requirements. You may want to arrive at Custom Design after approaching with other design options, if the cost is not prohibitive. **Design professionals begin with Custom Design.**

Mixture Design
For the product, survey, or other model such as the US National Budget where factors add up to a fixed sum, you may choose to investigate options with the Mixture Design. You are not limited to three 'ingredients' in the 'recipe' but can apply as many as you choose to include.



Choice Design
The term 'choice' does not mean it is the most choice, but rather included factors are by choice. At some point, your customer (who may be your boss) may want to specify the factors; or attributes of interest in the case of surveys.

Space Filling Design
To quote from the DOE Guide, "Space-filling designs are useful for modeling systems that are deterministic or near-deterministic. One example of a deterministic system is a computer simulation. Such simulations can be very complex involving many variables with complicated interrelationships. A goal of designed experiments on these systems is to find a simpler empirical model that adequately predicts the behavior of the system over limited ranges of the factors."
Note that all of the JMP manuals are 'live' under HELP when you run JMP.

Accelerated Life Test Design
To quote from the DOE Guide, "Often in reliability studies, the product reliability at use conditions is so high that the time required to test the product until it fails is prohibitive. As an alternative, you can test the product in conditions that are more extreme than normal use conditions. The extreme conditions enable the product to degrade and fail sooner, making a reliability study possible. Results are used to predict product reliability at normal use conditions."

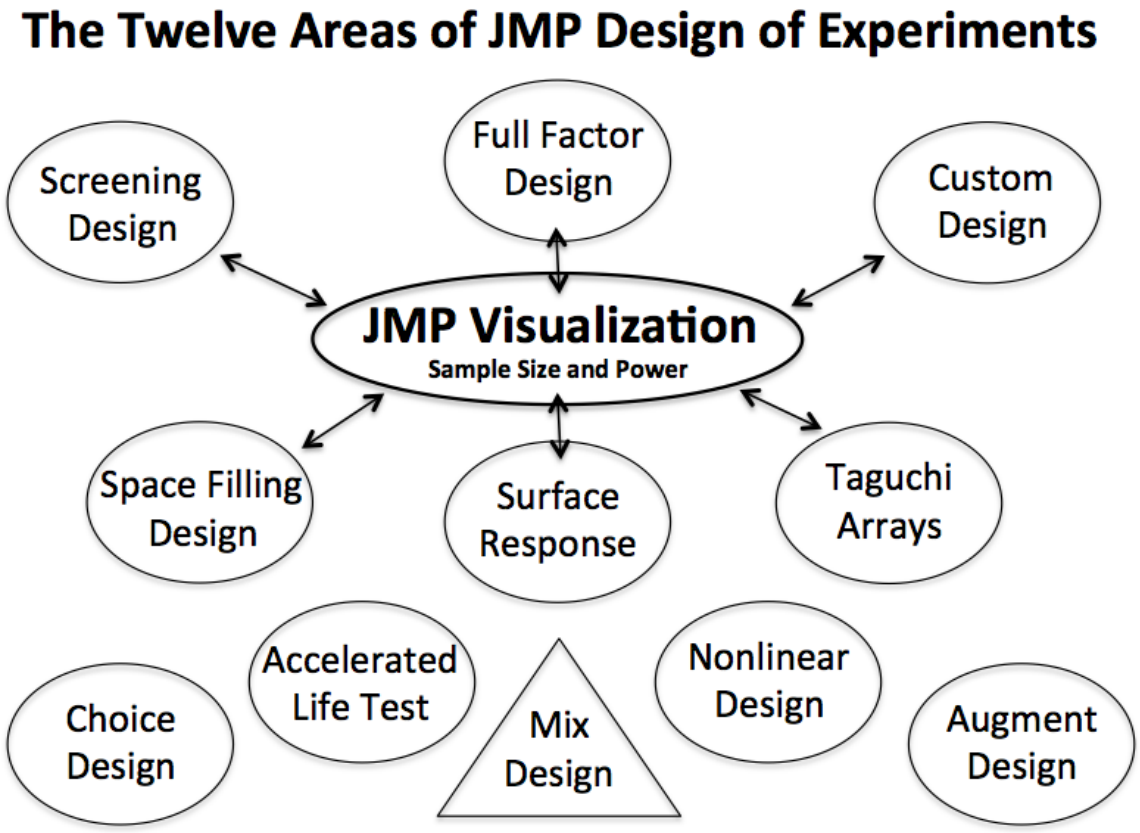


Figure 1

Referring to Figure 1, you can start with a screening design, a full factor design, a custom design, or some other approach such as a choice design (selecting factors specified by the customer) and end up with a final planned design—for example the custom design or the augment design. Start anywhere, end anywhere. The nature of discovery by design of experiments is that it is iterative.

Nonlinear Design
You can begin here if you want. Create the optimal design for models that are nonlinear in the parameters.

Taguchi Arrays
Make inner and outer arrays from signal and noise factors. This is classic.
There are two versions of the Taguchi methodologies, modern replaced classical.

Augment Design
Add more runs to an existing data table. Replicate, add center points or intermediate measurement points, fold over, or add model terms.

Sample Size and Power
Plot any two of the power to detect an effect, the sample size, and the effect size given the third. Or compute one given the other two.

Evaluate Design
Show the confidence level evaluation and the design diagnostics whether the plan is an optimum design or not.

CASE STUDY ONE

A company makes precision parts for aerospace pressing their own material. They have a lot of data on temperature; stir rate, time of curing, coating, and three other factors. 'Goodness' of the end product is based on an ad hoc formula involving measurements and management and is the factor to be maximized.

They spend about $500 each time they make a precision part, fortunately selling the part for much more, but cannot try all combinations to find the optimum settings. They have the experience and knowledge to create good precision parts, but want to do even better and also be assured they are doing the best possible.

After moving the data from instrumentation into a long JMP table, they run the JMP Custom Design platform and determine optimum settings; they then periodically run the JMP Augment Design to retune from each month.

SUMMARY AND CONCLUSION

JMP is superior to other tools because of its Custom Design platform that guides you through DOE. The power of JMP design of experiments gives you a competitive edge of superior products/services developed more economically. Companies and agencies trust the power of SAS Institute and JMP. In showing the 12 areas of JMP design of experiments, we cover examples for manufacturing, sales, and IT information technology simulation. Evaluation of optimum design is possible with Evaluate Design.

ACKNOWLEDGMENTS

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RECOMMENDED READING

Peter Goos and Bradley Jones, **Optimal Design of Experiments: A Case Study Approach**. 2012, SAS Press; (also available via Amazon.)

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