A support tool for the selection of statistical techniques for industrial product development and improvement processes

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Abstract. This paper presents a structured model to help the user choose the most appropriate statistical technique to solve problems relating to the product development process. Starting from a well-defined problem, the model helps the user convert the problem into statistical objectives. Based on those objectives, the decision model then defines a sequence of structured questions whose responses lead to the selection of the statistical technique. The sequence of questions is supported by examples, detailed explanations of the concepts involved, links to sites associated with the case, and a glossary of statistical terms. Statistical techniques are support tools for the New Product Development Process (NPD) and are used in various activities of this process. The main result expected from the use of the model is the dissemination of the application of statistical techniques during the NPD process in companies, especially small and medium companies, where this type of support is most lacking. To enable companies to use and test the structured model, a decision support system will be developed for free access on the Internet.

Keywords. Statistical Techniques, New Product Development Process, Web-based System.

1 Introduction

The industrial sector shows an increasing demand for statistical knowledge to deal with quantitative or qualitative data. This demand is partly a result of normative processes (ISO, TS, QS) and of quality improvement programs strongly based on statistical techniques. These techniques include the Six Sigma programs for the improvement of manufacturing processes and DFSS (Design for Six Sigma) for the improvement of new product development processes. These programs have created methodologies based on quality techniques and tools to lead to the solution of industrial problems. These tools and techniques can aid in the solution of different

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problems relating to the improvement of products and processes and of the new product development (NPD) process.

DFSS is based on the integration of tools such as QFD, Pugh's Matrix, and statistical tools of multivariate analysis and Design of Experiments in NPD. The objective is to establish an integrated set of tools as a means to efficiently translate information in the development phases, favoring the incorporation of technical, strategic and financial values to the product in order to meet consumer and market needs. While Six Sigma programs work in the ambit of reaction and correction of existing problems in the domain of the process, DFSS is used for the prevention of problems through the use of quality tools and statistical techniques in the product's conception phase [2].

The product development process, in turn, has been systematized and structured in so-called reference models, which represent the process and serve as a guide for its application. Starting from a generic reference model, a company can define its specific model, also known as standard process, which becomes a "manual of procedures" and serves as the basis for the specification of product development projects, thus ensuring the repeatability of the company's projects as well as constituting a repository of best practices.

Many of the activities of product development and process improvement make use of quality tools involving statistical techniques. Throughout NPD, from the conception phase of a product to its removal from the market, methods and tools are employed to support the execution of the diverse activities of this process. However, for the business user to apply the best statistical technique, he must be familiar with the available techniques and with all the presuppositions required for its correct application. This knowledge is normally a specialist skill, since a variety of questions and conditions must be analyzed before a specific technique is selected. In particular, the transition of a practical problem into statistical/research objectives is the first obstacle to the choice of the most suitable technique. Despite the advances in computational systems, which seek to improve the interface with the user and to automate some of the steps of statistical analysis, the phase prior to the application of the technique, involving the choice and planning of which analysis to use, is not effectively aided by existing software programs.

Based on the experience of the authors and on interviews with company users and specialists, a series of problems commonly encountered in the use of statistics was drawn up, which include learning strongly based on the teaching of the execution of the technique. Six Sigma programs, for example, are usually based on the execution of exercises carried out immediately after the presentation of a technique, which, to a certain extent, directs or guides its application. The interpretation of the data centers on the needs of the statistical software and on the output data supplied in the analysis. The companies interviewed indicated that a problem is the difficulty in recognizing which technique to use in real situations, even when there is a previous notion of the technique. It is difficult to understand how to organize thoughts, i.e., how to plan the study, from the definition of the sample to the identification of variables to be studied and the type of analysis that is viable.

The Six Sigma and DFSS programs are examples and an opportunity to integrate the statistical method to practical problems in the industrial context as a way to understand and analyze the solutions to problems. Despite the many efforts and advances in this area, the application of statistical techniques is still limited. There is a potential (a range of techniques and new possibilities for use) as yet unexplored by industry, but the use of statistics is not seen as something easy. It would be necessary to help users understand how this reasoning works, especially in terms of associating the theory with their reality and with their problem.

This article proposes a structured model for the selection of statistical techniques. Starting from a decision structure composed of questions and possible answers, the user is led to one or several statistical techniques that are suitable for his problem. This proposal is more than a simple guide, since it also provides knowledge to help the user understand the process of selection, based on the presentation of examples, a glossary of statistical terms and a description of key concepts to grasp the techniques.

2 Methodology

The approach most widely adopted in this project is the hypothetical-deductive approach proposed by Karl Popper in 1935. This approach allows for the creation of a set of postulates, tools and hypotheses that one attempts to refute by means of experiments, based on which one deduces the consequences, which, when refuted, are replaced by others [4].

With regard to technical procedures, this work is classified as action research, since it focuses both on action and on the creation of knowledge or theory about the realization of innovative projects. Action research is recommended for new approaches where new ideas must be explored and knowledge must be created from the standpoint of practical aspects. A close association must be conceived and made with an action or with a solution for a collective problem, in which the researchers and participants representing the problem are involved cooperatively or participatively [8].

Based on this methodological reference, the model foresees the phases of bibliographic review, content systematization that includes the classification of statistical techniques and modeling of the decision process for the choice of technique, and elaboration and organization of the content. These phases are described below.

2.1 Bibliographic review

The model was built based on consolidated information available in didactic books about techniques and application of statistics in a wide range of areas of knowledge. In this bibliographic review, information was collected enabled us to outline the decision structure for selecting the technique best suited to the problem in question. The most exhaustively consulted references were [2, 3, 5, 7].

2.2 Content systematization

2.2.1 Classification of statistical techniques
The classification of statistical techniques was organized to characterize the gamut of possibilities. The classification was based on the categorization of books on statistics summarized in the works [3, 8].

This phase is fundamental, since it is this combination of possibilities that allows for the indication of an analytical technique.

The proposed model initially broaches the use of several techniques, the ones most frequently used in the industrial sector, which are highlighted, for example, in DFSS.

2.2.2 Modeling of the decision process for the choice of a statistical technique
Based on the classification of the techniques, the possibilities and ramifications were defined, resulting in a structured decision model with the logic of what information would be necessary to recognize the statistical technique.

2.2.3 Elaboration and organization of the content
The structured model was used as the basis to elaborate the support contents, which will enable the user to know and learn more about the concepts involved in the analysis. From previous experience, it is known that the use of statistics produces better results when one presents practical examples relating to the user's daily routines. Thus, for each concept, the system intends to associate a description, with additional references (links), examples of cases and a glossary of terms.

2.3 Definition of the target public

The definition of the target public refers to the user of the model. The initial target public is a professional of the industrial sector possessing basic knowledge of statistics, with a degree in engineering, administration or the graduate of training courses such as Six Sigma or other quality programs encompassing statistical techniques. Thus, the user of the model is not a layman in the use of statistical techniques. We believe the system will serve as a support tool in various activities involving an understanding of data on the market and the product that is being developed. Therefore, the target public may be the product development team itself, which already has a way to treat and analyze data integrated with the team's technical knowledge.

2.4 Requisites of the model

Based on this context, the structured model should aid users in their selection of statistical techniques applicable to the improvement of industrial products and processes. This model includes some basic properties that are summarized in four main points: (1) It should help the user understand the research problem for the use of statistical techniques. (2) It must be a learning instrument that teaches terms employed in statistics, concepts and access to links to delve deeper into the subject.

(3) It should allow the user to standardize his research projects following the logic of the model. (4) It should favor the insertion of new techniques, broadening the range of possibilities for the problems involved in new product development.

3 The structured model

The selection of a suitable Statistical technique to solve a company's problem or to provide information about it depends on the user's technical knowledge and on an understanding of a series of questions of the Statistical domain for this decision. Starting from the theoretical review described in the bibliographic review phase and on the experience of the authors in the application of Statistics in the area of product development, a structure was outlined and subdivided into the following stages: (1) Scope of the problem; (2) Definition of the statistical objective; (3) Number of variables involved in the analysis; (4) Type of relationship among the variables; (5) Number of explanatory variables or number of samples; and (6) Measurement scale of the variables. The analytical technique is indicated based on a route (combination of the answers given by the user). Figure 1 presents the proposed decision model.

The selection of the technique is the result of a sequence of questions. These questions were drawn up based on the stages defined previously. One or more suitable techniques can be identified based on a set of answers given by the user. This process is described in greater detail below.

The application of statistical techniques usually involved general objectives, which allow one to direct a subset of techniques. In this work, since our focus is on the product development process and on the DFSS methodology, it was possible to specify several objectives, called the scope of the problem (stage 1), which represents the cycle of improvements of a product or process. This cycle is based on diagnostic, optimization, control and analytical techniques.

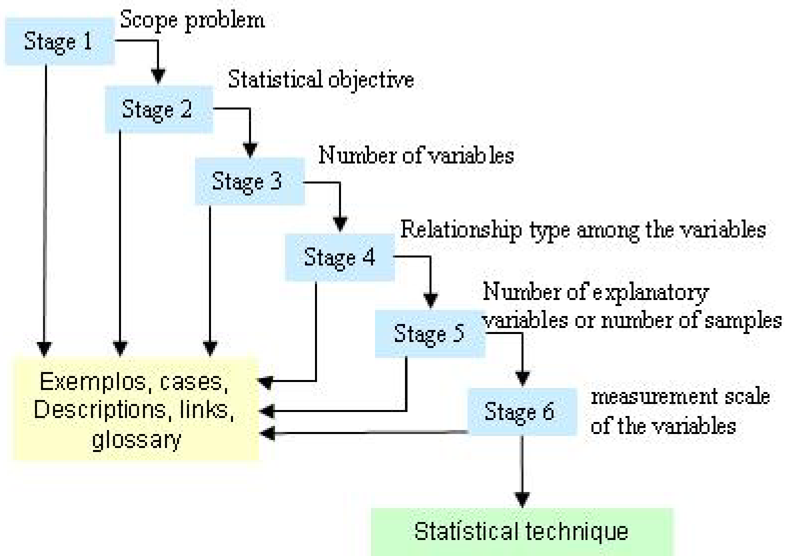

Figure 1. Structured model for the selection of a statistical technique

Diagnostic techniques are techniques of preparation and deepening of knowledge of the research problem. For example, the analysis of a mensuration system involves checking the capacity of the mensuration instruments and procedures to supply reliable measures for subsequent analysis. This group includes reliability analysis to evaluate the performance and quality of product development.

Optimization techniques are defined as the experimental design and surface-response methodology techniques.

Control techniques are those that monitor and ensure system quality, and are basically the techniques pertaining to Statistical Process Control (SPC).

Analytical techniques were classified as the statistical techniques most frequently used in industry and applicable to the PDP (product development process). The group of analytical techniques includes the following: hypothesis testing, simple regression, logistic regression, multiple regression, ANOVA, multivariate analysis, etc. The structured decision model was created for this group, since it comprises techniques that can be used during the phases of PDP.

In the group of techniques associated with analysis, the following statistical objectives can be specified (stage 2): relate, model, associate, verify, test or compare. Thus, the user's research objective should be aligned with some of these predefined statistical objectives.

Proceeding along the decision structure, one questions the number of variables involved in the analysis (stage 3). This option helps the user understand and classify his study as one variable at a time (univariate), two variables (bivariate) or K variables simultaneously (multivariate). In each stage, the process of choice is supported by examples, a glossary of terms with an explanation of the meaning of each of the statistical terms used in that stage, a more detailed technical description about the terms, and links for the user to consult.

In stage 4, one questions the type of relationships among the variables, e.g., dependent (simple or multiple) or independent. In stage 5, one verifies the number of explanatory or independent variables in the problem, or else the number of samples. And lastly, in stage 6, a question that is common to all the possible alternatives, the user classifies the measurement scale of the variables involved, i.e., as metric (intervallic) or nonmetric (nominal or ordinal).

To validate the proposed structure, new tests should be conducted to test the sequence of questions and their applicability to different cases. We believe that statistical technical language should always be accompanied by simpler language aided by examples. When the user is able to translate and relate statistical ratiocination into his daily routine, he will also be more qualified to read books, articles and other studies that deal with statistical techniques focusing on his area. As he uses the model for various studies (projects), this language will become incorporated into his everyday life. Thus, in the end, experiments planned more scientifically and reliably gradually become part of his routine.

It cannot be stated that all problems can be classified from the questions suggested here, but it should be noted that this classification encompasses most cases, although one can expect to encounter situations that do not fit into the set of foreseen possibilities. However, this is an initial proposal, which should be improved and perfected based on the results of its application in companies and on refinements of the available knowledge about the use of statistical techniques.

4 Results expected from the model

Some of the principal contributions expected from the use of this model are: (1) greater utilization of statistics in tests and experiments on existing products and in the development of new products, helping improve quality through a better understanding of how the characteristics and quality of a product are correlated and affect its performance; (2) An understanding of the nature and workings of alterations to products can be obtained through statistical analysis, such as the treatment of data from tests and simulations, contributing to basic research in the study of new technologies and materials; (3) The possibility of applying and perfecting techniques and methodologies for the dissemination of statistical knowledge integrated to product and process quality improvement; (4) The possibility of generating new methodologies to understand what variables are critical to the quality of a product, adapted to the sector under study; (5) Render viable the integration of statistical techniques as PDP tools.

5 Final considerations

This article presented the development of a proposal for the elaboration of a support model for users in the selection of statistical techniques applicable to industrial product and process improvements. The resulting systematics refers to a decision model that attempts to reproduce the questions a professional knowledgeable about statistics would ask himself in the selection and planning of a statistical technique.

The main users are professionals with a basic knowledge of statistics, who aid product development or quality project improvement teams in the use of statistical techniques for treating data, helping them understand, conceive and measure product performance. The model is also easily applicable to the stages of a Six Sigma project.

We intend to continue this project in the future, developing an interactive system in the Web environment, which will enable the user to include new information in the model, such as examples, definitions, comments about best practices, articles about cases of application, etc. In addition, the system will constitute a tool integrated to the reference model for the product development process [6], since it is already available for consultation on the URL hppt://www.pdp.org.br. Many activities of the model use statistical techniques. Details of which technique to use and how to use it would be supplied by the proposed system.

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