Foreword

If it were possible to add up, on a global basis, all of the benefits that organisations have experienced as a result of deploying Six Sigma techniques, the result would be truly staggering. The place of Six Sigma as an effective methodology for improving quality and performance is very well established.

Six Sigma is often introduced to organisations through training. Six Sigma practitioners gain personal development by attending a spectrum of courses from introductory sessions to expert level that is normally referred to as Six Sigma Black Belt. I personally have led many hundreds of practitioners through this process, and whilst I hope my interventions have been successful, I am only too aware that there is a limit to what participants can be expected to absorb in a classroom.

This is where Robin Henderson's book becomes truly invaluable. As well as providing students new to Six Sigma with a very readable and easy to understand introduction, this publication serves as comprehensive consolidation for those already trained. Furthermore this book extends the knowledge gained by recognised experienced practitioners.

Those looking for relevant and modern case studies from both service and manufacturing environments will be most satisfied to find them in abundance throughout the following pages. Robin Henderson demonstrates the wide applicability and power of these methods with an impressive collection of analyses and improvements drawn from his broad experience of working as a consultant as well as an academic. The combination of many chapter-end exercises, follow up activities, and the accompanying web site, form a wealth of extremely useful resources.

The success of Six Sigma would not have been realised had it not been for the development of statistical software such as Minitab. Minitab brings techniques to all of us that previously were only the domain of statisticians. Robin Henderson's book complements other well-known texts by taking the theory and explaining how to implement these methods in real situations through the use of Minitab software. Starting from a gentle introduction to Minitab, Robin builds our knowledge through detailed yet friendly explanations, and as we practice, gradually leads us on to tackle more sophisticated techniques with confidence.

I have spent much of my career working in the field of quality and performance improvement, utilising these tools and techniques, and teaching the subject to others. Since its publication, I have regularly turned to Robin Henderson's first edition of Six Sigma Quality Improvement with Minitab to check my understanding, to learn a bit more, and to find a way of explaining to my teams, a challenging concept in a straightforward way.

Now we have the benefit of this second edition that keeps us up to date on the latest developments within the Minitab tool and its brand new features. For example, Robin Henderson introduces the new Minitab Assistant that guides users through an analysis process.

There is no doubt that Robin Henderson has helped all of us in our endeavours to improve quality as author of various papers on the subject and through his involvement with the Six Sigma Study Group and the Quality Improvement Section of the Royal Statistical Society.

I warmly welcome the 2nd edition of Six Sigma Quality Improvement with Minitab and thoroughly recommend it to both new students and experienced practitioners of Six Sigma methodologies.

Colin Barr BSc (Hons), Six Sigma Black Belt

Colin Barr is the founder of Colin Barr Associates, providers of training and consultancy in Business Improvement using techniques such as Lean and Six Sigma. He is also founder of Stratile, where he developed FocalPoint, a web based strategy and performance management system. Colin Barr gained a BSc (Hons) Physics from Strathclyde University, and has held director level positions at DEC and Motorola where he was trained as a Six Sigma Black Belt.

Preface

Rationale

The Statistics Division of the American Society for Quality defines *statistical thinking* (http://www.asqstatdiv.org/stats-everywhere.htm, accessed 29 January 2011) as a philosophy of learning and action based on three principles:

- All work occurs in a system of interconnected processes.
- Variation exists in all processes.
- Understanding and reducing variation are key to success.

In a paper entitled 'Six-Sigma: the evolution of 100 years of business improvement methodology', Snee (2004) states that 'The three key elements to statistical thinking are process, variation and data' and that 'Statistical thinking enhances the effectiveness of the statistical methods and tools'. He describes Six Sigma* as a strategy and methodology for the deployment of statistical thinking and methods within an organization. This book aims to explain some of the most important statistical methods and demonstrate their implementation via the statistical software package Minitab® (Release 16). Minitab® and the Minitab logo are registered trademarks of Minitab, Inc. There are many excellent texts available on statistical methods for the monitoring and improvement of quality. In writing this book the author set out to complement such texts by providing careful explanation of important statistical tools coupled with detailed description of the use of Minitab, either to implement the statistical tools or as an aid to understanding them.

In *Six Sigma Beyond the Factory Floor*, Hoerl and Snee (2005, p. 23) wrote:

> Another reason Six Sigma has been effective is the general availability of user-friendly statistical software that enables effective and broad utilization of the statistical tools. The statistical software package most widely used in Six Sigma is Minitab. ... Prior to the availability of such user-friendly software, statistical methods were often the domain of professional statisticians, who had access to, and specialized training in, proprietary statistical software. Specialists in statistical methods have an important role to play in Six Sigma, but practitioners who are not professional statisticians do the vast majority of statistical applications.

The author believes that his book will be of value to such practitioners and to people involved in quality improvement strategies other than Six Sigma, to students of quality improvement and indeed to anyone with an interest in statistical methods and their implementation via software.

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*Six Sigma is a registered trademark and service mark of Motorola Inc.

Content

Among the features of the book are the following:

- Exposition of key statistical methods for quality improvement – data display, statistical models, control charts, process capability, process experimentation, model building and the evaluation of measurement processes.
- Detailed information on the implementation of the methods using Minitab with extensive use of screen captures.
- Demonstration of facilities provided by Minitab for learning about the methods and the software, including the new Assistant.
- Use of random data generation in Minitab to aid understanding of important statistical concepts.
- Provision of informative follow-up exercises and activities on each topic.
- No prior knowledge of statistical methods assumed.
- No prior knowledge of Minitab assumed.
- Access to Release 16 of the Minitab software is essential.
- An associated website providing data sets for download and answers and notes for the follow-up exercises.

There are eleven chapters and four appendices. In addition to the topics covered in the first edition, this edition includes new material on Pareto charts, cause-and-effect diagrams, the multivariate normal distribution, acceptance sampling, time-weighted and multivariate control charts, tolerance intervals, Taguchi experimental designs, comparison of measurement systems, analysis of categorical data and logistic regression. It also includes material on new features provided in Release 16 of Minitab such as the Assistant. A brief summary of the content of each chapter is as follows:

- Chapter 1 introduces the structured approach to quality improvement provided by Six Sigma via DMAIC – define, measure, analyse, improve and control. It outlines the role of statistical methods in Six Sigma and the capabilities of Minitab for their implementation.
- Chapter 2 provides an introduction to data display, and to Minitab and its features. It also addresses data input, output, storage and manipulation.
- Chapter 3 contains further material on the display and summary of data – exploratory data analysis techniques and techniques for use with multivariate data are introduced. Pareto charts and cause-and-effect diagrams are explained.
- Chapter 4 is devoted to fundamentals of probability and to univariate statistical models for measurements and counts. A brief introduction to the multivariate normal distribution is given and key results concerning means and proportions are presented. An

introduction to the application of discrete probability distributions in acceptance sampling is provided.

- Chapter 5 gives a comprehensive treatment of control charts and their application. Shewhart, exponentially weighted moving average (EWMA), cumulative sum (CUSUM) and multivariate control charts are covered. Reference is made to the dangers of tampering with processes and to feedback adjustment.
- Chapter 6 addresses the assessment of process capability via capability indices and sigma quality levels. Tolerance intervals are introduced.
- Chapter 7 deals with process experimentation involving a single factor and essentially addresses the question of whether or not process changes have led to improvement. The question is addressed via statistical inference and estimation.
- Chapter 8 extends the ideas introduced in the previous chapter to process experimentation involving two or more factors. Fundamental aspects of design of experiments are introduced together with the powerful features provided in Minitab for experimental design and the display and analysis of the resulting data. Taguchi experimental designs are introduced.
- Chapter 9 utilizes concepts from previous chapters in order to evaluate the performance of measurement processes for both continuous measurement and attribute measurement scenarios. Reference is made to the comparison of measurement systems.
- Chapter 10 is concerned with model building using simple and multiple regression. Response surface methodology and regression modelling with categorical response variables are introduced.
- Chapter 11 concludes the book by looking at ways in which Minitab can assist the user to learn more about the software and the statistical tools that it implements. An introduction to Minitab macros is provided.

Using the book

This is not a book to be read in an armchair! The author would encourage users to follow the Minitab implementation of displays and analyses as he/she reads about them and to work through the supplementary exercises and activities at the end of each chapter. All but the very smallest data sets referred to in the text will be available on the website `http://www.wiley.com/go/six_sigma` in the form of Minitab worksheets or Microsoft Excel™ workbooks. It is recommended that you download the files and store them in a directory on your computer. Some of the data sets are real, others have been simulated (using Minitab!) to provide appropriate illustrations. Many of the simulated data sets are set in the context of quality improvement situations that the author has encountered. The website will also provide specimen solutions to, and comments on, the supplementary exercises.

The needs of readers will differ widely. It is envisaged that many will find the first four or five chapters sufficient for their needs. It is important to note that although a brief introduction to the Help facilities will be given in Chapter 2, many readers might find it helpful to read the

first section of Chapter 11 immediately. The reference to Help has been encountered in Chapter 2 in order to obtain more comprehensive information facilities that are available.

The reader might wonder why the chapter on control charts is before the one on measurement process evaluation, whilst in DMAIC the order appears to be reversed. The author has endeavoured to order the chapter topics in a sequence that is logical from the point of view of the development of understanding of the applied statistics. For example, one cannot fully understand a gauge R&R measurement process evaluation without knowledge of analysis of variance for data from a designed experiment. Designed experiments are usually associated with the improve phase. Indeed, control charts may be of value during all four of the measure, analyse, improve and control phases of a Six Sigma project. Each chapter will give an indication of the relevance of its content to the DMAIC sequence that lies at the heart of Six Sigma.

There is always a danger that statistical software will be used in black box fashion with unfortunate consequences. Thus the reader is exhorted to learn as much as he/she possibly can about the methods and to take every opportunity to learn from successful, sound applications by others of statistical methods in quality improvement, whether on Six Sigma projects or as part of other strategies.

It is the author's earnest hope that, through using this book, you the reader will acquire understanding of statistical methods for quality improvement and Six Sigma, skill in the application of the Minitab software, and appreciation of just how easy it is to use and of all that it has to offer.

Acknowledgements

Grateful appreciation of help and encouragement is due to the following people: Sandra Bonellie, Colin Barr, Gary Beazant, Isobel Black, Roland Caulcutt, Shirley Coleman, Lorraine Daniels, Ross Davies, Martin Dennis, Jeff Dodgson, Geoff Fielding, Alan Fisher, Wendy Ford, Martin Gibson, Mary Hickey, Iain Henderson, Kevin Hetzler, Tom Johnstone, Graham Leigh, Ron Masson, Bill Matheson, Deborah Macdonald, Mark McGinnis, Gillian Mead, Charles Moncur, Douglas Montgomery, Bill Munro, David Panter, Gillian Raab, David Roberts, David Reed, Fiona Reed, Anne Shade, John Shrouder, William Woodall and Andrew Vickers.

Robert Raeside deserves a major thank-you for all that I learnt from him during shared involvement in the development and delivery of many training courses on quality improvement when we were both members of the Applied Statistics Group at Edinburgh Napier University. Another major influence was John Shade, a statistician with vast experience of quality improvement, with whom it was a pleasure to work, in a highly stimulating environment at Good Decision Ltd.

At John Wiley & Sons, Inc., Richard Davies, Heather Kay, Ilaria Meliconi and Prachi Sinha-Sahay have been a pleasure to work with. The author is most grateful to the copy editor Richard Leigh for his highly professional contribution to the project. Abhishan Sharma at Thomson Digital was most helpful during the typesetting phase of the project. Support from Minitab Inc. has been excellent. In particular, the author wishes to acknowledge the help of Austin Davey in the UK and of Eugenie Chung and Linda Holderman in the USA. Portions of the input and the output contained in this book are printed with permission of Minitab, Inc. Use of data sets included with the Minitab software is gratefully acknowledged. Grateful thanks are due to authors and publishers who have given permission for use of data and material. Specific acknowledgements are made in the text.

Finally, in preparing this second edition my wife Anne has been ignored once again for many, many hours – yet her support, as ever, has been immense.

About the Author

Having studied mathematics and physics at the University of Edinburgh, Robin Henderson embarked on a 35-year career in education. For much of that time he was employed in what is now Edinburgh Napier University, teaching mathematics and statistics, at all levels.

His interest in statistics for quality improvement grew during the 1980s, largely due to involvement with colleagues Professor Robert Raeside and Professor Ron Masson in providing training courses, including courses to prepare engineers to sit the Certified Quality Engineer examinations of the American Society for Quality, and consultancy for local organizations, particularly microelectronics companies. This interest led him to leave the University in 1998 in order to work as a statistical consultant for Good Decision Ltd, Dunfermline, where he was heavily involved in the development and delivery of training courses for industry in process monitoring and adjustment, measurement process evaluation and design and analysis of multifactor experiments.

His interest in and enthusiasm for Minitab also developed during the 1980s when it began to be used at Edinburgh Napier University in the teaching of students on a wide variety of courses. Release 7 of the software, with line-printer graphics, was a far cry from the sophistication of the current version!

Since 2001, Robin has been operating as a sole consultant, trading as Halcro Consultancy, Loanhead, providing training and consultancy in statistics for quality improvement and Six Sigma. He has assisted Colin Barr Associates with the training of Six Sigma Black Belts and with statistical consultancy projects. In 2009 Edinburgh Napier University received the Queen's Anniversary Prize, the highest accolade that can be conferred on a higher or further education institution in the UK, for its pioneering research in innovative construction techniques to improve insulation in new build homes. The author is very pleased to have provided the spin-out company, Robust Details Ltd., that was created to oversee uptake of the construction solutions stemming from the research, with training in both statistical methods and Minitab.

He is also currently employed as coordinator at the Royal Infirmary of Edinburgh for the Scottish National Stroke Audit. On this project he has introduced the use of Shewhart control charts for monitoring aspects of the processes involved in the care of stroke patients. Since the first edition was published he has been principal author of two papers on healthcare applications of control charts and co-author of a paper on the technical details of estimation of process variability. He has acted as secretary to both the Committee of the Quality Improvement Section and the Six Sigma Study Group of the Royal Statistical Society, of which he is a Fellow. In these roles he was responsible for collating the views of colleagues on the draft international standards BS ISO 13053-1/2 *Quantitative methods in process improvement – Six Sigma – Part 1: DMAIC methodology*, *Part 2: Tools and techniques* and for subsequently preparing the comments submitted by the Society on the drafts. He is a member of ENBIS, the European Network for Business and Industrial Statistics.