

STATISTICAL ISSUES ON QUALITY AND PROCESS CONTROL IN ITALY

An overview and some special topics

Editorial

The intention behind this special issue stems from both the invited session *Statistical Quality Control: Italian Contributions and New Perspectives* (Organizer: Umberto Magagnoli) at the Bologna SIS 2011 Conference “Statistics in the 150 years from Italian unification”, and the DEINDE (Design of INDUSTRIAL Experiments) Workshop held in Turin in 2011.

The Italian Statistical Society (SIS), which promotes the general spread and practical use of statistical methods in various fields, has for many years also been active in the area of Statistical Quality Control (SQC), mainly through the Working Group on Technology and Industry (WGTI), from 1990 to 2002, then through the Coordination Group on Statistics for Companies (CGSC), from 2003 to 2008. The aim of these groups is the establishment of systematic connections with statisticians operating in wide-ranging technological, industrial, and business areas and, at the same time, with universities that provide scientific training for the technical and managerial staff of companies.

A similar goal is pursued by the DEINDE Workshop, which was introduced in the early 1990s as an occasional cooperative endeavor between Turin Polytechnic, Turin University, and ENBIS (European Network for Business and Industrial Statistics). Since its first edition, the objective of DEINDE has been to encourage greater connection between theory and application of statistical methodologies, particularly in various areas of industrial experimentation.

This special issue includes three reviews. The first presents an outline of SQC development from the 1990s onwards with regard to Italian contributions, especially with respect to the activities of the WGTI and CGSC groups, which have led the way from mere technical assessment of defects and nonconformities to new structural paradigms, such as Total Quality Management (TQM), and to the measurement of abstract characteristics, such as customer satisfaction and loyalty. The second review concerns what is still a basic problem in mass production, measurement of process capability. The third review considers conditions under which, through insurance, it could make sense to envisage a form of quality control for financial portfolios.

Further, this special issue addresses the fact that achievement of good quality imposes a continuous adaptation, through scientifically designed experimentation, of goods and services to customer needs. The four contributions described below are devoted to this stronghold of SQC.

Constructs and methods of statistical quality control – The role of the Italian Statistical Society, by Angelo Zanella and Grazia Vicario gives an overview of the evolution of the concept of quality from the 1990s onwards by reviewing, in brief, several noteworthy contributions by Italian statisticians. This paper presents in some detail the evolution of the concept of quality hinted at above. Since the 1950s, it has been evident that the quality construct cannot be represented and measured via merely a few indices. In fact, quality is a kind of “overall imprint” on a product left by an appropriate production system as a whole. Hence, fundamental steps for achieving the goal of “high quality” result from a deliberate process design, suitable raw material selection, and proper management of the manufacturing process and its statistical control, which imply a large number of managerial operations. TQM, for example, represents an *overall* paradigm of quality, which suggests a rational and integrated combination of multiple types of choices and decisions, technical as well as economic and financial, and which has its focal point in personnel involvement. The second part of the paper examines a selection of contributions by Italian authors grouped into the following categories: 1) Scales and measurements; 2) Acceptance sampling plans; 3) Process control; 4) Taguchi approach; 5) Design of experiments for process improvement; 6) Environmental surveillance; and 7) Subjective evaluation and customer satisfaction.

The second paper is entitled *Measuring process capability under non-classical assumptions: A purposive review of the relevant literature*, by Claudio G. Borroni, Manuela Cazzaro, and Paola M. Chiodini. This paper concerns a basic problem in process control, i.e., a generic product characteristic, described by the random variable Y , assumes values in a specified interval (LSL, USL) , respectively the lower and the upper specification limit, with a probability p_1 of reaching LSL , p_2 of exceeding USL , and $(1-p)$ is near 1, $p=p_1+p_2$. In the classical Process Capability Index (PCI): $C_p = (USL-LSL)/6\sigma$, where Y has mean μ and standard deviation σ , it is assumed that Y has a normal probability distribution and, when the process is in control, the same is centered on the specification interval, that is, it should be $\mu=(USL+LSL)/2$ and, given the symmetry of the normal distribution, $p/2=p_1=p_2$, and there is symmetry regarding the rejection probability levels as well. When the hypotheses of normal distribution and/or symmetry are not satisfied, a classical PCI can become inaccurate. The paper presents and discusses recent univariate capability indices aimed at overcoming the difficulties arising in

such cases. Concerning departures from normality, the paper considers: 1) transformation of data to approach a normal distribution; 2) fitting data by a specific model, e.g., Pearson's family, so that quantile-related PCIs can be evaluated; and 3) non-quantile based PCIs, which for example, have recourse to the third central moment. Finally, an entire subsection is devoted to asymmetric tolerances.

The third contribution to this special issue is *Choices about probability distributions and systemic financial risk* by Angiola Contini. Inclusion of this paper in this collection is based on the fact that, besides technical processes and services, there are financial processes whose effects have proved highly negative in recent times and which pose the question of their control. This paper distinguishes between the situation in which the self-regulatory power of financial markets is accepted (hypothesis of market efficiency) and the present framework, which arose after the so-called subprime crisis of 2007. In the hypothesis of market efficiency, it appears to be possible to set up probabilistic limits for losses and to compensate them by means of pertinent insurance: it is as if, in technical statistical process control, a device were available to sort out and repair the defective items. Currently, despite deep mathematical and statistical investigation, financial market complexity appears to make impossible the establishment of reliable and at least medium-term risk thresholds; involvement by bank and state institutions are also factors in this issue.

The following four articles are among the best presented at the DEINDE meeting of 2011.

Form tolerance verification using the Kriging Method, by Grazia Vicario, Suela Ruffa, Giusy Donatella Panciani, and Francesco Ricci, addresses a flatness tolerance requirement, defined as the zone between two parallel planes within which a surface must lie. This paper uses data obtained using a Coordinate Measuring Machine (CMM), which allows probing of the Cartesian coordinates (x,y,z) at a finite number of points, of which only a few, the outer and inner ones, are relevant for the targeted verification. The suggested algorithm – to obtain efficient estimates of the flatness error – is based on the Kriging method, which is an interpolation technique that incorporates the assumption that response values that are spatially close are much more alike than more distant ones. In this method, “surrounding” measured points are weighted to predict unmeasured values with weights based on the distances of measured points and on those from the prediction location. This paper, conducted at a high methodological level, presents several correlation functions necessary to implement the algorithm, various criteria for selecting the next inspection point, and multiple evaluation methods. The paper

includes a final discussion of the experiments performed, comparing the flatness error predicted using Kriging models with various criteria for selecting the next inspection points via a sequential adaptive strategy.

In *Factors affecting measurement uncertainty in industrial CMM work*, by Francesco Aggogeri, Giulio Barbato, Emanuele M. Barini, Gianfranco Genta, and Raffaello Levi, a case study is examined concerning tolerance dimensional verification on a Coordinate Measuring Machine (CMM). The problem considered is how to improve the measurement process via control of factors affecting variability. This clearly manifests as a Taguchi problem, but is treated in a direct, simplified way. Basically, the investigation refers to a 2^3 factorial design with 3 systematic factors, each at two levels, and 8 different experimental conditions, with 5 replications of each trial. The data, including replications, are assumed to come from a fixed-effects linear model with double interactions under the hypothesis of normally distributed errors. The effect of systematic factors on variability is assessed by comparison of the contribution to overall error variance estimation of each of the fixed-effect factors, according to the linear model. In conclusion, an improvement follows with respect to the factors examined: qualification of pieces, temperature, and increasing machine speed. Several advantages are suggested in terms of productivity and lead-time reduction. The case under study is extensively illustrated via the data obtained and the related diagrams.

The third paper of this group is *Roller bench urban cycles identification for light commercial vehicles fuel consumption* by Laura Borgarello, Enrico Galliera, Andrea Avanzo, and Adriano Fagiano. This paper presents a study aimed at indirect evaluation of fuel consumption of light commercial vehicles in real-world conditions simulated on a roller bench through corresponding cycles representative of real, differing contexts. The novelty concerns the statistical approach, which has recourse to principal components, and discriminant and clustering analysis, used to determine the synthetic cycles to be simulated on the roller, starting from the measures obtained during the road experiments. It is shown that the defined roller cycles allow accurate estimation of real fuel consumption.

The last paper, *Agricultural multi-functional vehicles: Choice experiments and random utility models for investigating renewable energies* by Rossella Berni and Ginevra V. Lombardi, addresses an issue that is of capital importance today, encouraging recourse to renewable sources of energy, particularly in agriculture. This study examines the preference and attitudes of farmers regarding the use (assessed utility) of tractors of three types: A-electrical, B-bio-fuel, C-diesel. A sample of 137 plant nursery farms was considered with $137 \times 3 = 411$ stated

preferences, according to 3 supplied choice sets. The paper concludes that electrical tractor utility is positively influenced by the attitude toward electrical vehicles on the part of respondents, by machine noise characteristics, by farm size, by monthly cost difference, and by respondent age. The statistical methodology used is particularly complex, involving the use of choice sets, but this paper is nevertheless well worth reading.

This special issue demonstrates the richness in topics and methodological suggestions peculiar to statistical quality control, owing to their connection to one of the core elements of present economic organization, an integrated system of firms producing goods and services. It is natural that *Statistica Applicata - Italian Journal of Applied Statistics* should continue to contribute particular attention to this area.

Angelo Zanella and Grazia Vicario

Co-editors of this issue