Crystal Ball and Minitab

Complementary Tools for Statistical Automation

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Introduction

The explosive growth of Six Sigma methods in diverse industries has created a huge need for software to automate statistical analysis. Selection of the best tools for your company can be difficult.

As illustrated in Figure 1, a typical business uses three broad categories of software applications. At one extreme are general purpose applications, such as Microsoft® Office and Lotus Notes. These applications are used by everyone and are typically selected by a central IT department.

At the other extreme are specialized analysis tools used by only a few people for highly technical tasks. These applications are typically selected by users who have the advanced training to understand the methods.

In the middle are analytical automation tools. These are used by a broad base of people who want quick answers to tough problems. Those who select, purchase, and use these powerful tools may not be analytical experts, so these tools must be easy to learn and use.

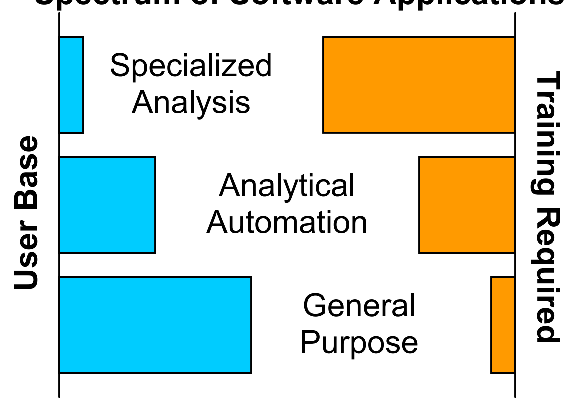


Figure 1

This paper provides an overview of two leading statistical automation tools, Minitab® and Crystal Ball®. For engineers, scientists and anyone who works with data, Minitab and Crystal Ball provide complementary capabilities for the automation of statistical tasks. Minitab is a comprehensive statistical analysis application, while Crystal Ball runs and analyzes simulations of models representing physical systems. Both tools are easy to learn and have developed large, international user bases through a wide range of industries.

This paper describes the different types of problems Minitab and Crystal Ball are designed to solve. The major capabilities and features of each application are reviewed. Finally, the paper describes a case study in which both applications are used together to optimize the design of a new product.

Why Statistical Analysis and Simulation are Important

Statistical methods were invented as tools to explain and predict phenomena observed in the natural world. Models developed through these methods have become essential aspects of business and science. For example, to design a product, an engineer relies

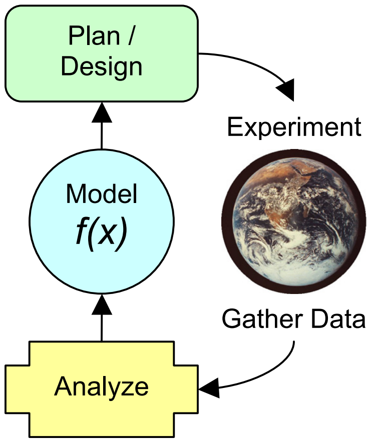


Figure 2 - Statistical Modeling

heavily upon models of physical systems. To assess a business plan, an accountant uses models of economic and human systems.

Figure 2 illustrates the general process of developing and refining these statistical models. Model building starts with a plan, perhaps of a designed experiment. As the experiment is run, data is gathered. The data is analyzed and processed into a mathematical model. The process may repeat with additional loops to verify or refine the model.

Now with the help of computers, we often use simulation as a parallel path to knowledge. Appropriate use of simulation can save a lot of time and money. For example, a manufacturing engineer can simulate the impact of tolerances on the fit of parts in a product. Without building a single prototype, the engineer can eliminate the risk of fit problems and assure a trouble-free production startup. Even phenomena which are impractical to measure with accuracy, such as fluid flows and electromagnetic fields, can be studied economically with simulations.

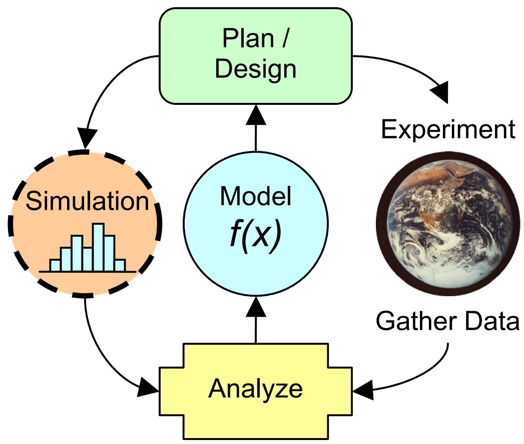


Figure 3 – Role of Simulation

Figure 3 illustrates how simulation relates to the process of building and using models. In some situations, experimental data leads to a simulation model which is used to study the system further. In other cases, the simulation model is based on scientific principles, and is used to select operating conditions, which are then verified with testing. Very often, both simulation and experiments are used in the same project.

Minitab Statistical Analysis Software

Minitab is a comprehensive program for statistical analysis and data visualization. It is a powerful tool for virtually any statistical task involving real-world data. Figure 4 illustrates the tasks for which Minitab works best.

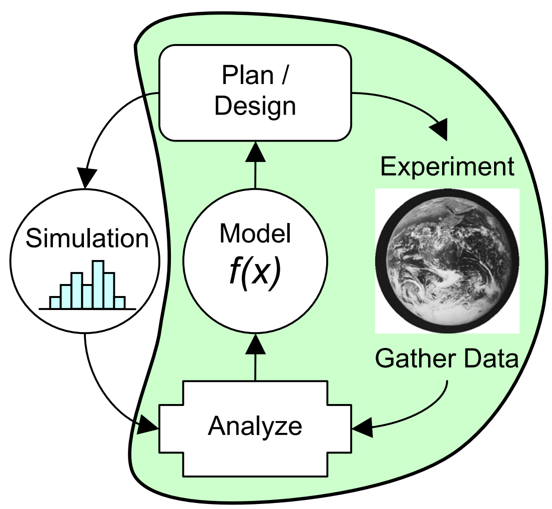


Figure 4 – Domain of Minitab

Minitab has a familiar spreadsheet interface, as seen in Figure 5. Minitab functions are organized into convenient menus. For these reasons, Minitab is fast and easy to learn, and it has become the dominant statistical tool for all levels of Six Sigma training.

The screen shot in Figure 5 shows an experiment designed and analyzed in Minitab. The graphs shown are two of the many Minitab graphs that help reveal how the system under study actually works.

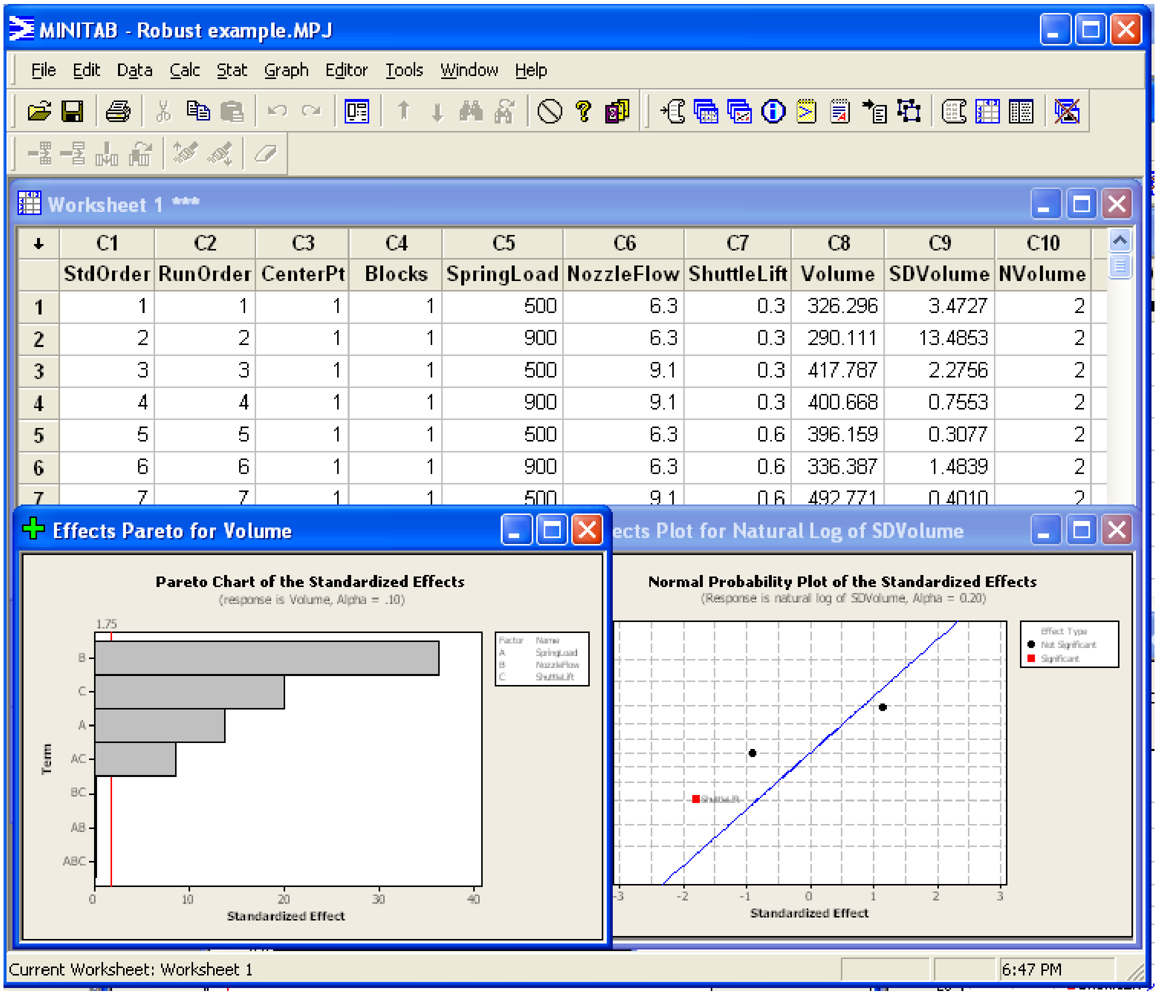


Figure 5 - Example Minitab Screen Shot

In addition to the design and analysis of experiments, Minitab has extensive capabilities for graphing data, regression analysis, time series and forecasting, reliability and survival analysis, multivariate analysis, statistical process control, measurement systems analysis, and more. For more information on Minitab, consult the Minitab Web site at www.minitab.com.

Crystal Ball Risk Analysis, Optimization and Forecasting Software

Crystal Ball is a program for defining, running, analyzing and optimizing a simulation of any system that can be represented by a mathematical model. Figure 6 illustrates the tasks where Crystal Ball software works best. By comparing Figures 5 and 6, it is clear how Minitab and Crystal Ball complement each other's capabilities.

Crystal Ball is an application based in Microsoft Excel that adds a new toolbar and new menus to the Excel window. The model for the system to be simulated is represented by a set of Excel formulas. Since Excel is already familiar to most technical professionals, Crystal Ball is easy to learn and to use.

Figure 7 shows a screen shot of Microsoft Excel with Crystal Ball. The spreadsheet contains formulas that are already set up for a simulation of a model representing a fuel injector.

The green-colored cells are "Assumptions" which are inputs to the simulation. Crystal Ball will assign random values to these assumptions during the simulation. The blue-colored cell is a "Forecast" which contains the output, or result of the simulation. During the simulation, Crystal Ball will save the forecast values produced by each set of random assumption values for statistical analysis.

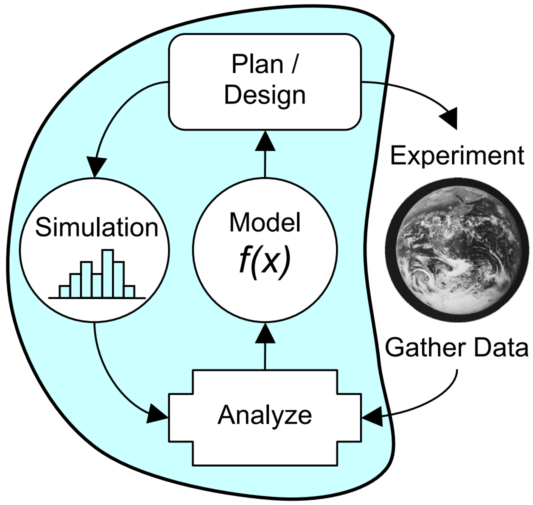
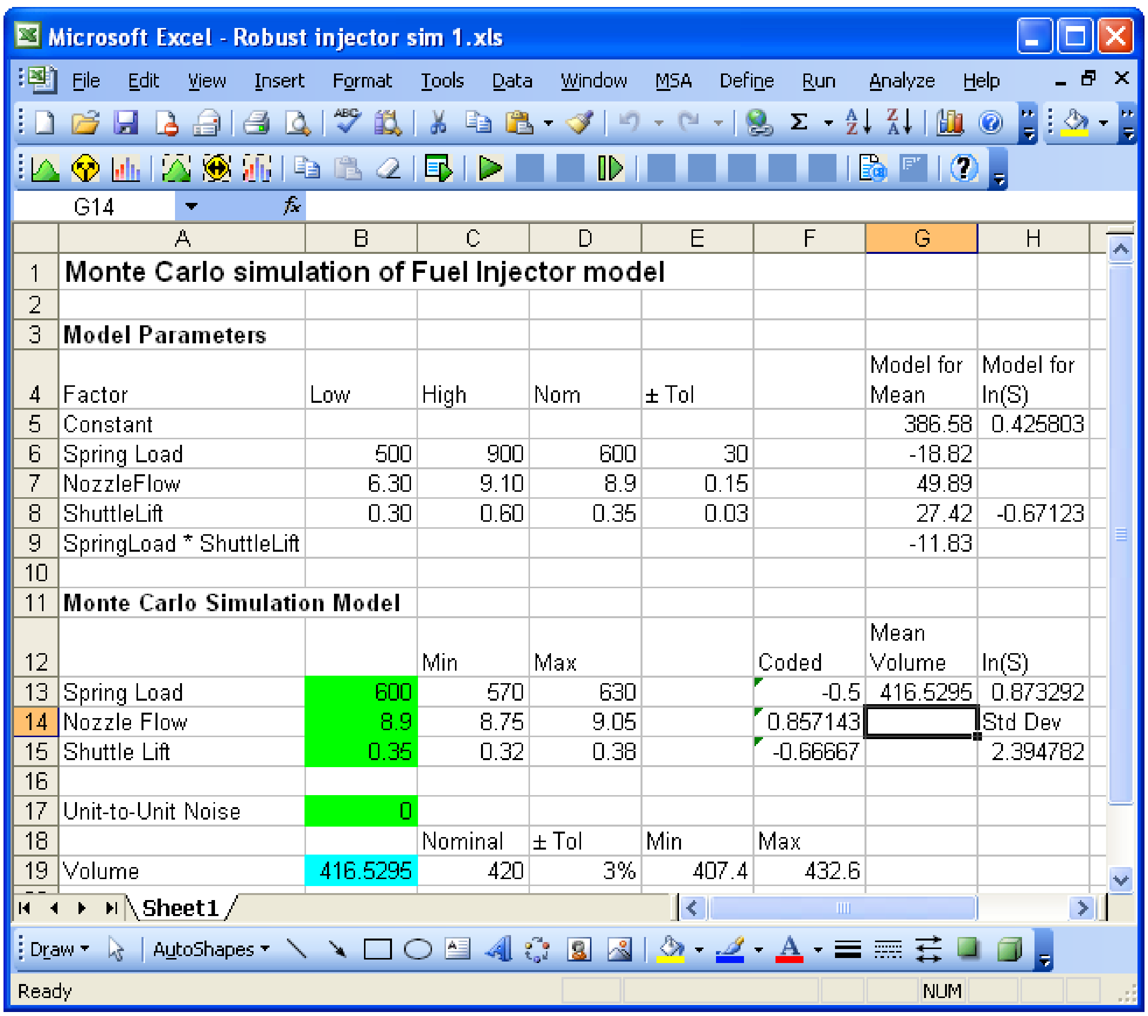


Figure 6 - Domain of Crystal Ball



	A	B	C	D	E	F	G	H
1	Monte Carlo simulation of Fuel Injector model							
2								
3	Model Parameters							
4	Factor	Low	High	Nom	± Tol		Model for Mean	Model for ln(S)
5	Constant						386.58	0.425803
6	Spring Load	500	900	600	30		-18.82	
7	NozzleFlow	6.30	9.10	8.9	0.15		49.89	
8	ShuttleLift	0.30	0.60	0.35	0.03		27.42	-0.67123
9	SpringLoad * ShuttleLift						-11.83	
10								
11	Monte Carlo Simulation Model							
12			Min	Max		Coded	Mean Volume	ln(S)
13	Spring Load	600	570	630		-0.5	416.5295	0.873292
14	Nozzle Flow	8.9	8.75	9.05		0.857143		Std Dev
15	Shuttle Lift	0.35	0.32	0.38		-0.66667		2.394782
16								
17	Unit-to-Unit Noise	0						
18			Nominal	± Tol	Min	Max		
19	Volume	416.5295	420	3%	407.4	432.6		

Figure 7 - Crystal Ball Screen Shot

Crystal Ball produces informative plots such as these to reveal how the system performed in the simulation.

Figure 8 is a histogram showing which values occurred more often in the simulation. In this example, one thousand trials, representing one thousand virtual fuel injectors, are represented on one graph. Some values in this simulation are outside the tolerance limits, and these are highlighted in red.

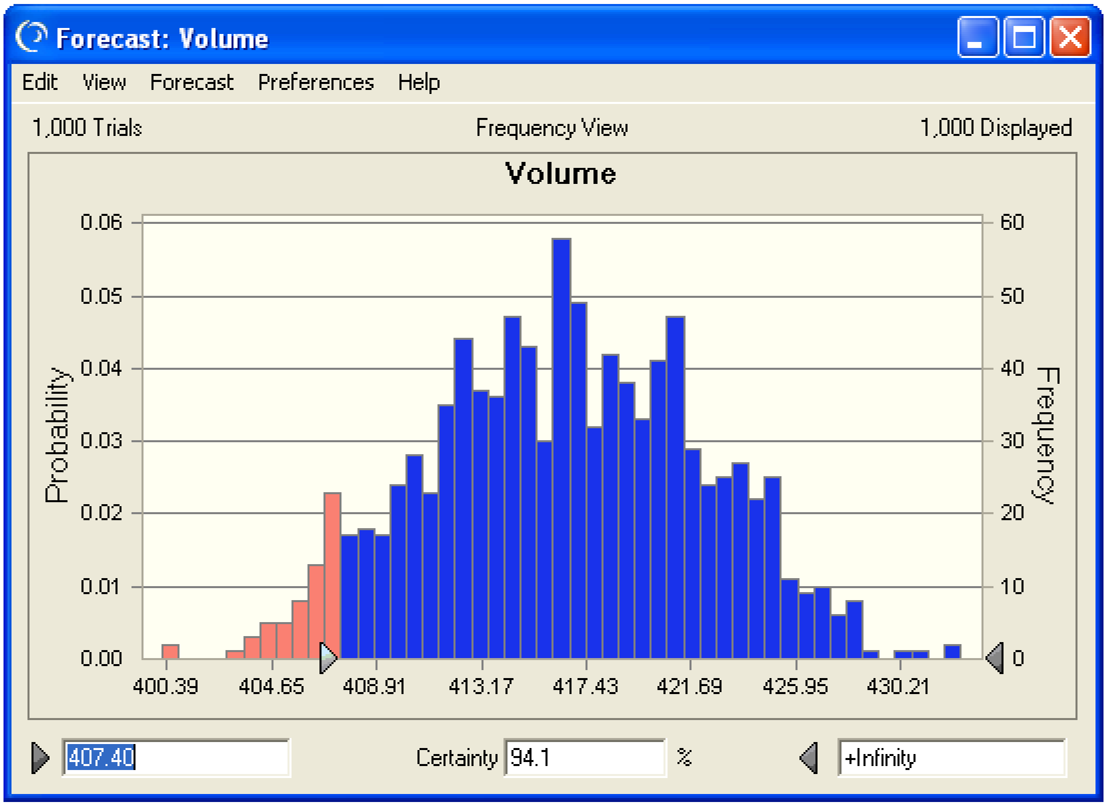


Figure 8 - Histogram of Simulation Results

The next question is how to fix the system to eliminate the values in red. Figure 9 is a sensitivity chart showing clearly which assumptions contribute most to the variation seen in the forecast.

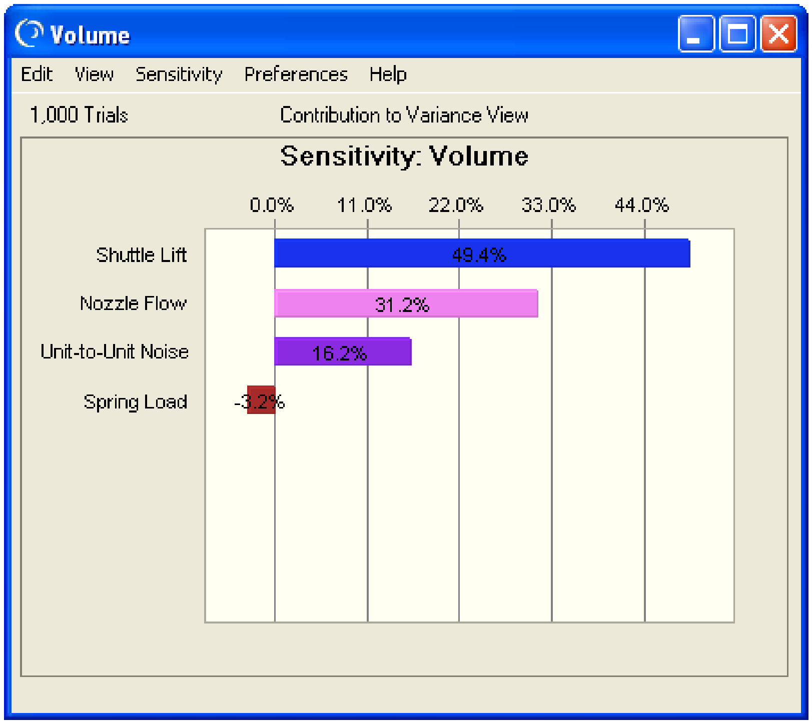


Figure 9- Sensitivity Chart

In addition to these simulation tools, Crystal Ball Professional Edition includes advanced software for system optimization, time series analysis and forecasting. For more information about Crystal Ball, consult www.crystalball.com.

Crystal Ball – Minitab Integration Case Study

This section describes a case study in which Crystal Ball and Minitab are used together for great benefit. The screen shots and graphs above all relate to this case study.

A product development team is designing a fuel injector, and wants to understand the sensitivity of the system to certain critical part values. The team wants to select the best part values to create a robust product that meets its tolerances with minimum variation. To study this empirically, the team uses Minitab to design an experiment with three factors, at two levels for each factor. The experiment will have one response variable, which is injected fuel volume. The tolerance for injected fuel volume is 420 mm^3 ± 3%.

The team runs the experiment by substituting various parts into an injector body and measuring the resulting fuel volume. After collecting the data from the 24 trials in the experiment, the team uses Minitab to analyze the data and derive models that represent the system behavior. Figure 5 is a Minitab screen shot from part of this analysis.

Next, the team wants to simulate the effect of component tolerances. The models computed by Minitab are represented by Excel formulas as shown in Figure 7. The model includes four random inputs. Three of these are for the three components, which may vary within their tolerance ranges. The fourth random input represents unit-to-unit variation as measured in the experiment. Crystal Ball will generate random values for all these parameters and predict the injected fuel volume. The histogram in Figure 8 shows the results of 1000 simulated injectors, with the red values representing injectors that fell outside the tolerance limits. The predicted process capability of this design is C_{PK} = 0.56 which is unacceptable.

To optimize the injector design, the team uses OptQuest software, an optimization tool which is part of Crystal Ball Professional Edition. Within a few minutes, OptQuest identifies a different set of component values with superior performance. With these new values, the predicted value of C_{PK} = 1.10. Figure 10 shows a histogram of predicted performance at these new settings.

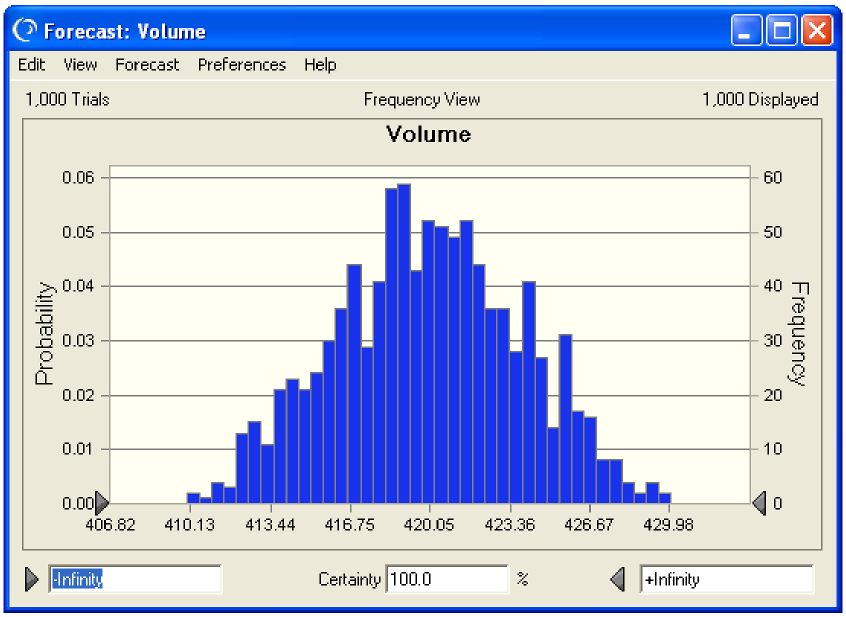


Figure 10 - Histogram of Revised Design

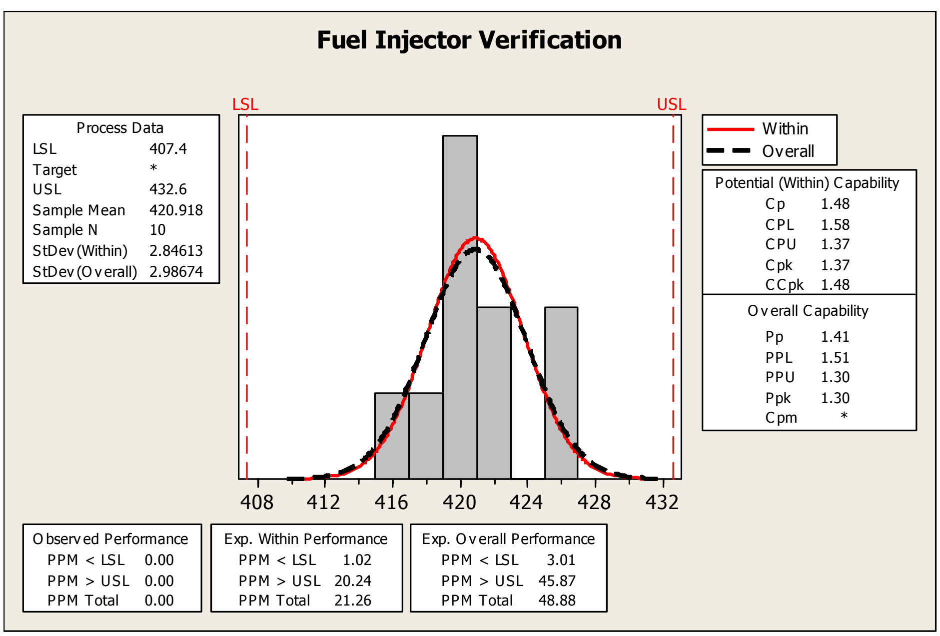


Figure 11 - Minitab Capability Analysis

Encouraged by this result, the team builds 10 sets of parts with the new values and tests them. The team uses Minitab to conduct a capability analysis, which estimates that $C_{PK} = 1.37$. Figure 11 illustrates this result.

In this case study, a team used Minitab to design and analyze an experiment. Based on the experiment, the team selected a mathematical model to represent the system. Using Crystal Ball, the team predicted the impact of component tolerances on the system. Using Crystal Ball's OptQuest, the team found a more robust design. After performing verification runs, Minitab provided a capability analysis.

This illustrates some of the benefits of using both Minitab and Crystal Ball. By integrating both tools into the project development process, this team was able to identify a more robust system design in a very short time.

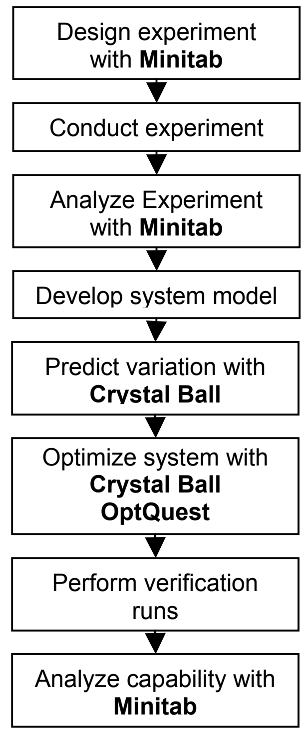


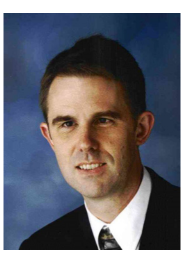
Figure 12 – Case Study Process Flow

Conclusion

Mathematical models are essential tools in all areas of science, engineering, business and quality improvement. Models allow us to understand how real systems behave and to predict how they are likely to behave in the future. People who work with models need software tools to automate statistical tasks that would otherwise be impractical.

Minitab and Crystal Ball are two powerful and user-friendly software tools to create and use mathematical models. Minitab helps to plan experiments, analyze data and visualize the meaning within the data. Crystal Ball simulates system performance, helping the user understand and optimize the system very rapidly. When used together, Crystal Ball and Minitab provide a comprehensive statistical automation toolkit for technical professionals in all fields

About the Author



Andy Sleeper is a Master Black Belt and General Manager of Successful Statistics LLC. He has worked with product development teams for 22 years as an engineer, statistician, project manager, Six Sigma Black Belt and consultant. Andy is an experienced instructor of statistical tools for engineers, having presented thousands of hours of training in countries around the world.

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