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ENHANCING SIX SIGMA THROUGH SIMULATION WITH IGRAFX PROCESS FOR SIX SIGMA

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ABSTRACT

Simulation of business and manufacturing processes has been helping companies improve their operations for several decades. During that time, business improvement programs have appeared, disappeared, grown and evolved. Six Sigma introduced another way of thinking about process improvement by focusing primarily on the financial impact and how defect reduction, customer satisfaction and improved processes all contribute. Only recently has Six Sigma broadly accepted the benefits and approach of simulation to streamline projects, improve results and instill a deeper understanding and appreciation of "the process." This paper begins with an overview of Six Sigma, followed by a description of the benefits of iGrafx Process for Six Sigma to a Six Sigma Black Belt and ends with an example of the benefits received by one company through the use of simulation.

1 INTRODUCTION TO SIX SIGMA

Six Sigma is the powerful force by which leading corporations such as GE, Motorola and Ford are delivering staggering results to their bottom line and customer satisfaction through fundamental changes in the way they operate and an overall improvement in the products and services they deliver. These leading companies believe so much in Six Sigma that they are willing to invest 100's of millions of dollars in Six Sigma with the expectation to receive billions of dollars in return.

Six Sigma places the emphasis on financial results that can be achieved through the virtual elimination of product and process defects. Gone are the days of quality at any cost. Today's quality improvement programs must deliver measurable results, short- and long-term, to operational effectiveness and the bottom line. The logical end of this approach is that as product and process defects are driven out, value for the customer goes up, customer satisfaction increases, the company captures the market with higher quality at lower price, and profits and company stakeholder value is maximized.

Sigma is a letter (σ) from the Greek alphabet used in statistics as shorthand for the *Standard Deviation,* one metric that describes the variability in a set of data. In Six Sigma, the focus is on the reduction of defects in a product or process. The measure is derived from the concept of a process predictably producing output that is about twice as good as that specified by the customer. At a "Six Sigma" level, a process predictably produces no greater than 3.4 defects per million opportunities (DPMO). A "defect opportunity" is defined as a chance for nonconformance or not meeting the required specifications. This assumes that the output is normally distributed and includes the assumption of a long term process shift of 1.5 to account for shift and drift of the mean. DPMO provides a base standard metric for comparing disparate systems in different industries.

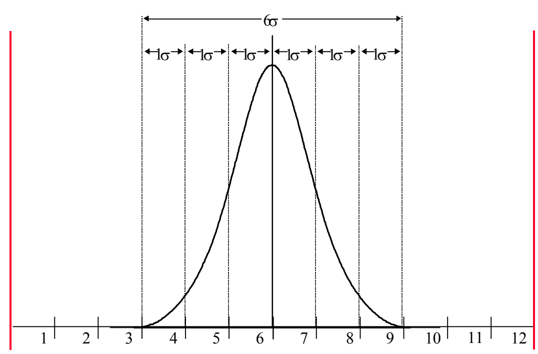

Figure 1: A Six Sigma Process; Output Twice as Good as Customer Requirements

Six Sigma has traditionally been and continues to be very statistics centric. Only recently, Six Sigma Black Belts have been introduced to the benefits that simulation brings to a Six Sigma project and many Black Belts now require a simulation solution as part of their Six Sigma toolkit. Black Belt is the common term for those experts within a company that facilitate improvement projects and will be used in this paper to collectively refer to Six Sigma practitioners.

2 SIX SIGMA PHASES

Approaches to Six Sigma dictate the use of a model to drive a disciplined approach to the solution of quality problems. The most commonly used model is the five-phase model commonly known by the acronym DMAIC (Define, Measure, Analyze, Improve, Control). The model acts as a roadmap for improvement projects, leading the teams through:

- Defining the process or problem that forms the focus of the project;
- Measuring the key variables that drive process performance in order to find leverage points for improvement;
- Analyzing the data to test hypothetical solution variables;
- Making improvements based on analysis and experimentation; and
- Rolling the improved processes out on a large scale and implementing process management systems, both to hold the gains and identify further opportunities for improvement.

Modeling has been a vital contributor to process improvement since flowcharting was introduced in the 1950s. The additional capabilities provided by process simulation have added a powerful, dynamic dimension to what previously were flat, two-dimensional maps of processes. Mapping processes has traditionally been used in helping define processes and later, in setting up training and control plans as process improvements came online. Indeed, most of the "low hanging fruit" (easy but high-yield improvement opportunities) are found through the use of flowcharts. The dynamic aspects of a simulation environment, however, makes the working model an important tool throughout the DMAIC Model.

In the Define phase, adding resource and cost information, durations and decision statistics can help quantify the improvement opportunity beyond the capabilities of conventional financial analysis. Cycle time problems, system bottlenecks and hidden factories can be identified, leading to enhanced understanding of the current state of the system and more realistic prioritization of improvement initiatives. The model can also pinpoint areas for data collection and "quick hit" targets for improvement.

Data collected in the measure phase may be used to update the model, allowing for more in-depth systems analysis, more true-to-life simulations and the ability to plan Designed Experiments.

In the Analyze phase, multi-factor multi-level Designed Experiments may be carried out via simulation. The impact and interactions of many otherwise expensive improvement ideas can thus be tested at little to no cost or other risk, allowing effective screening out of those that clearly would yield no improvement and may sub-optimize the system. Additionally, some elements of an FMEA (Failure Modes and Effects Analysis) could be flexed in a simulation to point out mistake-proofing opportunities.

In the improve phase, data from the improved process is used to update the model. Simulations act as validity checks of the model and its underlying assumptions. The new model provides input for a control plan and training plan. Some elements of a Critical Path for implementation might be experimented with in order to analyze risk and examine the need for resource leveling.

The model will become an important piece of the plan for large-scale rollout in the control phase. A model that matches real-life process performance will serve as a documentation and standardization vehicle and a powerful training aid. By updating the model as the process changes, impacts in other parts of the system can be tracked and the system as a whole may be worked toward optimization.

3 SIX SIGMA METRICS

When you take a look at the metrics used in Six Sigma to measure, analyze and improve a product or process, you start to see what process simulation experts have known since the early 70's and manufacturing simulation experts for several decades prior – simulation delivers real value to any process improvement effort. Let's take a look at some of the key metrics in Six Sigma.

Defects per Unit (DPU), Defects per Opportunity (DPO), Defects per Million Opportunities (DPMO), Yield, Rolled Throughput Yield (RTY), Critical-to-Quality (CTQ) and Critical to Process (CTP), Cycle time and value added analysis are some of the more common metrics. A thorough discussion of most of these metrics is beyond the scope of this paper, but a few concepts are important, especially in the simulation world.

Although specifics may change from project to project, most organizations want to use Six Sigma methodology to optimize for "better, faster, and cheaper." They want to maximize quality, shorten cycle times, and minimize costs. To that end, they measure process yields (and the inverse, Defects per Opportunity or Defects per Unit), the critical process measures that drive them (CTQs, CTPs), process cycle times, and costs of production.

The trick is optimizing the balance of efficiency and effectiveness. It does little good to reduce cycle time in a process step if that reduction results in poor quality that will later require rework or warranty work. It does immeasurable harm to maximize the sales process (through incentives based on percentage of sales, for instance) if the salespeople sell at a loss or oversell the capacity of the production system to make the higher numbers.

In general, we could say that value has to be maximized and waste eliminated at each step throughout the value stream (from supplier to customer). Metrics and measures used to gage the value resulting from a process should be derived to help maximize the value from every resource in the system.

These measures should be clearly operationally defined (for minimum ambiguity), easy to collect and easy to analyze. They should be planned for use in tools such as control charts, which enable prediction of the process performance. They should provide more than a report card, they should provide insight into system and process performance and enable appropriate action when needed and leave the process alone when needed. Some metrics must also be used that allow a company to keep a finger on the pulse of operational cost.

Although this seems as though it is the simplest sort of common sense, it is certainly not common. Six Sigma improvement teams are consistently amazed in the early stages of the effort to find out: a) how little they know about the current process; and—once they do start measuring some things—b) how much waste they have been operating with, in some cases for years. In one recent case, one of the authors worked with a team that had estimated "about two weeks" cycle time for an administrative process. When the team actually collected baseline data and modeled the process, they found that it was taking an average of 72 days, only 17 minutes of which could be justified as value-added time. In addition, the total actual resource cost for running a single transaction through the 72-day process cost almost $32,000.

4 KEY BENEFITS OF SIMULATION TO SIX SIGMA

Shannon identifies the key benefits of simulation as summarized in the list below. It should be no surprise that these benefits are directly applicable to a Six Sigma Black Belt.

- Test designs without committing costly resources
- Explore new staffing policies, operating procedures, decision rules, organizational structures, information flows, etc. without disrupting the operation
- Identify bottlenecks in information, material and product flows and test improvement options
- Test hypotheses about how or why operations behave the way they do
- Control time: speed up to reduce experiment time frames or slow down to conduct detailed analysis
- Gain understanding of current state and desired state systems and identify the critical few variables from the many
- Experiment with new and unfamiliar situations to conduct "what-if" analysis

When one considers the types of improvements that Black Belts undertake, and the CTQs they are trying to improve, it becomes quite obvious that simulation is indeed vital to the long-term success of Six Sigma projects.

To simulation experts and practitioners, it is curious that Six Sigma has for so long gone without the benefits of simulation. It is obvious from the documented cases from companies like Motorola, GE, Allied Signal, ABB and more, that Six Sigma has delivered significant results – without the benefit of simulation. The question that simulation brings is; "Could Six Sigma be even more successful now that simulation has been accepted as a critical component of the standard Black Belt toolkit?"

The authors believe the answer to that question is a resounding; "Yes!". The list below identifies the major ways that simulation can add significant value to a Six Sigma project and, in turn, to an enterprise engaged in Six Sigma.

- Reduced Experimentation Costs
  - Eliminate or minimize manufacturing, materials and disposal costs of inventory that would be created without simulation
  - Eliminate or minimize resource costs of line, management, support and project team required without simulation
  - Eliminate or minimize rental and purchase of additional software, machines, people and expertise required without simulation
- Reduced Project Time
  - Experiments that could take weeks in the field can be simulated in seconds or minutes
  - More projects can be completed, leading to increased returns per Black Belt
  - Quick hit successes help to gain and sustain momentum for Six Sigma programs
  - Early hypothesis testing can help prevent 'going down a rat hole'
- Improved Results
  - Processes conducted seasonally, those that require long cycles, or those that are irregularly exercised can be simulated when desired
  - Explore more options to ensure the optimal solution has been identified
  - Low cost simulation eliminates the need for fractional experimentation
  - Have greater confidence in your proposed solution due to extensive testing
- Improved Data Integrity and User Productivity
  - Integrate with statistics package
  - Greatly reduce data entry errors through automated interfaces
  - Leverage work done in earlier steps such as creating process map and capturing operational data

- Easy to use simulation helps to quickly solve the less complex problems more quickly
- More comprehensive software solutions are required as the projects get tougher and more complex
- Use measured data to create a more accurate model

5 SOFTWARE SOLUTION

iGrafx Process for Six Sigma by Micrografx is the leading simulation package for the Six Sigma community. Built on the award winning *iGrafx FlowCharter* package, iGrafx Process for Six Sigma enables Black Belts to simulate processes through a powerful simulation engine tied with a visual process map.

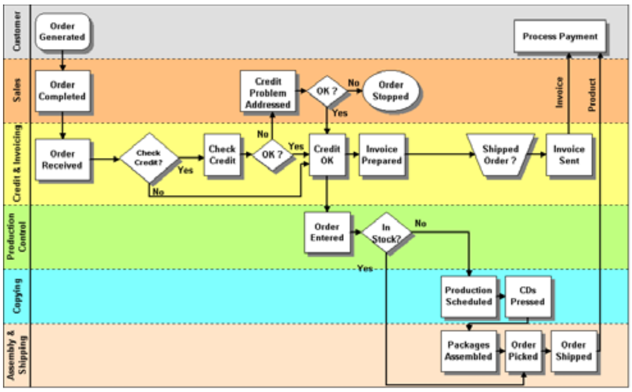

Figure 2: Process Map in iGrafx Process for Six Sigma

iGrafx Process for Six Sigma is the ideal simulation package for Black Belts because it does not require any knowledge of a custom programming or scripting language.

iGrafx Process for Six Sigma also provides some unique functionality for the Black Belt that greatly reduces the effort they need to take in designing and running simulations. These benefits are discussed in the following sections.

5.1 Design of Experiments

Simulation does not equal Design of Experiments (DOE). Simulation handled properly can greatly aid in the experimentation required by Six Sigma. Simulation often requires the manual setting of variables and then rerunning the simulation to measure the "what-if". A full factorial design demands a minimum of 4 simulations; the number of experimental runs can often be much higher than that, especially when replications are considered To obtain a good estimate of the process's performance, anywhere from 2-10 replications *of each experiment* might be necessary. A Black Belt can not be expected to manually manipulate the variables for each of these runs.

iGrafx Process for Six Sigma reduces the need for manual data manipulation and, through integration with the leading statistics application for Six Sigma, MINITAB, delivers the most comprehensive means for designing, conducting and analyzing simulated experiments.

Through an intuitive user interface, Black Belts simply select the experimental factors and their values, the response variables to measure and the number of replications. The *design* of DOE refers to the set of all possible combinations of the experimental factors – the runs. Therefore, after selecting the factors and variables, the experiment design is returned to the user and the application.

Through automated means, each run is simulated, responses are measured and deposited into MINITAB for statistical analysis.

5.2 Building on the Process Map

A major user benefit of iGrafx Process for Six Sigma is that it is a graphical interface to a behavioral modeling system and therefore does not require any knowledge of a programming language. This accessibility to simulation broadens the user base to include those that are not proficient in programming languages.

An additional benefit, particularly to Black Belts, is that the simulation is driven by the process map and the model. The process map, or flowchart, is a required deliverable early in the measure phase of Six Sigma. By leveraging the work done in this early phase, the Black Belt can build upon the process map to create a dynamic model that easily represents the as-is state and ultimately the desired state.

By using a graphics-based simulation solution, Black Belts have a single application that enables them to 1. create a process map; 2. collect and manage process data such as durations, costs, resource requirements, etc; and 3. a simulation engine that uses the graphics and data developed in earlier steps.

5.3 Data Fitting

Selecting a distribution model to represent operational data in your model is an important step in creating an accurate representation of the 'real-world'. iGrafx Process for Six Sigma, through an integration with MINITAB, evaluates and rates the applicability of key distributions for a given data set.

Through a dialog in iGrafx Process for Six Sigma, the user selects a MINITAB worksheet that contains the sample data. MINITAB analyzes the data in the background and returns the parameters for several distributions including Normal, Uniform and Weibull. MINITAB also calculates the Anderson-Darling (A-D) statistic.

Once MINITAB has returned the parameters and A-D statistic, iGrafx Process for Six Sigma provides the user with the data as well as graphs for the Cumulative Distribution Function, Probability Density Function and Residuals. With the combination of the data and graphs, als. With the combination of the data and graphs, the user can select the most appropriate distribution for their data.

The more real-world data that a Black Belt can use to populate their model, the greater the validity of the model.

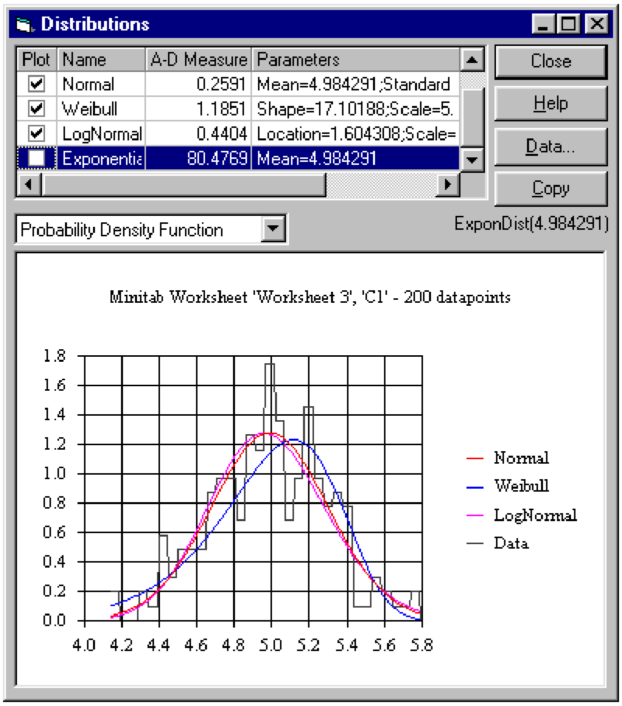

Figure 3: Data Fit Representation of 200 data points

6 PRACTICAL EXAMPLE

Xaytronix Corporation (the fictitious name for a real-life company) provides comprehensive technological solutions for businesses worldwide; from simple networking hardware and software packages to full-scale, customized, fully-integrated LAN/WAN business systems.

6.1 Xaytronix Problem

Xaytronix had been a leading pioneer in the field, but believed that arcane, archaic and convoluted business processes had cost them their competitive advantage. As example, the product delivery process averaged 230 days from order to delivery. Customers believed 3-4 weeks to be acceptable (and competitive analysis revealed that some of Xaytronix's competition was close to delivering within that timeframe). Xaytronix chartered a Six Sigma project to improve the order-delivery process and meet the customer's Critical to Quality measurement.

6.1.1 Define Phase

Initial modeling revealed little waste in production-delivery. Production averaged around 12 percent of total cost of pre-project production; more importantly, it accounted for 4.5 percent of the Non-Value-Added cost. The business process used to process orders, however, accounted for the other 88 percent of cost and 95.5 percent of Non-Value-Added cost. Also very important was the fact that, over the course of a model year, only 19 of 1249 transactions (orders) that entered the system made it past planning to production. Those orders that did not make it were due to errors or inadequate information in the sales process (comparison with real-world data indicated a good working model; these numbers were consistent with real-world performance).

The model revealed that an inordinate amount of cycle time was wasted in delays and rework created by inaccurate or unfeasible orders. Proposals coming from the sales activities often contained requirements that could not be met by purchasing or manufacturing, causing the entire proposal to be reworked and/or renegotiated with the potential customers.

Inaccuracies in order processing led to other losses, as well. Potential customers were put off by the delays and were often angry at the number of renegotiations required before coming to some workable compromise on what they wanted. Many walked.

The Six Sigma improvement team, therefore, decided to concentrate their efforts on the first segment of the process, from customer contact to proposal submission. A look at their preliminary model revealed that, if they could achieve a higher degree of accuracy they could probably preclude most of the renegotiations, potentially leading to much higher revenues. They could also shorten the cycle time within that portion of the process, thus considerably shortening the overall cycle time.

As an example, one step involved a meeting of the planning committee. The planning committee examined the feasibility of new proposals and plan for production of equipment and software for those that were deemed feasible. Simulation revealed that of 91 proposed projects that might reach the planning committee in a year's time, only 32 would be passed through to production.. This was well within the limits calculated from the historical data (between 73 to 103 projects proposed over the past several years; between 25 and 37 accepted). Rejected proposals had to be renegotiated with the client and redrafted. Although no data existed, anecdotal data strongly suggested that very few (if any) clients ever hired Xaytronix following a second or third round of renegotiations.

Each of these projects represented an average of about $500,000 in revenue. Therefore it seemed reasonable to assume that, if they could eliminate rejections by the planning committee, they might close on approximately 54 more projects per year, gaining an extra $26 million in revenue. The team tested this hypothesis by eliminating the planning committee step in the model.

Because a comprehensive model simulates the interactions between process areas, the results of simulation runs often contain unanticipated differences. In this case, the results were clear.

Table 1: Simulation Results – First Pass at Preliminary "Quantification of the Opportunity"

	Simulation 1 "As-is"	Simulation 2 "What-if"
# Transactions completed	19	101
Avg. Revenue per proposal	$503,000.00	$503,000.00
Total Revenue	$9,557,000.00	$50,803,000.00
Cost of Sales	$2,944,257.35	$2,950,984.29
Sales cost as pct of revenue	30.81%	5.81%
Operations Cost	$397,062.27	$988,847.96
Ops cost as pct of revenue	4.15%	1.95%

This simulation made for a compelling argument in the business case, and makes an important point about cost-cutting. Although cost of sales went up slightly and cost of operations tripled under the new scheme, the effectiveness of the cost skyrocketed. As demonstrated in Table 1, revenues increased five-fold, sales costs as a percentage of revenue decreased almost five-fold, and operations costs as a percent of revenue decreased by more than one hundred percent.

This argument alone was compelling enough to garner a "go-ahead" at the champion's turnstile review. The team now began looking for strategies to eliminate planning committee rejections.

6.1.2 Measure Phase

One major purpose of the measure phase is to collect and examine more closely data relevant to the process under study. The focus of the effort in this step is finding key input variables (KIVs or "x's") which drive the key output variables (KOVs or "y's"). Process modeling helps identify opportunities for improvement and KIVs to collect. Simulation is an aid in testing those KIVs and their impact on the KOVs.

In studying the model, the team found that salespeople making calls on potential clients carried the catalog of products and services they had received in training. Proposals were examined by the sales supervisor and sales manager before being approved and submitted to clients. However, no one from operations was involved in the pre-submission process. Pre-submission checks dealt more with compliance with company policies and legal requirements.

The team decided to examine the success rate of proposals through the process. They gathered data at several key inspection points, including a check for legal problems, the sales supervisor's and sales manager's pre-submission audit, customer renegotiations, and the planning committee review.

Key findings from this phase suggested a couple of quick hits. For instance, the team found that new salespeople's work was much more closely scrutinized by the sales supervisor and managers than the proposals of experienced salespeople, even though their work resulted in no higher numbers of rejections by customers or the planning committee. It is important to note that causes for rejection by the supervisor were completely different from those of the customers or planning committee.

Pursuing that avenue of inquiry, the team discovered that the supervisor was only interested in looking over the proposals as a "training aid." The supervisor felt that it was necessary to carefully scrutinize each proposal from a new salesperson to find problems which would help the new salesperson understand "the way we do things here." For experienced salespeople, the supervisor only cared to be informed about the scope, potential revenue and schedule for any upcoming projects.

The team felt that there was some potential for saving some cycle time if the close scrutiny by the sales supervisor could be eliminated. An attribute reliability and repeatability (Attribute R&R) study was planned, to test whether the inspection step produced results consistent with the supervisor's assumptions. Meanwhile, data from the process was used to update the model.

6.1.3 Analyze Phase

In the analyze phase, the model was useful in identifying possible areas for improvement. Inspection points are generally non-value-added (NVA) and are prime candidates for elimination. The model also identifies areas where the resource utilization is excessively high or low, pointing to possibilities for reallocation of existing resources or the necessity for hiring new resources.

As the team began working through these possibilities, modeling and simulation proved very cost-effective. For instance, there were a number of bottlenecks that seemingly needed new resources. What would be the optimum mix for cost? For production volume? For both? Situations like this, with multiple contributing factors and numerous possibilities for interaction effects, call for designed experiments to help optimize the factor set.

The cost of conducting designed experiments involving shifting or adding personnel in a real-world situation is extremely prohibitive. Do we add two salespeople to the sales department, two technicians to the lab, or one salesperson and three technicians? The possibilities, in a complex transactional environment, quickly become hundreds or thousands of combinations of factors. Considering the cost of training (or hiring) people for new positions and running different operations to gather experimental data, simulation becomes an extremely attractive alternative.

Simulation also provides an opportunity to run full factorial experiments with many more factors than would be practical in the real world. Real-world scenarios generally require running some fractional or other screening designs to eliminate unlikely factors, then verifying or optimizing a system using a full factorial. By using simulation, full factorial designs up to 2^{10}, with 4 replicates, may be run in less than half an hour.

Of course, the better the model, the less risk is involved in running experiments. Once the Sales Process Improvement Team had decided the model was sound, they ran a simulated designed experiment to determine the need for new personnel, and the allocation of those personnel.

6.1.4 Improve and Control Phases

The model and the other analyses indicated that the process required some significant shifts in existing personnel, and the hiring of a couple of new personnel. A training plan was put into place, new job descriptions were written, and people began to work according to the changes the team recommended. The model acted as a sanity check in this phase, and data from the new, improved process was fed back into the model to keep it updated.

Xaytronics realized significant improvements in cost effectiveness. Cost of sales as a percentage of profit shrank to less than one percent, and the number of deliveries per year went from 19 at the outset of the project to over 300 in the first full year following the project. With lower costs, and greater revenues, Xaytronix was able to cut their prices dramatically and capture a much larger share of the market.

6.2 Xaytronix Results

Through simulation, Xaytronix was able to surface previously hidden resource allocation problems, hidden factories, and inefficient processes. Xaytronix also realized significant savings by simulating costly experiments, screening out those least likely to produce results. Results: a 5-day process. Estimated benefit: up to $550,000 savings during experimentation directly attributable to simulation and $600,000-$700,000/month in increased revenue and decreased costs.

7 SUMMARY

Simulation is a powerful tool for process analysis that is being used in Six Sigma in ever increasing numbers. Six Sigma Black Belts and their companies can gain increased financial benefits through the use of simulation. iGrafx Process for Six Sigma is a uniquely designed solution that is helping many Black Belts today and has become a standard requirement by many companies and consultants worldwide.

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