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Introduction: ENBIS, Pro-ENBIS and this book

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The practical application of statistics has fascinated statisticians for many years. Business and industrial processes are rich with information that can be used to understand, improve and change the way things are done. This book arose from the work carried out by members of the European Network for Business and Industrial Statistics (ENBIS) which was strengthened by a three-year thematic network called Pro-ENBIS funded by the European Commission under the Fifth Framework Programme (FP5). Contributions have been made by statistical practitioners from Europe and from other parts of the world. The aim of the book is to promote the wider understanding and application of contemporary and emerging statistical methods. The book is aimed at people working in business and industry worldwide. It can be used for the professional development of statistical practitioners (a statistical practitioner is any person using statistical methods, whether formally trained or not) and to foster best practice for the benefit of business and industry.

This introductory chapter gives a brief description of ENBIS followed by an overview of the Pro-ENBIS project.

In August 1999 a group of about 20 statistical practitioners met in Linköping, Sweden, at the end of the First International Symposium on Industrial Statistics to initiate the creation of the European Society for Industrial and Applied Statistics (ESIAS). As a first step, a list of interested members was drawn up and a dialogue started. The internet was identified as a feasible platform cheaply and efficiently to co-ordinate the activities of any body formed out of these meetings. A network of people from industry and academia from all European nations interested in

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applying, promoting and facilitating the use of statistics in business and industry was created to address two main observations:

- As with many disciplines, applied statisticians and statistical practitioners often work in professional environments where they are rather isolated from interactions and stimulation from like-minded professionals.
- Statistics is vital for the economic and technical development and improved competitiveness of European industry.

By February 2000 an executive committee was formed which held a founding meeting at EURANDOM in Eindhoven, the Netherlands, on 26–27 February. The name ENBIS was adopted as the defining name for the society. It was decided to have a founding conference on 11 December 2000 in Amsterdam, and during that meeting ENBIS was formally launched. The conference was accompanied by a three-day workshop on design of experiments lead by Søren Bisgaard, a renowned European statistician.

The mission of ENBIS is to:

- foster and facilitate the application and understanding of statistical methods to the benefit of European business and industry;
- provide a forum for the dynamic exchange of ideas and facilitate networking among statistical practitioners;
- nurture interactions and professional development of statistical practitioners regionally and internationally.

ENBIS has adopted the following points as its vision:

- to promote the widespread use of sound science driven, applied statistical methods in European business and industry;
- that membership consists primarily of statistical practitioners from business and industry;
- to emphasise multidisciplinary problem-solving involving statistics;
- to facilitate the rapid transfer of statistical methods and related technologies to and from business and industry;
- to link academic teaching and research in statistics with industrial and business practice;
- to facilitate and sponsor continuing professional development;
- to keep its membership up to date in the field of statistics and related technologies;
- to seek collaborative agreements with related organisations.

ENBIS is a web-based society, and its activities can be found at http://www.enbis.org.

ENBIS has arranged annual and occasional conferences at various locations around Europe which have allowed the showcasing of a broad spectrum of applications and generated discussion about the use of statistics in a wide range of business and industrial areas. Ideas for new projects often arise from these meetings, and ENBIS provides an ideal forum for gathering project partners and cementing working relationships. Conferences organised by ENBIS members have been held in Oslo (2001), Rimini (2002), Barcelona (2003), Copenhagen (2004), Newcastle (2005), Wroclaw (2006) and Dortmund (2007). In addition to the annual conferences, ENBIS runs spring meetings dedicated to particular topics. These include design of experiments in Cagliari (2004), data mining in Gengenbach (2006) and computer experiments versus physical experiments in Turin (2007).

The Pro-ENBIS thematic network sought to build on the success of ENBIS and to develop partnerships within Europe to support selected projects at the forefront of industrial and business statistics, with the specific mission 'to promote the widespread use of sound science driven, applied statistical methods in European business and industry'.

Pro-ENBIS was contracted for three years until 31 December 2004 by the European Commission with a budget of €800 000. The project was co-ordinated by the University of Newcastle upon Tyne (UK) and had contractors and members from across Europe. There were a total of 37 partners from 18 countries, 10 of which were principal contractors. There was also an invited expert, Søren Bisgaard, who helped with strategic thinking and dissemination.

The thematic network was funded so that it could achieve specific outcomes, including promoting industrial statistics through workshops and industrial visits and through publishing both academic papers and articles in the popular press. These activities relate to the network's aim to provide a forum for the dissemination of business and industrial statistical methodology directly from statisticians and practitioners to European business and industry. They were very successful in generating considerable interest in ENBIS and in statistical practice generally.

The deliverables were grouped around statistical themes, with eight work packages:

- WP1 Design of experiments
- WP2 Data mining/warehousing
- WP3 General statistical modelling, process modelling and control
- WP4 Reliability, safety and quality improvement
- WP5 Discovering European resources and expertise
- WP6 Drafting and initiating further activity

- WP7 Management statistics
- WP8 Network management

Work packages 1, 2, 3, 4 and 7 each focused on a particular area of statistics. As a thematic network, the outcomes for these work packages included organizing workshops, events and network meetings on relevant topics as well as publishing papers, articles and notes. The project deliverables agreed with the European Commission were all met or exceeded.

Many papers co-authored by partners were published in the academic press and some of these are listed below. The partners were enthusiastic to publish relevant articles in the popular press. These were typically written in languages other than English and appeared in local newspapers, press releases and other outlets. The articles published in the popular press have been important in drawing attention to activity in statistical practice across Europe as well as publicizing the Pro-ENBIS project and raising awareness of the ENBIS organisation and its activities. A lot of thoughtful responses and comments relating to these articles from people in business and industry have been received by the authors. Discussions continue within the framework of ENBIS.

Work packages 5, 6 and 8 were concerned with networking, information gathering and project management.

The chapters in the book cover all of the areas addressed in the work packages.

Work package 1: Design of experiments

- *Mission*. Dedicated to furthering the use of (DoE) in an industrial and commercial context. The emphasis is on developing concepts, to be of use daily in quality and productivity improvement.

Work package motivation

International competition is getting tougher, product development cycles shorter, manufacturing processes more complex, and customers' expectations of quality higher. Dealing with these problems and generating new knowledge often require extensive experimentation. Research and development scientists and engineers are therefore under pressure to be more effective in conducting experiments for quality, productivity and yield optimisation. In particular, it is recognised that quality cannot economically be inspected into products and processes, but must be designed upstream in the design and development phases. Design of experiments is a powerful and economically efficient strategy employing modern statistical principles for solving design and manufacturing problems, for the discovery of important factors influencing product and process quality and for experimental optimisation. Experimental design is also an important tool for developing new products that are robust (insensitive) to environment and internal component variation. Carefully planned statistical studies can remove hindrances to high quality and productivity at

every stage from concept development to production, saving time and money. The emphasis is on discussing and developing concepts, to be of use daily in quality and productivity improvement.

A key contribution of WP1 was a series of very successful workshops. There was good industrial participation and they also provided a forum to discuss connected issues. The area of application of DoE covered was satisfyingly wide and newer areas provided much interest: for example, applications to the service sector, market research and sensory evaluation.

Work package outcomes

WP1 achieved more than the minimum numbers of visits, workshops, papers and articles during the project. Four industrial visits were required but six were actually carried out. The requirement of two journal papers to be submitted was surpassed with five actually submitted for this work package. Seven workshops were carried out, five more than specified in the contract. Four articles were published in the popular press, two more than required by the contract.

Sample papers produced by Pro-ENBIS network

D. Romano and A. Giovagnoli (2004) Optimal experiments for software production in the presence of a learning effect: a problem suggested by software production. *Statistical Methods & Applications*, **13**(2), 227–239.

A. Bucchianico, T. Figarella, G. Hulsken, M.H. Jansen and H.P. Wynn (2004) A Multi-scale approach to functional signature analysis for product end of life management. *Quality Reliability Engineering International*, **20**(5), 457–467.

D. Romano, M. Varetto and G. Vicario (2004) Multiresponse robust design: a general framework based on combined array. *Journal of Quality Technology*, **36**(1), 27–37.

Work package 2: Data mining/warehousing

- *Mission*. Dedicated to exposing researchers and industrialists in the field of statistics to data mining problems and tools, so that the natural skills of statisticians, such as the ability to model real observational data, can be applied to data mining as well.

Work package motivation

Data mining is not only the statistical analysis of large databases, using established statistical techniques, but also a new challenging field, which involves:

- sampling appropriately the available massive data;

- learning the data generating mechanism underlying the data at hand;
- being able to deliver results of statistical data analysis in ways that are efficient and communicable to practitioners;
- working at the interplay between statistical modelling and computationally intensive methods.

Data mining tools can be classified into three broad areas: association rules, classification problems, and predictive problems. In the first area would fit methodologies such as descriptive multivariate measures of association, log-linear models and graphical models. In the second area regression methods, classification trees, neural networks and cluster analysis seem the most obvious choices. Finally, probabilistic expert systems (Bayesian networks), regression methods and neural networks seem to fit in the third class. Concerning applications, the network decided to confine itself to applications that relate to business and industry, leaving alone others related to areas such as epidemiology or genetics.

Work package outcomes

WP2 achieved more than the minimum numbers of workshops and published papers during the project. Four industrial visits were carried out and two articles were published in the popular press for this work package as required by the contract. Three journal papers were submitted, one more than required, and six workshops were run, four more than required by the contract.

Sample papers produced by Pro-ENBIS network

R.J.M.M. Does, E.R. van den Heuvel, J. de Mast and S. Bisgaard (2003) Comparing non-manufacturing with traditional applications of Six Sigma. *Quality Engineering*, **15**(1), 177–182.

R. Kenett, M. Ramalhoto and J. Shade (2003) A proposal for managing and engineering knowledge of stochastics in the quality movement. In T. Bedford and P.H.A.J.M. van Gelder (eds), *Safety and Reliability*. A.A. Balkema, Lisse, Netherlands.

P. Johansson, B. Bergman, S. Barone and A. Chakhunashvili (2006) Variation mode and effect analysis: a practical tool for quality improvement. *Quality and Reliability Engineering International*, **22**(8), 865–876.

Workshops and papers were beneficial because of the information dissemination to professional users and/or improving the body of scientific knowledge through constructive comments and scientific discourse in the peer review of the papers. The general benefits of the published articles are to stimulate interest in the project and to advertise its use as a resource to industry.

Work package 3: General statistical modelling

- *Mission*. To improve the use of process monitoring and control methods for both industry and commerce and to help companies introduce advanced techniques via workshops and visits.

Work package motivation

Methods such as control charts, cusums, range charts, variance charts, means charts, exponentially weighted moving average (EWMA) charts and the newer multivariate charts are well known. There is a need to develop and further the application of these and associated methods in European industry – in particular, the use of multivariate methods using principal components and factor analysis. The advanced use of statistical modelling, using generalised linear models and similar applications, needs to made better known.

Work package outcomes

WP3 achieved more than the minimum numbers of visits, workshops, papers and articles during the project. For example, a manufacturing process from raw materials to finished products can be modelled by simulation. Statistical process control (SPC) and DoE can be used for inspection and improvements. This work package prepared a template, using these tools, to apply to a wide variety of manufacturing contexts. It was used for short (half-hour) demonstrations for works visits up to workshops of several days.

Overall eight industrial visits were completed, twice as many as the four required. Six journal papers were submitted, four more than required, and 12 workshops were run, 10 more than the contract required. Four articles were published in the popular press for this work package, two more than required by the contract.

Sample papers produced by Pro-ENBIS network

A. Zempléni, M. Véber, B. Duarte and P. Saraiva (2004) Control charts: a cost-optimisation approach for processes with random shifts. *Journal of Applied Stochastic Models in Business & Industry*, **20**(3), 185–200.

L. Marco, X. Tort-Martorell, J.A. Cuadrado and L. Pozueta (2004) Optimisation of a car brake prototype as a consequence of successful DOE training. *Quality and Reliability Engineering International*, **20**(5), 469–480.

D.J. Stewardson, M. Ramalhoto, L. Da Silva and L. Drewett (2003) Establishing steel rail reliability by combining fatigue tests, factorial experiments and data transformations. In T. Bedford and P.H.A.J.M. van Gelder (eds), *Safety and Reliability*. A.A. Balkema, Lisse, Netherlands.

Much of the first 18 months of the contract period was devoted to developing material, including instructional software for workshops and works visits which was used more fully in the second 18 months of the contract period. The following programmes have been developed:

1. Simulation of production processes (aluminium wheels and oil filters) for teaching DoE and SPC. The concepts behind the simulation apply to most processes and production. Aluminium wheels were chosen as they are part of the automotive industry, which is well recognised as being in the forefront of industrial statistics applications. Oil filters were chosen, as the co-ordinators have had long-term connections with a company manufacturing filters and could advise on details to make the simulation realistic. This package is currently called Process Training. Details can be found on http://www.greenfieldresearch.co.uk.

2. Simulation of clinical trials, for teaching the design of trials protocols and the analysis of simulated data. This package is called MetaGen. It will enable the user to develop and compare protocols for clinical trials to discover the best protocol for any situation. Details can be found at http://www.greenfieldresearch.co.uk.

Work package 4: Reliability, safety and quality improvement

- *Mission*. To disseminate help on improving the reliability of processes, products and systems and help facilitate the philosophy of statistical thinking as applied to the world of work, via workshops and visits.

Work package motivation

There is a need to further the use of reliability modelling – in particular to help companies understand better the whole-lifetime issues involved in product design and how to measure this. Warranty data analysis, lifetimes, failure rates of products and systems all need scrutiny. This work package focused on helping people to understand how to measure these and more complex issues in an operational sense.

The work package investigated ideas relating to the concept of stochastics for quality movement (SQM). SQM brings together several recent research results to develop a structural approach to analysis of reliability data, and introduces some other aspects of reliability analysis, for example data manipulation prior to analysis and analysis of multivariate and covariate structures.

Work package outcomes

WP 4 achieved more than the minimum numbers of visits, workshops, papers and articles during the project. Six industrial visits were completed, two more than the

four required. Five journal papers were submitted, three more than required, and six workshops were run, four more than the contract required. Three articles were published in the popular press, one more than required for this work package.

Sample papers produced by Pro-ENBIS network

D. Romano and G. Vicario (2003) Assessing part conformance by coordinate measuring machines. In T. Bedford and P.H.A.J.M. van Gelder (eds), *Safety and Reliability*. A.A. Balkema, Lisse, Netherlands.

O. Evandt, S.Y. Coleman, M.F. Ramalhoto and C. van Lottum (2004) A little-known robust estimator of the correlation coefficient and its use in a robust graphical test for bivariate normality with applications in the aluminium industry. *Quality and Reliability Engineering International*, **20**(5), 433–456.

C. McCollin, C. Buena and M. Ramalhoto (2003) Exploratory data analysis approaches to reliability: some new directions. In T. Bedford and P.H.A.J.M. van Gelder (eds), *Safety and Reliability*. A.A. Balkema, Lisse, Netherlands.

Work package 5: Discovering european resources and expertise

- *Mission*. To find the statistical resources already available in the European Community, preparing lists of journals, providing a knowledge base of all resources available for the mentoring of European company staff, developing a European database of relevant teaching resources, and organizing a pan-European audit of statistical expertise.

Work package motivation

One of the main purposes of this work package was to investigate what European statistical resources are available. Each country has its own unique provision and very few people are familiar with those of other countries. The various lists produced helped collaboration between members and also led to the creation of the ENBIS Academic Publication Panel, which advises members on how and where to publish their work, and the ENBIS Academy, which co-ordinates the various short courses and workshops run by members at ENBIS conferences.

Work package outcomes

The knowledge base of resources includes four categories:

- A collection of organisations. These are specialist consultancies, institutes, companies, that concentrate on industrial statistics. The database lists the

organisations by country. which makes searching for expertise in a particular country very easy.

- University departments. These statistics departments may or may not concentrate on industrial statistics applications. The database lists the organisations by country. The list also includes entries for non-European countries, such as Australia, Brazil, Canada, China, India, Mexico, New Zealand, South Africa, South Korea, Taiwan, Thailand and United States.
- The national statistics bureaux. These are generally European government statistics agencies that may have useful information.
- Statistical societies. These are a useful contact point, and are listed by country.

The list of European statistical expertise was created by the use of an on-line questionnaire facility provided by a Pro-ENBIS partner. The survey builder can be found at http://www.kpa.co.il/english/surveys/index.php. The website also includes instructions for use and how to launch the survey when constructed.

Work package 6: Drafting and initiating further activity

- *Mission*. Dedicated to drafting and initiating outcomes such as: a series of conferences around Europe on various applications of statistical methodology to measurement in industry and commerce; a new journal that concentrates on application-based case-study material; a European business-to-business mentoring scheme for helping small and medium-sized enterprises; a European measurement system audit programme; and a European training network for helping young graduates to gain advanced statistical skills.

Work package motivation

There was a lot of enthusiasm from partners and members of Pro-ENBIS for working together, and ideas were widely contributed for each of the deliverables. Typically a draft was prepared by the co-ordinator and circulated via the web and/or discussed at a project meeting. The final copy was then completed and presented on the Pro-ENBIS website. A series of meetings and discussions were conducted with relevant standards agencies, in particular in relation to measurement and measurement systems. Other work involved discussions and preparations for introducing a British Standard on Six Sigma.

Work package outcomes

WP6 achieved the deliverables that it set out to complete during the project. A draft for holding a series of conferences around Europe was produced during the

project. Members of Pro-ENBIS have extensive experience of holding conferences. The draft begins with a summary of the conferences held, the numbers attending and the Pro-ENBIS members directly involved in the organisation. It continues with plans for future conferences. Guidelines for costing conferences and a roadmap for organizing them are given, followed by a summary of important points.

The issue of starting a journal produced a very interesting discussion with vigorous debate at a project meeting and thereafter in email exchanges. Broadly there were two camps. There were some people who considered a journal vital to the continued success of ENBIS, even though it would mean that ENBIS members had to pay to join what is at the moment a free-to-join society. Others took the view that there are already too many journals, that it would be difficult to obtain enough material consistently and that ENBIS is better as a rather unusual free-to-join society. In the end an excellent compromise was reached and ENBIS produced a four-page magazine within *Scientific Computing World* (SCW). SCW is posted every 2 months to all ENBIS members who request it. The editors have plenty of material for this and there been no need to raise a subscription.

A list of partners for the European business-to-business mentoring scheme was drawn up in consultation with ENBIS members, as was a list of partners for a European measurement system audit programme and a list of potential partners for a European training network.

Work package 7: Management statistics

- *Mission*. Dedicated to furthering the use of statistics in strategic planning, operational control and marketing in an industrial and commercial context. The emphasis will be on developing concepts for ease of application within the management capabilities of European industry.

Work package motivation

The central question for research in this work package is: What are the contributions of statistics to management processes in organisations? This question is approached from different viewpoints: the quality management viewpoint, the economics viewpoint, an empirical viewpoint, a historical viewpoint, and the statistical programmes viewpoint. The research strategy is to study the central question from these more limited perspectives.

This work package aimed to improve, and in many cases introduce for the first time, the use of process investigation, monitoring and control methods for the better strategic management and operational control of business. Many of the techniques used to monitor processes in industry are directly transferable to the improvement of business processes. Methods such as control charts, cusums, range charts, variance charts, means charts, EWMA charts and the newer multivariate charts are applicable. In addition, a combination of these with other quantitative methods, such as risk analysis, and management tools can greatly improve business

performance. The use of key performance indicators, if properly founded, can enhance the outcomes of most commercial enterprises.

Work package outcomes

The network has developed and furthered the application of management statistics and associated methods in European commerce during the project – in particular, the use of risk analysis within strategic decision-making, advanced methods within operational control and statistical methods to help marketing. The use of conjoint analysis and market analysis via multivariate methods has been promoted throughout the project. The advanced use of statistical modelling, using generalised linear models and similar applications, has been disseminated widely during the project.

Sample papers produced by Pro-ENBIS network

S. Bisgaard and P. Thyregod (2003) Quality quandaries: a method for identifying which tolerances cause malfunction in assembled products. *Quality Engineering*, **15**(4), 687–692.

I. Ograjenšek and P. Thyregod (2004) Qualitative vs. quantitative methods. *Quality Progress*, **37**(1), 82–85.

S. Bisgaard, R.J.M.M Does and D.J. Stewardson (2002) European Statistics Network grows rapidly: Aims to increase understanding, idea exchange, networking and professional development. *Quality Progress*, **35**(12), 100–101.

Work package 8: Network management

This work package was responsible for providing and maintaining the network website, contacting standardization bodies in Europe and reporting and preparing published material. All partners contributed. All periodic reports, including the final project report, were completed on time and the Pro-ENBIS project was successfully concluded on time to the satisfaction of the funding European Commission.

In conclusion

The value of the network was in helping to release the true effectiveness of the many facets of business and industrial statistics for the benefit of Europe. It also helped to introduce these quality methods into non-manufacturing sectors of the economy. Some particular benefits from more effective dissemination of the methods include:

- greater involvement by industry generally;
- better scope for cross-sector learning;
- more intra-state collaborations;

- better-quality products;
- less material and energy wastage;
- technology transfer from wealthier member states to the less well off;
- improved business processes;
- better job creation.

Members are involved directly with the European Committee for Standardization (CEN), the International Organisation for Standardisation (ISO), the Royal Statistical Society (RSS) and most of the major European statistical and quality organisations.

Achievements and the future

- *ENBIS Magazine*, within *Scientific Computing World*, posted free to ENBIS members every 2 months;
- George Box medal for exceptional contributions to industrial statistics established and awarded annually at ENBIS conference;
- prizes for best presentation, young statistician and supporting manager awarded annually at ENBIS conference;
- establish local networks in most European countries;
- have ENBIS members in the top 10 companies in each European country;
- continue Pro-ENBIS type workshop and research activities;
- PROMOTE ENBIS membership widely.

Presidents of ENBIS

2000 Henry Wynn
2001 Dave Stewardson
2002 Tony Greenfield
2003 Poul Thyregod
2004 Shirley Coleman
2005 Fabrizio Ruggeri
2006 Ron Kenett
2007 Andrea Ahlemeyer-Stubbe