4

The statistical efficiency conjecture

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4.1 The quality ladder

Modern industrial organizations in manufacturing and services are subject to increasing competitive pressures and rising customer expectations. Management teams on all five continents are striving to satisfy and delight their customers while simultaneously improving efficiencies and cutting costs. In tackling this complex management challenge, an increasing number of organizations have shown that the apparent conflict between high productivity and high quality can be resolved through improvements in work processes and quality of design.

In this chapter we attempt to demonstrate the impact of statistical methods on process and product improvements and the competitive position of organizations. We describe a systematic approach to the evaluation of benefits from process improvement and quality by design (QbD) that can be implemented within and across organizations. We then formulate and validate the *statistical efficiency conjecture* that links management maturity with the impact level of problem solving and improvements driven by statistical methods.

The different approaches to the management of industrial organizations can be summarized and classified using a four-step *quality ladder* (Kenett and Zacks, 1998). The four approaches are: (1) fire fighting; (2) inspection; (3) process control; and (4) and strategic management. To each management approach there corresponds

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a particular set of statistical methods, and the quality ladder maps each management approach to appropriate statistical methods.

Managers mainly involved in reactive fire fighting need to be exposed to basic statistical thinking. Their challenge is to evolve their organization from typical data accumulation to data analysis so that numbers are turned into information and knowledge. Managers who attempt to contain quality and inefficiency problems through inspection and 100 % control can simplify their work by using sampling techniques. More proactive managers, who invest in process control and process improvement, are well aware of the advantages of control chart and process control procedures. At the top of the quality ladder is the approach where up-front investments are secured to run experiments designed to optimize product and process specifications. At that level of maturity, robust designs are run for example on simulation platforms, reliability engineering is performed routinely and reliability estimates are compared with field returns data to monitor the actual performance of products and improve the organization's predictive capability (Kenett and Zacks, 1998; Bates *et al*., 2006).

Efficient implementation of statistical methods requires a proper match between management approach and statistical tools. In this chapter we demonstrate, by means of case studies, the benefits achieved by organizations from process and quality improvement initiatives. The underlying theory behind the approach is that organizations that increase the maturity of their management system, moving from fire fighting to, enjoy increased benefits and significant improvements in their competitive positions.

In August 2002 the Food and Drug Administration (FDA) announced the Pharmaceutical current Good Manufacturing Practices (cGMP) for the 21st Century Initiative. In that announcement the FDA explained its intention to integrate quality systems and risk management approaches into existing programmes with the goal of encouraging industry to adopt modern and innovative manufacturing technologies. The cGMP initiative was spurred by the fact that since 1978, when the last major revision of the cGMP regulations was published, there have been many advances in manufacturing science and in the understanding of quality systems. This initiative resulted in three new guidance documents from the International Conference on Harmonisation – pharmaceutical development (ICH Q8), quality risk management (ICH Q9) and pharmaceutical quality systems (ICH Q10) – with the new vision that ensuring product quality requires "a harmonized pharmaceutical quality system applicable across the life cycle of the product emphasizing an integrated approach to quality risk management and science". This new approach is encouraging the implementation of QbD and hence, de facto, encouraging the pharmaceutical industry to move up the quality ladder (Nasr, 2007).

Figure 4.1 presents the quality ladder in graphical form. The right-hand side shows the management approach and the left-hand side shows the matching statistical techniques. In the next sections we discuss improvement projects and Six Sigma initiatives which help organizations go up the quality ladder.

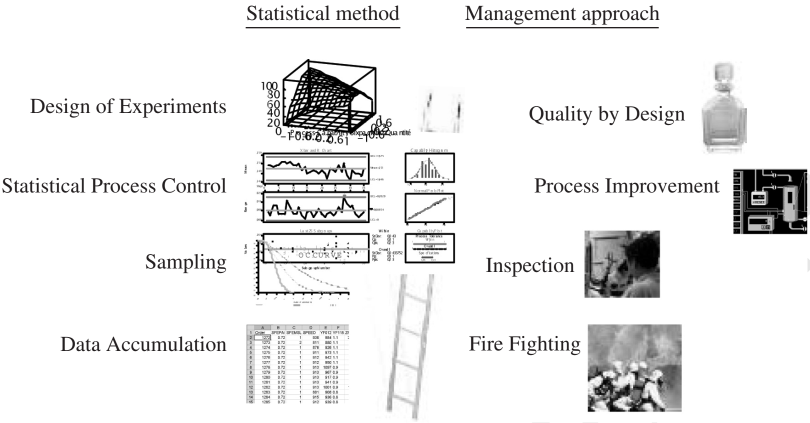

Figure 4.1 The quality ladder.

4.2 Improvement projects

Since the 1960s, many organizations have tackled the improvement of quality by means of focused improvement projects. A project-by-project improvement strategy relies on successful employee participation in project identification, analysis and implementation. Many factors influence a project's success; these are often overlooked and, in many cases, may be unknown. A project-by-project quality improvement programme must be supported by quality principles, analysis techniques, effective leaders and facilitators, and extensive training. While quality improvement teams can vary in size (even during the duration of the project), a typical team size is five to seven (Juran, 1986, 1989; Aubrey and Felkins, 1988; Godfrey and Kenett, 2006).

The proper selection and formulation of a problem is critical for effective quality improvement. The link between problem/project selection and team member selection must be direct and relevant. The regular management team, a quality council, or the team itself can select the problem or project.

While the end result of a quality improvement project remains the primary concern from a management perspective, time is critical for the success of quality improvement teams. The typical time for project completion is 3–5 months, which is about 32 person-hours per team member (2 hours per week for 16 weeks).

Team factors are critical to success. Managers should be involved in the project selection process and the outcome of the project. The team size and the length of the project are both important in ensuring that group dynamics and motivation are effectively employed. A structured improvement plan is essential, including a list of steps to be followed, with clear definitions, milestones and the tools to be used, many of them statistical.

Typical areas of improvement include defect reduction, performance to standard, cost reduction and customer satisfaction improvement. Some teams develop quality measures by using basic flowcharting, work simplification, and data collection tools. Teams should be able to compare data collected before and after they have solved the problem and implemented their solution. This enables teams to track improvements and demonstrate the return on investment of the improvement project.

Surveys are effective in tracking customer satisfaction before and after project solution implementation. With surveys, teams can assess the impact of improvements using customer satisfaction ratings. For more information on customer surveys, see Kenett (2006).

4.3 Six sigma

The Six Sigma business improvement strategy was introduced by Motorola in the 1980s and adopted successfully by General Electric and other large corporations in the 1990s. The key focus of all Six Sigma programmes is to optimize overall business results by balancing cost, quality, features and availability considerations for products and their production in a best business strategy. Six Sigma programmes combine the application of statistical and non-statistical methods to achieve overall business improvements. In that sense, Six Sigma is a more strategic and more aggressive initiative than simple improvement projects. Effective Six Sigma projects are orchestrated at the executive level and consist of a *define–measure–analyse–improve–control* (DMAIC) roadmap. Moreover, executives support Six Sigma as a business strategy when there are demonstrated bottom-line benefits.

The term *measure* to describe a phase in the Six Sigma DMAIC strategy can be misleading. Within Six Sigma training, the measure phase encompasses more than just measurements. It typically includes the tracking of key process output variables (KPOVs) over time, quantifying the process capability of these variables, gaining insight into improvement opportunities through the application of cause-and-effect diagrams and failure mode and effects analysis, and quantifying the effectiveness of current measurement systems. These activities help define how a KPOV is performing, and how it could relate to its primary upstream causes, the key process input variables (KPIVs). The measure step is repeated at the successive business, operations and process levels of the organization, measuring baseline information for KPOVs in order to provide an accurate picture of the overall variation that the customer sees. Measurements provide estimates of the process capability relative to specifications and drive investigations of all significant sources of variation (including measurement system analyses). This information is then used throughout the *analyse, improve* and *control* phases to help make overall business improvements.

Several unique Six Sigma metrics, such as sigma quality level, yield and cost of poor quality (COPQ), have been developed to help quantify and reduce the *hidden factory* (hidden production costs). Six Sigma relies heavily on the ability to access information. When the most important information is hard to find, access or understand, the result is extra effort that increases both the hidden factory and the COPQ (Juran, 1989).

Many organizations set a dollar threshold as they begin to prioritize Six Sigma projects. Successful projects thereby provide returns that will pay for up-front investments in Six Sigma training and full-time Black Belt team leaders. The definition of what types of savings are considered (hard or soft) is also critical and drives specific behaviours to enable low hanging fruit to be identified first. In many organizations, soft or indirect benefits fall into categories such as cost avoidance related to regulatory or legal compliance or benefits related to improving employee morale or efficiency. Such benefits cannot be directly tied to operating margins or incremental revenues through a specific measurement. For more information on Six Sigma, see Chapter 2 of this book.

4.4 Practical statistical efficiency

Fisher (1922) states that 'the object of statistical method is the reduction of data'. He then identifies 'three problems which arise in the reduction of data'. These are:

- *specification* – choosing the right mathematical model for a population;
- *estimation* – methods to calculate, from a sample, estimates of the parameters of the hypothetical population;
- *distribution* – properties of statistics derived from samples.

Later, Mallows (1998) added a 'zeroth problem' – considering the relevance of the observed data, and other data that might be observed, to the substantive problem.

Building on a suggestion by Godfrey (1988, 1989), Kenett *et al.* (2003) define *practical statistical efficiency* (PSE) using an eight-term formula and demonstrated its applicability using five case studies. PSE is an important addition to the statistical consultancy toolkit; it enhances the ability of practising statisticians to show the extent of their contribution to the resolution of real-life problems. The original reason for introducing PSE was the pervasive observation that the application of statistical methods is, in many cases, an exercise in using statistical tools rather than a focused contribution to specific problems. PSE is calculated by a multiplication formula:

$$PSE = V\{D\} \times V\{M\} \times V\{P\} \times V\{PS\} \times P\{S\} \times P\{I\} \times T\{I\} \times E\{R\}$$

where $V\{D\}$ is the value of the data actually collected, $V\{M\}$ the value of the statistical method employed, $V\{P\}$ the value of the problem to be solved, $V\{PS\}$ the value of the problem actually solved, $P\{S\}$ the probability level that the problem actually gets solved, $P\{I\}$ the probability level that the solution is actually implemented, $T\{I\}$ the time the solution stays implemented, and $E\{R\}$ the expected number of replications.

A straightforward approach to evaluating PSE is to use a scale from 1 for 'not very good' to 5 for 'excellent'. This method of scoring can be applied uniformly for each PSE component. Some of the PSE components can be also assessed quantitatively: $P\{S\}$ and $P\{I\}$ are probability levels, $T\{I\}$ can be measured in months, and $V\{P\}$ and $V\{PS\}$ can be evaluated in monetary terms. $V\{PS\}$ is the value of the problem actually solved, as a fraction of the problem to be solved. If this is evaluated qualitatively, a large portion would be scored 4 or 5, a small portion 1 or 2.$V\{D\}$, the value of the data actually collected, is related to Fisher's zeroth problem presented in Mallows (1998). Whether PSE terms are evaluated quantitatively or qualitatively, PSE is a conceptual measure rather than a numerically precise one. A more elaborate approach to PSE evaluation can include differential weighing of the PSE components and/or non-linear assessments. In the next section we describe a maturity ladder that maps the management approach with statistical techniques. The idea is that proper mapping of the two is critical for achieving high PSE.

As organizations move up the quality ladder, more useful data is collected, more significant projects get solved, and solutions developed locally are replicated throughout the organization. We therefore postulate that increasing an organization's maturity by going up the quality ladder results in higher PSEs and increased benefits. Let L denote the organizational level of management maturity on the quality ladder, where $L = 1$ stands for fire fighting, $L = 2$ inspection, $L = 3$ process improvement, and $L = 4$ quality by design. Let PSE be the practical statistical efficiency of a specific project, such that $1 \leq PSE \leq 5^8$, and $E\{PSE\}$ be the expected value of PSE over all projects. Our goal in this chapter, and related work, is to prove the following *statistical efficiency conjecture* on PSE improvement, which links expected practical statistical efficiency with the maturity of an organization on the quality ladder.

Conjecture. Conditioned on the right variable, $E\{PSE\}$ is an increasing function of L.

Possible conditioning variables include company size, business area, ownership structure and market types. In the next section we provide a set of case studies to demonstrate this conjecture empirically.

4.5 Case studies

The 21 case studies described in the appendix to this chapter are taken from a mix of companies at different maturity levels on the quality ladder. The PSE was evaluated for each case study. Figure 4.2 plots PSE values against maturity level. Interestingly, the PSE scores do not seem to strongly reflect the maturity level of the company. The implication is that the PSE is affected by several variables, not just maturity level.

We stratify the data by company size and type of activity to explain the variability of PSE. As can be seen in Figure 4.3, PSE tends to increase with company size and, from Figure 4.4, companies with international activity tend to have higher PSE.

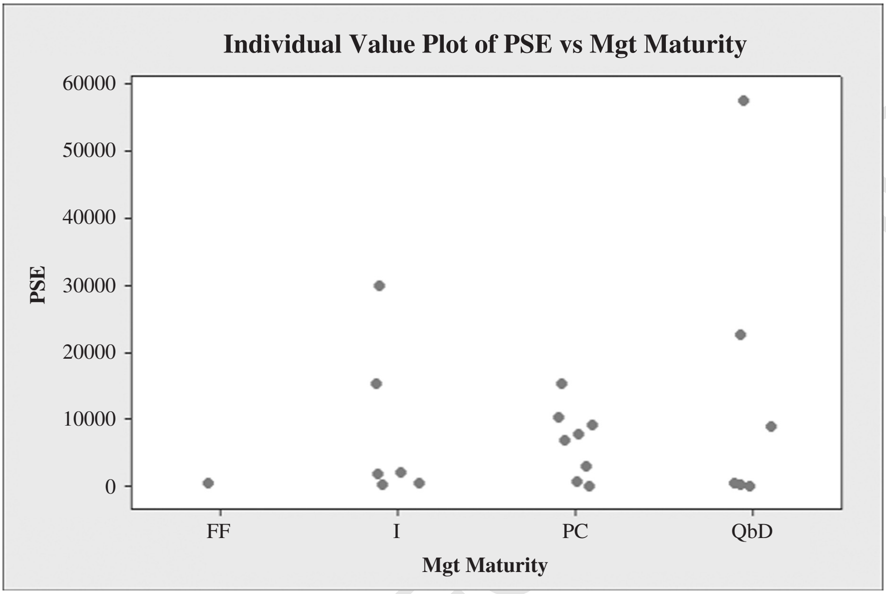

Figure 4.2 PSE versus maturity level (FF = fire fighting, I = inspection, P = process control, QbD = quality by design).

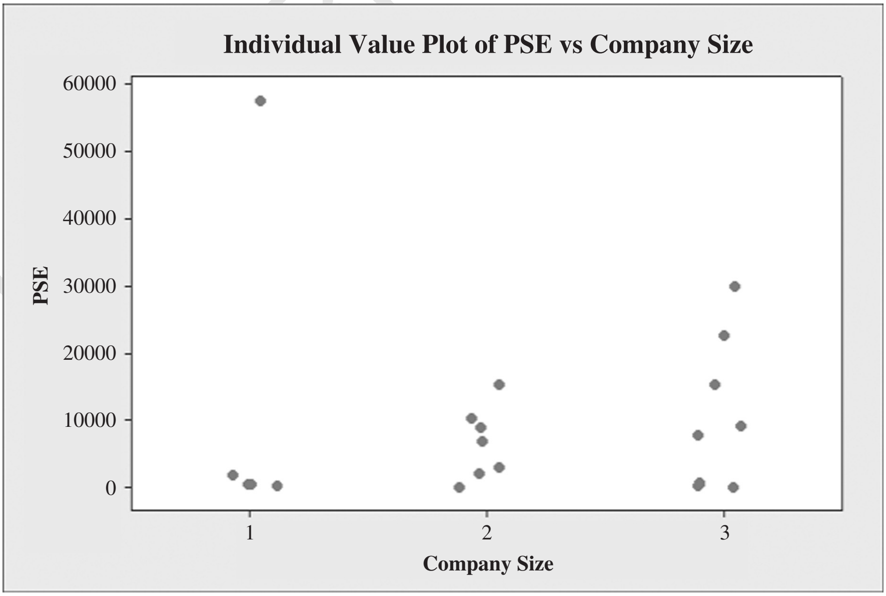

Figure 4.3 PSE by company size (1 = SME, 2 = large, 3 = very large).

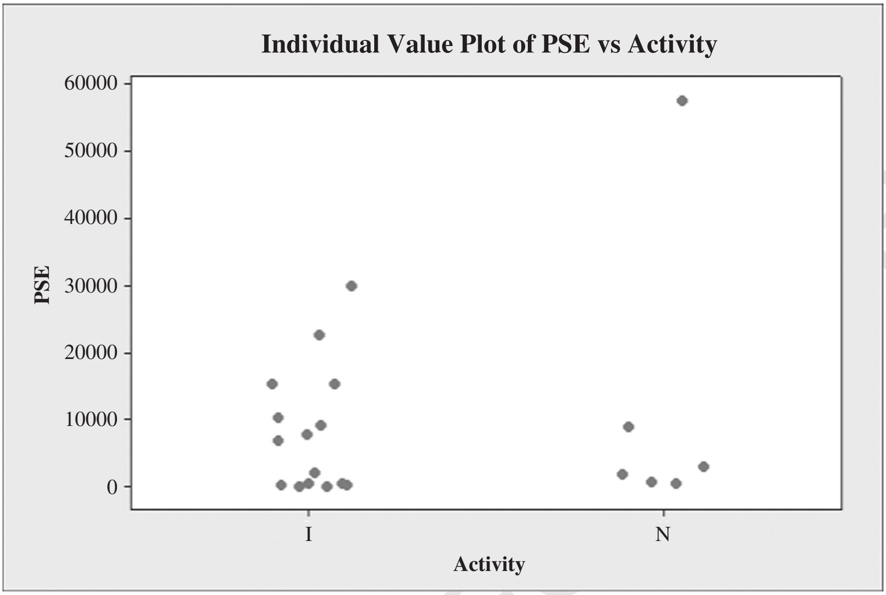

Figure 4.4 PSE by type of activity (I = international, N = national).

An application of Bayesian networks to this data set contributes some additional insights. Figure 4.5 presents a learned network generated using the Greedy Thick Thinning algorithm implemented in the GeNIe version 2.0 software (http://genie.sis.pitt.edu). It shows that maturity level is affected by the type (production, service, . . .) and scope of activity (international versus national). It also shows that PSE is mainly affected by maturity. Relationships between the individual PSE components are also displayed. For example, we can see that the value of the statistical method is affected by the value of the data and the probability that the problem gets actually solved.

Figure 4.6 shows the fitted data conditioned on a company being located at the highest maturity level: 33 % have the very low PSE, 17 % very high PSE. In contrast, Figure 4.7 shows companies at the inspection maturity level: 42 % have very low PSE and 8 % very high PSE. These are only initial indications of such possible relationships and more data, under better control, needs to be collected to validate such patterns.

A repeatability analysis confirmed that the PSE evaluation is robust, possibly due to the use of the five-point scale. Expansion of this scale would increase the measurement error. An issue that arises from the analysis is that of the weights given to the different variables. Are they really equivalent regarding their impact on PSE? A better PSE measure is perhaps a combination of additive and multiplicative contributors. Also, conditioning the PSE on covariates, such as company size, might improve the picture. The point is that, even with our very rough maturity assessment and qualitative PSE, the right conditioning variable is unknown.

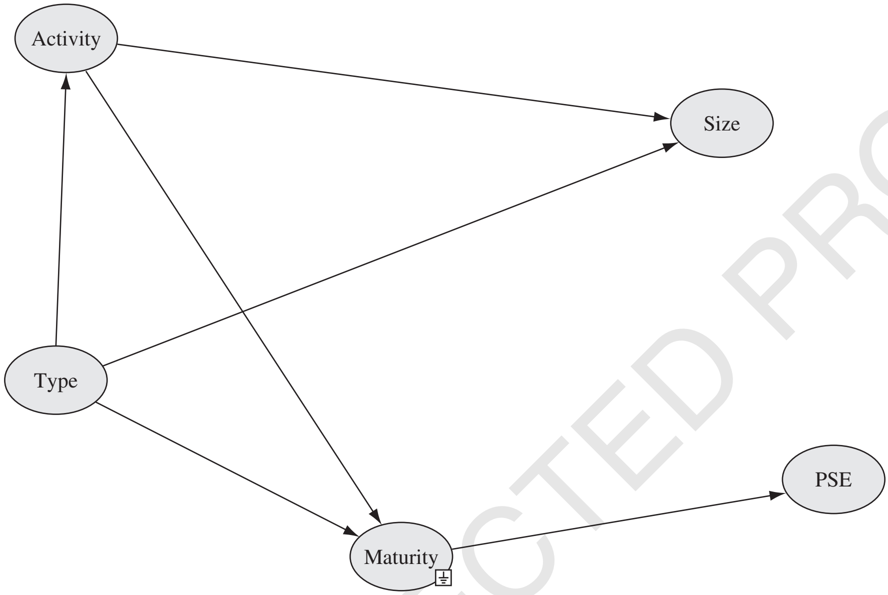

Figure 4.5 Bayesian network of PSE data.

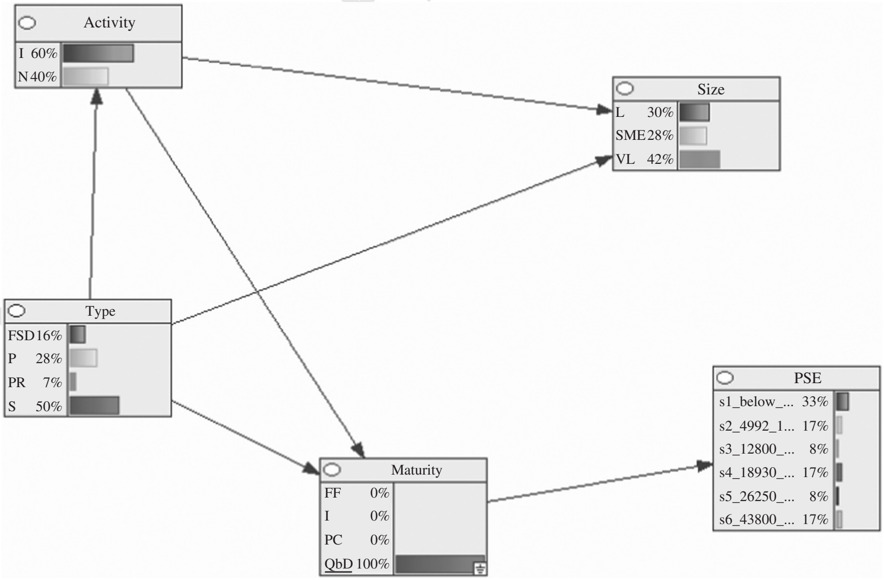

Figure 4.6 Bayesian network of PSE data with values for QbD maturity level.

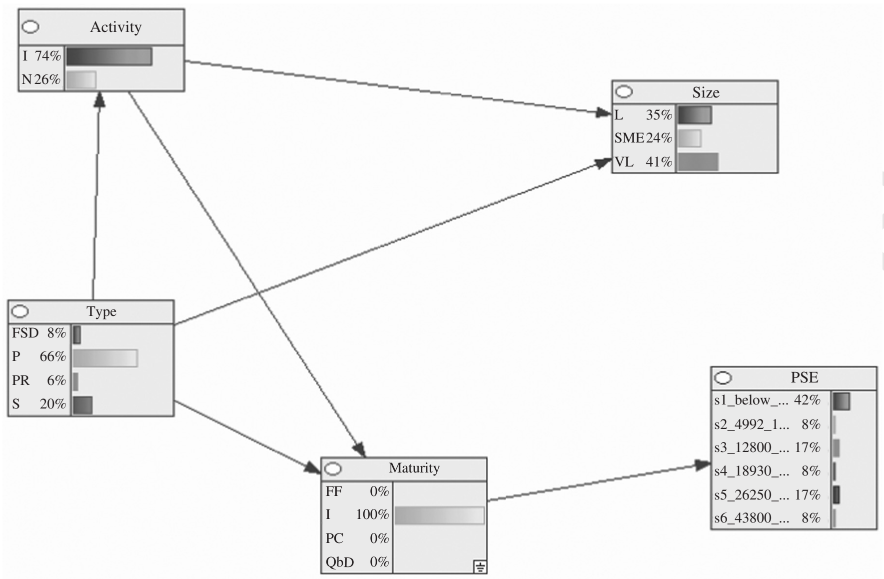

Figure 4.7 Bayesian network of PSE data with values for inspection maturity level.

Our case studies are all from companies in Europe and Israel and represent varied cultural clusters. We should remark that QbD and robust experiments were first introduced in Japan in the 1950s using Western design of experiments (DoE) technology. In fact, Genichi Taguchi, who introduced concepts of robust design, visited Bell laboratories in 1981 to teach these techniques as a way to return an intellectual debt. The first author attended these seminars at Holmdel where Madhav Phadke, who was hosting Taguchi, followed up Taguchi's presentations with discussions looking for opportunities to conduct demonstration experiments to better understand the potential of robust designs. At the time, Taguchi's QbD ideas and process improvement in general were difficult to grasp in the West. In contrast, Japanese organizations have had Ishikawa's seven quality tools well established in the workplace since the early 1950s (Godfrey and Kenett, 2007). The comprehensive nature of the PSE tool highlights the potential gains a company can achieve from thorough implementation of improvement projects. If a problem is not viewed within an overall context of improvement, then a company will waste money when the problem reoccurs. The PSE measure identifies if work is needed to solve a particular problem and indicates numerically the extent of the problem-solving effort.

4.6 Conclusions

This chapter is a first attempt to show how going up the quality ladder, from process improvement to QbD, can increase practical statistical efficiency. Our study of 21 case studies demonstrates how such an investigation can be carried out. Obviously more data is needed to prove or disprove the conjecture summarized in Table 4.1. If we disprove the conjecture we should have to expand the PSE formula by including some factors not currently considered. Such a research effort would help statisticians properly evaluate the impact of their work and demonstrate to others the added value they bring to their customers. The idea is to link PSE evaluations with the maturity level of organization on the quality ladder. If the conjecture linking the two holds, statisticians interested in achieving a high impact on organizations will also have to become proactive in getting organizations to go up the quality ladder – thus also becoming 'management consultants'. In reviewing the careers of W. Edwards Deming, J.M. Juran. Brian Joiner and others, we can see this common denominator (see Joiner, 1985, 1994; Deming, 1986; Juran, 1986, 1989; Godfrey and Kenett, 2007; Kenett and Thyregod, 2006). They all began as statisticians, with significant contributions to statistical methodology, and developed into world-class management consultants.

Table 4.1 Characteristics of the quality ladder maturity levels.

Quality ladder	Fire fighting	Inspection	Process control	Quality by design
Statistical tool	None	Sampling	Statistical CS	DoE
Time	Short	Short	Medium	Long
Action	Correction	Correction	Correction Prevention	Prevention
Benefits	Very low	Low	High	Very high
Customer satisfaction	Very low	Low	High	Very high
Organization maturity	Very low	Low	High	Very high
PSE measure	Very low	Low	High	Very high

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Appendix 4A

Case 1 (with instructions)

Problem name: Missile Storage Failure Data

Date of project: 1977 Reporter: C. McCollin
I (International)
S (Service)
VL (Very large company size)
QbD (Very high management maturity)

Scope of activity (S): International, national
Type of business (T): Prototype, full-scale development, production, service
Company size (CS): SME, large, very large
Management maturity (MM): Fire fighting, inspection, process improvement, QbD

Problem description:
Shipborne missiles kept in storage on a land facility tested periodically for operational status.

Context:
Data collected to monitor dormant failure rates

Data collected:
Number of failures N, time of operation during test t_1, time of non-operation t_2

Data analysis:
Standard regression using mainframe computer package: $N = \lambda_1 t_1 + \lambda_2 t_2$

Conclusions and recommendations:
Negative failure rates!! That more work was required on improving software routines or upgrading software (if possible).

Impact:
Critical analysis of available off-the-shelf software for in-company analysis.
The number that reflects the evaluation of the PSE criteria on a scale from 1 to 5 is underlined.

5 – Very high value
4 – High value
3 – Average value
2 – Low value
1 – Very low value

		Value				Level
	Criteria	−				+
1	***V*{*D*}** = value of the data actually collected	1	2	3	$\underline{4}$	5
2	***V*{*M*}** = value of the statistical method employed	1	$\underline{2}$	3	4	5
3	***V*{*P*}** = value of the problem to be solved	1	2	$\underline{3}$	4	5
4	***V*{*PS*}** = value of the problem actually solved	$\underline{1}$	2	3	4	5
5	***P*{*S*}** = probability that the problem actually gets solved	$\underline{1}$	2	3	4	5
6	***P*{*I*}** = probability the solution is actually implemented	$\underline{1}$	2	3	4	5
7	***T*{*I*}** = time the solution stays implemented	$\underline{1}$	2	3	4	5
8	***E*{*R*}** = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 24$

Case 2

Problem name: Electricity Generation Company Valve Failure Data

Date: 1983 Reporter: C. McCollin
N (National)
S (Service)
VL (Very large company size)
PI (Medium management maturity)

Problem description:
Analysis of valve failure data for a complete generating facility for reliability calculations

Context:
Data collected for monitoring possible plant safety shutdown issues

Data collected:
Type of valve, time to failure

Data analysis:
Weibull process estimates

Conclusions and recommendations:
Reliability of many valves was decaying and working valves were being maintained although they had not failed (possibly leading to the reliability decay). Available maintenance procedures were based on Weibull distribution analysis software (hence maintenance intervals based on incorrect statistical assumption (independent and identical distribution)).
Set of procedures written on how to analyse repairable systems data including searching for trend, seasonality.

Impact: None.

		Value				Level
	Criteria	−				+
1	$V\{D\}$ = value of the data actually collected	1	2	3	[✓ 4]	5
2	$V\{M\}$ = value of the statistical method employed	1	2	3	[✓ 4]	5
3	$V\{P\}$ = value of the problem to be solved	1	2	3	[✓ 4]	5
4	$V\{PS\}$ = value of the problem actually solved	1	[✓ 2]	3	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	[✓ 1]	2	3	4	5
6	$P\{I\}$ = probability the solution is actually implemented	[✓ 1]	2	3	4	5
7	$T\{I\}$ = time the solution stays implemented	[✓ 1]	2	3	4	5
8	$E\{R\}$ = expected number of replications	1	2	3	4	[✓ 5]

$PSE = 640$

Case 3

Problem name: Military System Reliability Prediction

Date: 1985 Reporter: C. McCollin
I (International)

S (Service)
VL (Very large company size)
QbD (High management maturity)

Problem description:
Provide mean time between failure (MTBF) estimates to customer as part of contract

Context:
Customer requirement for data to be provided for life cycle cost estimates

Data collected:
Calendar time to failure, duty cycle, number of relevant failures

Data analysis:
MTBF calculation

Conclusions and recommendations:
Information forwarded to customer to use for spares provisioning.

Impact:
Spares provisioning.

	Criteria	Value −				Level +
1	***V*{*D*}** = value of the data actually collected	1	2	$\underline{3}$	4	5
2	***V*{*M*}** = value of the statistical method employed	1	$\underline{2}$	3	4	5
3	***V*{*P*}** = value of the problem to be solved	1	2	3	4	$\underline{5}$
4	***V*{*PS*}** = value of the problem actually solved	1	2	3	4	$\underline{5}$
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6	***P*{*I*}** = probability the solution is actually implemented	1	2	3	4	$\underline{5}$
7	***T*{*I*}** = time the solution stays implemented	1	2	$\underline{3}$	4	5
8	***E*{*R*}** = expected number of replications	1	$\underline{2}$	3	4	5

$PSE = 22\,500$

Case 4

Problem name: Military System Failure Analysis

Date: 1985 Reporter: C. McCollin
I (International)
S (Service)

VL (Very large company size)
QbyD (High management maturity)

Problem description:
Customer declares system is unreliable based on in-service field data. Requires some action to be taken.

Context:
Customer upset

Data collected:
About 50 failure reports

Data analysis:
Classification of reports into how many systems failed (2!!), types of failure (mainly corrosion, rust) – led to conclusion that these two systems had been dropped in the sea, picked up at a later date and then investigated for failures.

Conclusions and recommendations:
Specification and testing tender costs forwarded to customer for next-update systems if they are required to work after being in such an environment. No response from customer.

Impact:
Customer did not criticize system again.

	Criteria	Value −			Level	 +
1	$V\{D\}$ = value of the data actually collected	1	2	3	4	$\underline{5}$
2	$V\{M\}$ = value of the statistical method employed	$\underline{1}$	2	3	4	5
3	$V\{P\}$ = value of the problem to be solved	1	2	3	$\underline{4}$	5
4	$V\{PS\}$ = value of the problem actually solved	1	2	3	4	$\underline{5}$
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	4	$\underline{5}$
6	$P\{I\}$ = probability the solution is actually implemented	$\underline{1}$	2	3	4	5
7	$T\{I\}$ = time the solution stays implemented	$\underline{1}$	2	3	4	5
8	$E\{R\}$ = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 500$

Case 5

Problem name: Military System Warranty Analysis

Date: 1985 Reporter: C. McCollin

I (International)
P (Production type)
VL (Very large company size)
Inspection (Low management maturity)

Problem description:
Customer queries why delivered systems are all failing within the warranty period. No future contracts with this customer's country or near neighbours until problem resolved.

Context:
Country could not fly their military aircraft.

Data collected:
About 80 warranty reports

Data analysis:
Classification of failures into whether they were design, manufacturing, testing, systematic or one-off failures (one-off failures may be used for MTBF calculations).

Conclusions and recommendations:
Only one one-off failure classified, hence MTBF was good enough for system if design, manufacturing and test had been satisfactory. Production manager carpeted, project manager sidelined, design engineer who helped reporter analyse the design failures promoted. Ban lifted by countries.

Impact:
New procedures on systems management for project leaders.

	Criteria	Value −				Level +
1	$V\{D\}$ = value of the data actually collected	1	2	$\underline{3}$	4	5
2	$V\{M\}$ = value of the statistical method employed	$\underline{1}$	2	3	4	5
3	$V\{P\}$ = value of the problem to be solved	1	2	3	4	$\underline{5}$
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5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	4	$\underline{5}$
6	$P\{I\}$ = probability the solution is actually implemented	1	2	3	4	$\underline{5}$
7	$T\{I\}$ = time the solution stays implemented	1	2	3	$\underline{4}$	5
8	$E\{R\}$ = expected number of replications	1	2	3	$\underline{4}$	5

$PSE = 30\,000$

Case 6

Problem name: Commercial Software Failure Analysis

Date: 1991 Reporter: C. McCollin
I (International)
FSD (Full-scale development type)
SME (SME size)
QbD (High management maturity)

Problem description:
Analysis of a very large data set (100 000 records), search for structure including change points. Why are there failures after delivery?

Context:
Data arose from major software producer as part of the Alvey Software Reliability Modelling project.

Data collected:
Date of failure, number of faults per failure per source code per product version, number of repairs per failure per source code per product version, in-house/in service, programmer

Data analysis:
Sorting and ordering routines written to identify missing or corrupt data, exploratory data analysis, time series (ARIMA), proportional hazards modelling, proportional odds modeling, logistic regression, discriminant analysis, principal components analysis, hazard estimation, proportional intensity modelling

Conclusions and recommendations:
Main findings were that number of failures was dependent on the day of the week, statistical structure is a function of development effort (no effort = random structure, effort = reliability growth).

Impact:
Programmers carpeted by project manager for not working to contract. Data could not answer why there are failures after delivery.

	Criteria	Value −				Level +
1	$V\{D\}$ = value of the data actually collected	1	2	3	4	[✓ 5]
2	$V\{M\}$ = value of the statistical method employed	1	2	3	[✓ 4]	5
3	$V\{P\}$ = value of the problem to be solved	[✓ 1]	2	3	4	5

4	***V*{*PS*}** = value of the problem actually solved	1	[✓ 2]	3	4	5
5	***P*{*S*}** = probability that the problem actually gets solved	[✓ 1]	2	3	4	5
6	***P*{*I*}** = probability the solution is actually implemented	[✓ 1]	2	3	4	5
7	***T*{*I*}** = time the solution stays implemented	[✓ 1]	2	3	4	5
8	***E*{*R*}** = expected number of replications	1	2	3	4	[✓ 5]

$PSE = 200$

Case 7

Problem name: Availability Analysis

Date: 1995 Reporter: C. McCollin
N (National)
PR (Prototype type)
SME (SME size)
FF (Lowest management maturity)

Problem description:
Carry out an availability analysis to show customer that requirement was being met

Context:
Small company did not know how to meet customer requirement.

Data collected:
Date of delivery, number and types of failures

Data analysis:
Availability analysis

Conclusions and recommendations:
Requirement were met with a possible saving of not manufacturing unrequired units.

Impact:
None. Company carried on developing original solution at extra costs

	Criteria	Value −				Level +
1	***V*{*D*}** = value of the data actually collected	1	2	3	[✓ 4]	5
2	***V*{*M*}** = value of the statistical method employed	1	2	3	[✓ 4]	5
3	***V*{*P*}** = value of the problem to be solved	1	[✓ 2]	3	4	5

4	$V\{PS\}$ = value of the problem actually solved	1	2	3	4	[✓ 5]
5	$P\{S\}$ = probability that the problem actually gets solved	[✓ 1]	2	3	4	5
6	$P\{I\}$ = probability the solution is actually implemented	[✓ 1]	2	3	4	5
7	$T\{I\}$ = time the solution stays implemented	[✓ 1]	2	3	4	5
8	$E\{R\}$ = expected number of replications	1	2	[✓ 3]	4	5

$PSE = 480$

Case 8

Problem name: Commercial switch reliability analysis

Date: 1994 Reporter: C. McCollin
I (International)
P (Production type)
SME (SME size)
Inspection (Low management maturity)

Problem description:
Carry out exploratory reliability analysis on switch life data

Context:
Data made available by company for analysis. Previous Weibull analyses made available.

Data collected:
Operating time to failure, initializing current on delivery, electrical specification documents

Data analysis:
Proportional hazards modelling

Conclusions and recommendations:
Time to failure was found to be dependent on initializing current. Recommendation by author to company to determine why variable was significant (would require failure mode and effects analysis and DoE).

Impact:
None. Company carried on using available techniques. No requirement by standards or customers to avert this problem.

			Value		Level	
	Criteria	−			+	
1	$V\{D\}$ = value of the data actually collected	1	2	3	$\underline{4}$	5
2	$V\{M\}$ = value of the statistical method employed	1	2	3	$\underline{4}$	5
3	$V\{P\}$ = value of the problem to be solved	1	2	3	4	$\underline{5}$
4	$V\{PS\}$ = value of the problem actually solved	1	$\underline{2}$	3	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	$\underline{1}$	2	3	4	5
6	$P\{I\}$ = probability the solution is actually implemented	$\underline{1}$	2	3	4	5
7	$T\{I\}$ = time the solution stays implemented	$\underline{1}$	2	3	4	5
8	$E\{R\}$ = expected number of replications	1	2	$\underline{3}$	4	5

$PSE = 480$

Case 9

Problem name: Electrical cut-off protection switch test data analysis

Date: 1998 Reporter: C. McCollin
I (International)
P (Production type)
VL (Very large company size)
Inspection (Low management maturity)

Problem description:
Carry out exploratory reliability analysis on electrical switch test data

Context:
Teaching company course on reliability techniques

Data collected:
Operating time to failure, stress level, batch number, number of failures

Data analysis:
Proportional hazards modeling, Weibull analysis

Conclusions and recommendations:
First 50 hours of test under normal stress was having no effect on the time to failure of the unit.

Impact:
None. Company did not want to approach customer with change to test conditions for fear of losing contract. If implemented, cost savings of thousands of pounds.

	Criteria	Value			Level	
		−			+	
1	$\boldsymbol{V}\{\boldsymbol{D}\}$ = value of the data actually collected	1	2	3	$\underline{4}$	5
2	$\boldsymbol{V}\{\boldsymbol{M}\}$ = value of the statistical method employed	1	2	$\underline{3}$	4	5
3	$\boldsymbol{V}\{\boldsymbol{P}\}$ = value of the problem to be solved	$\underline{1}$	2	3	4	5
4	$\boldsymbol{V}\{\boldsymbol{PS}\}$ = value of the problem actually solved	1	2	3	$\underline{4}$	5
5	$\boldsymbol{P}\{\boldsymbol{S}\}$ = probability that the problem actually gets solved	$\underline{1}$	2	3	4	5
6	$\boldsymbol{P}\{\boldsymbol{I}\}$ = probability the solution is actually implemented	$\underline{1}$	2	3	4	5
7	$\boldsymbol{T}\{\boldsymbol{I}\}$ = time the solution stays implemented	$\underline{1}$	2	3	4	5
8	$\boldsymbol{E}\{\boldsymbol{R}\}$ = expected number of replications	1	2	3	$\underline{4}$	5

$PSE = 192$

Case 10

Problem name: Reduce number of defects in a car assembly chain

Date: 1993 Reporter: A. De Frenne
I (international)
P (Production type)
VL (Very large company size)
Process improvement (High management maturity)

Problem description:
Reduce the number of defects on the car assembly chain

Context:
SPC was implemented in the company without or with very light worker training. Method was misused.

Data collected:
Check sheets, control charts on one month at different stages

Data analysis:
Control chart limits, cause and effect diagram

Conclusions and recommendations:
The quality improvement of one assembly stage was measured by the next assembly stage (client). Better communication between them reduced number of defects by 40 %.

Impact:
Reduction of defects due to a careful follow-up with control chart

		Value				Level
	Criteria	−				+
1	$V\{D\}$ = value of the data actually collected	1	2	[✓ 3]	4	5
2	$V\{M\}$ = value of the statistical method employed	1	2	[✓ 3]	4	5
3	$V\{P\}$ = value of the problem to be solved	1	2	[✓ 3]	4	5
4	$V\{PS\}$ = value of the problem actually solved	1	2	[✓ 3]	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	[✓ 4]	5
6	$P\{I\}$ = probability the solution is actually implemented	1	2	3	[✓ 4]	5
7	$T\{I\}$ = time the solution stays implemented	1	[✓ 2]	3	4	5
8	$E\{R\}$ = expected number of replications	1	2	[✓ 3]	4	5

$PSE = 7776$

Case 11

Problem name: Production start-up of new product

Date: 1997 Reporter: A. De Frenne
I (International)
P (Prototype type)
VL (Very large company size)
Process improvement (High management maturity)

Problem description:
Tune the production equipment to produce within legal specifications

Context:
Weight and pressure of a prototype aerosol were out of control. It has to be fixed within legal limits.

Data collected:
Weight and pressure measurements for one week's production.

Data analysis:
Control chart and histogram

Conclusions and recommendations:
The tuning of the equipment was not fine enough. Each modification of production setting introduced too much or not enough product, rarely at target value. Better training of worker on machine tuning solved the problem.

Impact:
Product better on target and within specification limits.

		Value				Level
	Criteria	−				+
1	$\boldsymbol{V\{D\}}$ = value of the data actually collected	1	2	3	[✓ 4]	5
2	$\boldsymbol{V\{M\}}$ = value of the statistical method employed	1	2	[✓ 3]	4	5
3	$\boldsymbol{V\{P\}}$ = value of the problem to be solved	1	2	3	[✓ 4]	5
4	$\boldsymbol{V\{PS\}}$ = value of the problem actually solved	1	2	3	[✓ 4]	5
5	$\boldsymbol{P\{S\}}$ = probability that the problem actually gets solved	1	2	3	[✓ 4]	5
6	$\boldsymbol{P\{I\}}$ = probability the solution is actually implemented	1	2	3	[✓ 4]	5
7	$\boldsymbol{T\{I\}}$ = time the solution stays implemented	1	2	[✓ 3]	4	5
8	$\boldsymbol{E\{R\}}$ = expected number of replications	[✓ 1]	2	3	4	5

$PSE = 9216$

Case 12

Problem name: Defect reduction in precision smelting

Date: 2000 Reporter: A. De Frenne
I (International)
P (Production type)
L (Large company size)
Inspection (Low management maturity)

Problem description:
Headquarters asked to use DoE to reduce the percentage of defects in precision smelting pieces

Context:
60 % of production was defective for some specific pieces

Data collected:
History of production for 3 years

Data analysis:
Cause and effect diagram, identification of key characteristics at each step of the process, DoE

Conclusions and recommendations:
DoE identified the significant key characteristics of the process. The optimal combination was completely reversed from the current settings. Simulation programs confirmed the optimal result.

Impact:
Defect reduction from 60 % to 19 %.

		Value			Level	
	Criteria	−				+
1	***V*{*D*}** = value of the data actually collected	1	2	$\underline{3}$	4	5
2	***V*{*M*}** = value of the statistical method employed	1	2	3	$\underline{4}$	5
3	***V*{*P*}** = value of the problem to be solved	1	2	3	$\underline{4}$	5
4	***V*{*PS*}** = value of the problem actually solved	1	2	3	$\underline{4}$	5
5	***P*{*S*}** = probability that the problem actually gets solved	1	2	3	$\underline{4}$	5
6	***P*{*I*}** = probability the solution is actually implemented	1	2	3	$\underline{4}$	5
7	***T*{*I*}** = time the solution stays implemented	1	2	3	4	$\underline{5}$
8	***E*{*R*}** = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 15\,360$

Case 13

Problem name: Peeling of coating on aircraft wing

Date: 2002 Reporter: A. De Frenne
N (National)
P (Production type)
L (Large company size)
QbD (Very high management maturity)

Problem description:
Coating of aircraft piece of wings was peeling without reproducibility. Understand the source of the trouble.

Context:
About 30 % of pieces were peeling and for scrap.

Data collected:
History of production conditions for 5 runs.

Data analysis:
Cause-and-effect diagram, identification of key characteristics, DoE

Conclusions and recommendations:
None of the parameters from the DoE was found significant. However, well-controlled DoE allowed identification of the key characteristic due to the logic of the production organization. Problem was fixed.

Impact:
Defect reduction from 30 % to 0 %

		Value			Level	
	Criteria	−				+
1	$V\{D\}$ = value of the data actually collected	1	$\underline{2}$	3	4	5
2	$V\{M\}$ = value of the statistical method employed	1	2	3	$\underline{4}$	5
3	$V\{P\}$ = value of the problem to be solved	1	2	$\underline{3}$	4	5
4	$V\{PS\}$ = value of the problem actually solved	1	2	$\underline{3}$	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	4	$\underline{5}$
6	$P\{I\}$ = probability the solution is actually implemented	1	2	3	4	$\underline{5}$
7	$T\{I\}$ = time the solution stays implemented	1	2	3	4	$\underline{5}$
8	$E\{R\}$ = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 9000$

Case 14

Problem name: Production improvement in catalytic converter substratum

Date: 2002 Reporter: A. De Frenne
I (International)
P (Production type)
L (Large company size)
Process control (High management maturity)

Problem description:
The final product should be circular. Identify sources of improvement when product is fresh before cooking in the oven.

Context:
Product size changes dramatically during cooking in the oven. Very tight specifications are imposed on production of fresh product.

Data collected:
History of product measurements by laser for 1 month

Data analysis:
Control chart of product dimensions

Conclusions and recommendations:
Control charts show no potential improvement at the fresh product production. Improvement could be realized up-front on raw material and with better control of the oven.

Impact:
Production changes to be implemented but were not accepted by management.

	Criteria	Value −				Level +
1	$V\{D\}$ = value of the data actually collected	1	2	3	[✓ 4]	5
2	$V\{M\}$ = value of the statistical method employed	1	2	[✓ 3]	4	5
3	$V\{P\}$ = value of the problem to be solved	1	2	[✓ 3]	4	5
4	$V\{PS\}$ = value of the problem actually solved	[✓ 1]	2	3	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	[✓ 1]	2	3	4	5
6	$P\{I\}$ = probability the solution is actually implemented	[✓ 1]	2	3	4	5
7	$T\{I\}$ = time the solution stays implemented	[✓ 1]	2	3	4	5
8	$E\{R\}$ = expected number of replications	[✓ 1]	2	3	4	5

$PSE = 36$

Case 15

Problem name: Reduce porosity in Aluminium injection process for making wheels

Date: 1990 Reporter: X. Tort-Martorell
I (International)
P (Production type)
L (Large company size)
Process improvement (High management maturity)

Problem description:
Reduce porosity and possibly other types of defects (mainly adhered material and filling problems) in car aluminium wheels produced by a gravity injection process

Context:
The company asked for outside help in using DoE to improve the process. Outside help included training in DoE of several plant engineers and using the case as a learning-by-doing experience.

Data collected:
A 2^5 design with three responses, followed by a 2^3 design and several confirmatory experiments

Data analysis:
Calculation and interpretation of effects, interaction plots

Conclusions and recommendations:
Three factors were found important (two of them interacting, one had a quadratic effect). Better operating conditions were identified.

Impact:
The rejection rate drop from 20–25 % to 5–10 %. In spite of the improvement the factory closed 2 years later.

		Value			Level	
	Criteria	−				+
1	$\boldsymbol{V}\{\boldsymbol{D}\}$ = value of the data actually collected	1	2	3	$\underline{4}$	5
2	$\boldsymbol{V}\{\boldsymbol{M}\}$ = value of the statistical method employed	1	2	3	4	$\underline{5}$
3	$\boldsymbol{V}\{\boldsymbol{P}\}$ = value of the problem to be solved	1	2	3	$\underline{4}$	5
4	$\boldsymbol{V}\{\boldsymbol{PS}\}$ = value of the problem actually solved	1	2	3	$\underline{4}$	5
5	$\boldsymbol{P}\{\boldsymbol{S}\}$ = probability that the problem actually gets solved	1	2	3	$\underline{4}$	5
6	$\boldsymbol{P}\{\boldsymbol{I}\}$ = probability the solution is actually implemented	1	2	3	$\underline{4}$	5
7	$\boldsymbol{T}\{\boldsymbol{I}\}$ = time the solution stays implemented	1	$\underline{2}$	3	4	5
8	$\boldsymbol{E}\{\boldsymbol{R}\}$ = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 10\,240$

Case 16

Problem name: Designing a test for comparing slot machines

Date: 1996 Reporter: X. Tort-Martorell
I (International)
FSD (Full-scale development)
L (Large company size)
Process improvement (High management maturity)

Problem description:
After slot machines are designed and prototypes produced, they are tested in real conditions. The aim is to devise a testing methodology (location, time, type of data gathered, test to conduct, ...) to forecast whether the slot machine is going to be liked by customers and be a money-maker.

Context:
The new machines are tested by comparing them to existing good machines. There are important factors to be taking into account, the most important one being the novelty effect (during an initial period machines are always money-makers).

Data collected:
Income produced by different types of machines trough time taking into account other important factors. Data related to trials of the test procedure designed.

Data analysis:
Graphical methods, DoE, statistical tests

Conclusions and recommendations:
The conclusion of the project was a test procedure described in a step-by-step protocol that included a MINITAB macro to analyse the data coming from the test.

Impact:
Introduction of better prototypes to the market

		Value			Level	
	Criteria	−				+
1	$\boldsymbol{V}\{\boldsymbol{D}\}$ = value of the data actually collected	1	2	$\underline{3}$	4	5
2	$\boldsymbol{V}\{\boldsymbol{M}\}$ = value of the statistical method employed	1	2	$\underline{3}$	4	5
3	$\boldsymbol{V}\{\boldsymbol{P}\}$ = value of the problem to be solved	1	2	3	$\underline{4}$	5
4	$\boldsymbol{V}\{\boldsymbol{PS}\}$ = value of the problem actually solved	1	2	3	$\underline{4}$	5
5	$\boldsymbol{P}\{\boldsymbol{S}\}$ = probability that the problem actually gets solved	1	2	3	$\underline{4}$	5
6	$\boldsymbol{P}\{\boldsymbol{I}\}$ = probability the solution is actually implemented	1	2	3	$\underline{4}$	5
7	$\boldsymbol{T}\{\boldsymbol{I}\}$ = time the solution stays implemented	1	2	$\underline{3}$	4	5
8	$\boldsymbol{E}\{\boldsymbol{R}\}$ = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 6912$

Case 17

Problem name: Reduction of label defects in a cava bottling process

Company name: Codorniu
Date: 1997 Reporter: X. Tort-Martorell
N (National)
P (Production type)
L (Large company size)
Process improvement (High management maturity)

Problem description:
Cava bottles have six labels. The correct position and alignment of these is crucial in customer-perceived quality.

Context:
There was no clear classification of defects and specifications.

Data collected:
Production of a clear defect classification, description and specifications for each type of defect. Data collected on 2500 bottles of different cava types.

Data analysis:
Pareto analysis, cause-and-effect diagram, identification of key causes (stratification, correlation). Design of a control procedure based on statistical process control.

Conclusions and recommendations:
Definition of types of defects and ways to measure them were fundamental and, through the data collected, identify process improvements. The control procedure allowed for easy monitoring.

Impact:
Important defect reductions. Wide variability, depending on the production line and type of defect, ranging from 4–30 % for some types to 3–5 % in others.

	Criteria	Value				Level
		−				+
1	$V\{D\}$ = value of the data actually collected	1	2	$\underline{3}$	4	5
2	$V\{M\}$ = value of the statistical method employed	1	$\underline{2}$	3	4	5
3	$V\{P\}$ = value of the problem to be solved	1	$\underline{2}$	3	4	5
4	$V\{PS\}$ = value of the problem actually solved	1	$\underline{2}$	3	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	$\underline{4}$	5
6	$P\{I\}$ = probability the solution is actually implemented	1	2	3	$\underline{4}$	5
7	$T\{I\}$ = time the solution stays implemented	1	2	3	$\underline{4}$	5
8	$E\{R\}$ = expected number of replications	1	$\underline{2}$	3	4	5

$PSE = 3072$

Case 18

Problem name: Monitoring the cleaning process in a municipality

Date: 1998 Reporter: X. Tort-Martorell
N (National)
S (Public service type)
S (SME size)
Inspection (Low management maturity)

Problem description:
Cleaning services for municipal dependencies and the road and park network are outsourced. Citizens complain about dirtiness and the municipal authorities have

the conviction that the money spent should be enough to accomplish a satisfactory cleaning level. They would like an inspection procedure to produce a cleanness index and check on the subcontractor.

Context:
The municipality has 60 000 inhabitants and occupies 30 km^2

Data collected:
Cleanness attributes for different types of dependencies

Data analysis:
Sampling, operating characteristic curves, control charts. Definition of inspection procedures and training for inspectors. Definition of weights for different types of dirtiness according to citizens' perceptions.

Conclusions and recommendations:
The procedure designed was included in the tender for the new cleaning contract incorporating economic penalties.

Impact:
Difficult to assess due to the lack of previous data

		Value			Level	
	Criteria	−				+
1	***V*{*D*}** = value of the data actually collected	1	$\underline{2}$	3	4	5
2	***V*{*M*}** = value of the statistical method employed	1	$\underline{2}$	3	4	5
3	***V*{*P*}** = value of the problem to be solved	1	2	$\underline{3}$	4	5
4	***V*{*PS*}** = value of the problem actually solved	1	2	$\underline{3}$	4	5
5	***P*{*S*}** = probability that the problem actually gets solved	1	2	$\underline{3}$	4	5
6	***P*{*I*}** = probability the solution is actually implemented	1	2	3	$\underline{4}$	5
7	***T*{*I*}** = time the solution stays implemented	1	2	3	$\underline{4}$	5
8	***E*{*R*}** = expected number of replications	$\underline{1}$	2	3	4	5

$PSE = 1728$

Case 19

Problem name: Welding Process Optimization

Company name: Alstom Transport
Date: 2001 Reporter: X. Tort-Martorell
I (International)
P (Production type)

VL (Very large company size)
Process control (High management maturity)

Problem description:
Optimize the parameters of a welding process conducted by a new robot in the train chassis. Both the materials to be welded and the welding conditions were quite specific.

Context:
Factory engineers knew a lot about welding but little about experimental design. They had conducted some experiments and started production that was good in general, but showing some contradictions and unexpected results.

Data collected:
A 2^{8-3} design assigned factors to columns to allow for a favourable confounding pattern. A lot of work in preparing the plates to be welded and the procedures to measure the responses.

Data analysis:
Calibration, measurement system analysis, regression analysis, calculation and interpretation of effects

Conclusions and recommendations:
More important than the knowledge and improvements gained from the conclusions of the design was the knowledge gained from the preparation (understanding that the robot-programmed intensity was different than the real intensity, that intensity varied during the welding process, understanding the causes of sparks, etc.).

Impact:
Faster welding with increased traction and shearing

	Criteria	Value −				Level +
1	$V\{D\}$ = value of the data actually collected	1	2	3	[✓ 4]	5
2	$V\{M\}$ = value of the statistical method employed	1	2	3	4	[✓ 5]
3	$V\{P\}$ = value of the problem to be solved	1	2	3	[✓ 4]	5
4	$V\{PS\}$ = value of the problem actually solved	1	2	[✓ 3]	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	[✓ 4]	5
6	$P\{I\}$ = probability the solution is actually implemented	1	2	3	[✓ 4]	5
7	$T\{I\}$ = time the solution stays implemented	1	2	3	[✓ 4]	5
8	$E\{R\}$ = expected number of replications	[✓ 1]	2	3	4	5

$PSE = 15\,360$

Case 20

Problem name: Scale-Up Optimization

Company name: 'Sofist'
Date: 2004 Reporter: R. Kenett
I (International)
P (Production type)
L (Large company size)
Inspection (Low management maturity)

Problem description:
Optimize the parameters of a chemical compound during scale-up pilot experiments using a simulation package to simulator the production process

Context:
Engineers of the pilot plan were requested to optimize a chemical compound used in the pharmaceutical industry. The materials involved in producing the compound are of very high cost, so that the cost of physical experimentation is prohibitively high. The pilot unit manager decided to invest in a sophisticated simulation package to help reduce experimentation cost and speed up the scale-up process.

Data collected:
A space-filling Latin hypercube design assigned factor levels to experimental runs. Experiments were conducted using a special-purpose simulation package for scale-up processes. Kriging models were used to determine the response surface and derive optimal set-up conditions.

Data analysis:
Stochastic emulators, radial base kriging models, multi-objective optimization methods

Conclusions and recommendations:
The simulation results first had to be calibrated using a small set of simple experimental runs. Calibration consisted of comparing simulation results to physical experiments results. Following calibration, a full-scale simulation experiment was conducted and optimization of economic indicators was performed.

Impact:
Significantly improved parameter set-up points, as measured by the simulation predictions of the economic indicators. The results, however, were ignored by management who preferred to rely on simple physical experiments.

	Criteria	Value −				Level +
1	$V\{D\}$ = value of the data actually collected	1	2	3	[✓ 4]	5
2	$V\{M\}$ = value of the statistical method employed	1	2	3	4	[✓ 5]
3	$V\{P\}$ = value of the problem to be solved	1	2	3	4	[✓ 5]
4	$V\{PS\}$ = value of the problem actually solved	1	2	3	[✓ 4]	5
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	[✓ 4]	5
6	$P\{I\}$ = probability the solution is actually implemented	[✓ 1]	2	3	4	5
7	$T\{I\}$ = time the solution stays implemented	[✓ 1]	2	3	4	5
8	$E\{R\}$ = expected number of replications	[✓ 1]	2	3	4	5

$PSE = 1600$

Case 21

Problem name: Employee Suggestion System

Company name: 'Basil'
Date: 2006 Reporter: R. Kenett
N (National)
S (Service)
SME (SME company size)
Process control (High management maturity)

Problem description:
The results of the Basil employee survey indicated several weaknesses, among them the participation of the workforce through suggestions and other bottom-up communication channels.

Context:
Basil conducted an employee satisfaction survey, in which every employee participated. This outstanding result reflected the efficient planning and execution of the survey and the motivation of the employees to have their voice heard. The company set up a steering committee to manage focused initiatives to address the weaknesses. The committee was essentially made up of top management and chaired by the chief executive. An improvement team, with a mission to improve the flow of employee suggestions, was launched by the steering committee, along with several other teams directed at other issues. A team leader was assigned and a monthly progress review by the steering committee was conducted. The team was commissioned to work with the DMAIC roadmap.

Data collected:
The employee suggestion system improvement team reviewed minutes and reports covering a period of 12 months to identify where, how and if employee suggestions were identified and implemented. The data was organized in tabular form.

Data analysis:
Pareto charts, trend charts and P charts for comparing proportion of adopted suggestions by various classifications. Following the diagnostic analysis, a full intranet-based suggestion was designed and deployed.

Conclusions and recommendations:
The team was able to prove that a great majority of the employee suggestions recorded in various minutes of meetings and reports were not implemented. It was also clear that no formal recognition or systematic tracking of these contributions was carried out.

Impact:
The new suggestion system generated many ideas that resulted in significant savings and improved motivation of the workforce. This positive experience enhanced participation of the workforce in several additional areas.

	Criteria	Value −				Level +
1	$V\{D\}$ = value of the data actually collected	1	2	3	$\underline{4}$	5
2	$V\{M\}$ = value of the statistical method employed	1	2	3	4	$\underline{5}$
3	$V\{P\}$ = value of the problem to be solved	1	2	3	$\underline{4}$	5
4	$V\{PS\}$ = value of the problem actually solved	1	2	$\underline{3}$	4	5
5	$P\{S\}$ = probability that the problem actually gets solved	1	2	3	$\underline{4}$	5
6	$P\{I\}$ = probability the solution is actually implemented	1	2	3	$\underline{4}$	5
7	$T\{I\}$ = time the solution stays implemented	1	2	3	$\underline{4}$	5
8	$E\{R\}$ = expected number of replications	1	2	$\underline{3}$	4	5

$PSE = 57\,600$