# Methodology of Teaching Statistical Methods for Quality Control and Process Improvement

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ABSTRACT: *The study branch of Quality Management has been guaranteed by the department of Quality Management which was established in 1992 at the Faculty of Metallurgy and Material Engineering at VŠB-Technical University of Ostrava, Czech Republic. In the frame of full-time and extramural (bachelor and PhD) studies we prepare specialists for building, maintenance and development of Quality Management Systems, Environmental Management Systems, Integrated Management Systems. Except the questions of the above systems human factor and technical and technological issues we put the extra stress on the knowledge and skills in the area of the applied statistics especially on methods for the quality control and process improvements.*

*The methodology of teaching applied statistics is based on the following main premise:* ***"Students must have deep and excellent theoretical grounding."*** *This premise we try to meet by teaching two theoretical subjects: "Theory of Probability" and "Mathematical Statistics".*

***"The deep knowledge of algorithms of every taught method"*** *is the second basic premise.*

*This has been met by the division of teaching applied statistics into several special subjects: "Special Statistical Methods", "Econometrics", "Design of Experiments". Some statistical methods are studied in the frame of subjects "Quality Planning" and "Computer Aided Quality Management".*

*Two basic premises mentioned above are necessary but not sufficient ones. Additional pre-conditions for the student to be able to apply statistical methods in practice correctly are as follows:*

- *ability to select correct method,*
- *knowledge of pre-conditions for effective application of every statistical method,*
- *knowledge of procedures for validation of these pre-conditions,*
- *ability to interpret obtained results in a correct way,*
- *ability to apply methods in various practical conditions (for manufacturing and non-manufacturing processes, too),*
- *ability to use correctly statistical software (to understand input requests and interpret correctly outputs).*

*In this paper the application of the above premises on teaching methodology in the frame of the subject „Special Statistical Methods" is shown using the analysis of the exercise*

*„Complex Statistical One-Variable Analysis". An example of the outputs of the applied statistical software STATGRAPHICS Plus for Windows ,version 5 is the part of the exercise analysis.*

## 1 INTRODUCTION

The study branch of Quality Management has been guaranteed by the department of Quality Management which was established in 1992 at the Faculty of Metallurgy and Material Engineering at VŠB-Technical University of Ostrava, Czech Republic. In the frame of full-time and extramural (bachelor and PhD) studies we prepare specialists for building, maintenance and development of Quality Management Systems, Environmental Management Systems, Integrated Management Systems. Except the questions of the above systems human factor and technical and technological issues we put the extra stress on the knowledge and skills in the area of the applied statistics especially methods for the quality control and process improvements.

The methodology of teaching applied statistics is based on the following main premise: **"Students must have deep and excellent theoretical grounding."** This premise we try to meet by teaching two theoretical subjects: "Theory of Probability" and "Mathematical Statistics".

**"The deep knowledge of algorithms of every taught method**" is the second basic premise. This has been met by the division of teaching applied statistics into several special subjects: "Special Statistical Methods", "Econometrics", "Design of Experiments". Some statistical methods are studied in the frame of subjects "Quality Planning" and "Computer Aided Quality Management".

The scopes of mentioned subjects for full-time (FT) studies in hours per week and for extramural studies (E) in hours per one term are in table 1.

Table 1. The scopes of statistical subjects for study branch of Quality Management

| **Subject** | **FT** | | **E** | **Obligatory Subject** |
|---|---|---|---|---|
| | ***Lecture*** | ***Exercise*** | ***Block*** | |
| Mathematical Statistics | 3 | 2 | 20-0 | Yes |
| Special Statistical Methods | 2 | 4 | 10-10 | Yes |
| Econometrics | 2 | 2 | 14-0 | Yes |
| Design of Experiments | 2 | 1 | 14-0 | Yes |
| Quality Planning | 2 | 4 | 18-0 | Yes |
| Computer Aided Management | 1 | 3 | 8-6 | Yes |

Two basic premises mentioned above are necessary but not sufficient ones. Additional pre-conditions for the student to be able to apply statistical methods in practice correctly are as follows:

- ability to select correct method,
- knowledge of pre-conditions for effective application of every statistical method,
- knowledge of procedures for validation of these pre-conditions,
- ability to interpret obtained results in a correct way,
- ability to apply methods in various practical conditions (for manufacturing and non-manufacturing processes, too),
- ability to use correctly statistical software (to understand input requests and interpret correctly outputs).

In this paper the application of the above premises on teaching methodology in the frame of the subject „Special Statistical Methods" is shown using the analysis of the exercise „Complex Statistical One-Variable Analysis". An example of the outputs of the applied statistical software STATGRAPHICS is the part of the exercise analysis.

## 2 GENERAL CHARACTERISATION OF SUBJECT "SPECIAL STATISTICAL METHODS"

Subject "Special Statistical Methods" can be briefly characterised as follows:

The understanding of statistical thinking principles inclusive methods of practical process variability analysis is the main goal of this subject. The subject especially deals with the basic tools of quality control (check sheets, histograms, Ishikawa diagram, flow charts, Pareto analysis, scatter plots) and with complex methodology of statistical process control and acceptance sampling. The special stress is put on verification of meeting the preconditions for every studied tool application (using testing of statistical hypotheses, exploratory data analysis methods etc.) and on the obtained results interpretation.

Theoretical subjects "Theory of probability" and "Mathematical Statistics" form the prerequisites for "Special Statistical Methods".

In the frame of "Special Statistical methods" students must work out four complex individual programs with topics:

Program 1 - complex statistical one-variable analysis,

Program 2 - application of flow charts, Ishikawa diagram and Pareto analysis,

Program 3 – application of acceptance sampling,

Program 4 - application of statistical process control.

In the next chapter the main goals and content of the exercise for training the complex statistical one-variable analysis are defined. This exercise gives theoretical and practical background for program 1.

# 3 THE GOALS AND CONTENT OF EXERCISE FOR COMPLEX STATISTICAL ONE-VARIABLE ANALYSIS

## 3.1 The general goals

The exercise on complex statistical one-variable analysis has following goals:

- summarise and extend information obtained from theoretical subjects "Theory of Probability" and "Mathematical Statistics",
- fail into the habit of verifying the data preconditions as the basis for the right selection of statistical tool for the next statistical analysis (for instance before selection of the suitable control chart for monitoring and control of processes),
- learn the basic data precondition (data normality, data independence, data homogeneity) using alternative tests of statistical hypotheses and various exploratory graphs,
- learn selection of suitable test of statistical hypothesis or graphical tool considering conditions for their application (for instance considering sample size by the selection of the test for normality),
- learn the interpretation of the results from tests of statistical hypotheses and graphical tools,
- learn making the conclusions, knitting the results of the tests of statistical hypotheses and graphical methods altogether.

## 3.2 Contents of the exercise

In this paragraph the tasks of the exercise for complex statistical one-variable analysis and their goals are defined.

**Task 1 definition**

Using random number generator generate a population form

a) normal distribution,
b) normal distribution with outliers,
c) skewed distribution.

**Task 1 goals**

– create data basis for the solution of the next tasks,
– learn exploitation of the random number generator.

**Task 2 definition**

Verify normality of all three populations using

a) histogram,
b) Box-Whisker plot,
c) Q-Q plot,
d) Chi square test,
e) Kolmogorov-Smirnov test,
f) combined test for skewness and kurtosis

and compare results.

**Task 2 goals**

– show various alternatives of tests of statistical hypotheses and exploratory graphs for verifying the data normality,
– explain interpretation of their results,
– discuss conditions for the application of the different statistical tests for normality and
– goodness-of-fit tests,

– discuss the influence of the distribution type on the results of the different normality tests and on the shape of various exploratory graphs,
– learn creation of own statistical test for normality that is not the part of the applied statistical software (for instance combined test for skewness and kurtosis).

**Task 3 definition**
Verify homogeneity of all three populations using
a) graphical tools,
b) Grubbs test.
Make a discussion about the influence of outliers on the results of the tests for normality and goodness-of-fit tests.

**Task 3 goals**
– learn special data homogeneity tests their limitations including,
– discuss the influence of the outliers on the results of the different normality tests and on the shape of exploratory graphs,
– learn how to solve outliers (obvious elimination of outliers from the population is not suitable solution for every situation).

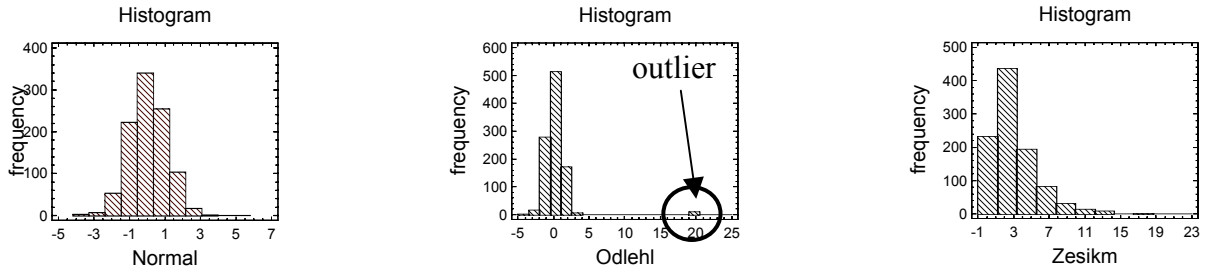
**Task 4 definition**
Verify the data independence using
a) graphical tools,
b) tests for randomness.

**Task 4 goals**
– learn construction of the own autocorrelation plot,
– learn interpretation of selected tests of statistical hypotheses and graphical tools for verifying the data autocorrelation.

## 4 EXAMPLES OF SELECTED OUTPUTS OF THE EXERCISE FOR COMPLEX ONE-VARIABLE ANALYSIS

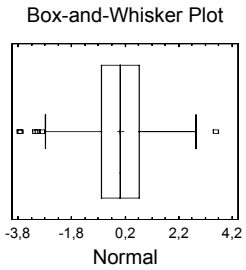
In this chapter some examples of the outputs from tasks 2, 3 and 4 of the analysed exercise are shown. The exercise has been solved using statistical software package STATGRAPHICS Plus for Windows, version 5.

**Task 2 and 3 outputs**
On Figure 1-3 various exploratory graphs for different generated populations are shown.

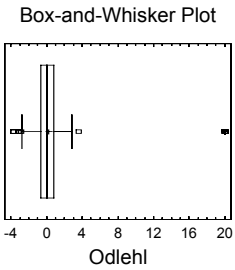



Population from normal distribution | Population from normal distribution with outlier | Population form skewed distribution

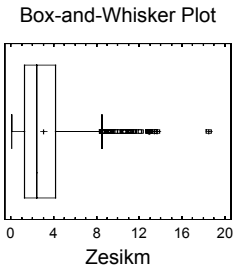
Figure 1 - Histograms for three generated populations




Population from normal distribution

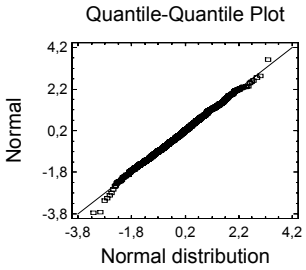



Population from normal distribution with outlier

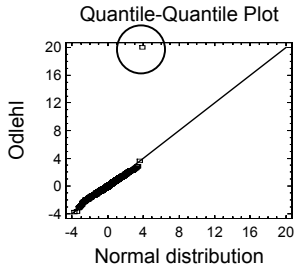



Population form skewed distribution

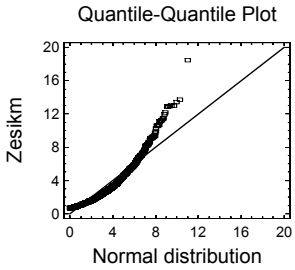
Figure 2 - Box-Whisker plots for three generated populations




Population from normal distribution




Population from normal distribution with outlier




Population form skewed distribution

Figure 3 - Q-Q plots for three randomly generated populations

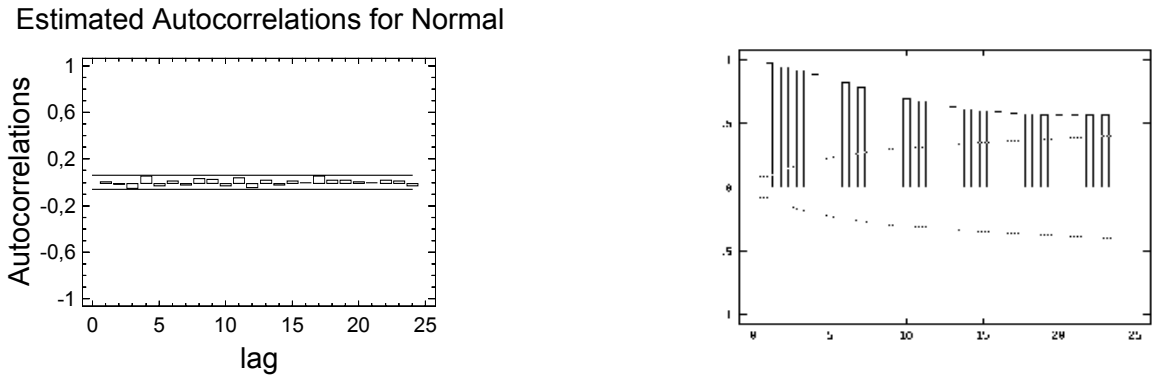
In Table.2 the different results of selected normality tests are shown.

Table 2. Results of Chi square test and K-S test for populations from various distributions

| **Results of Chi square test** | **Results of K-S test** |
|---|---|
| ***Population from normal distribution*** | |
| Chi-square = 4,87365 with 8 d.f.<br>P-value = 0,770991 | DPLUS=0,0144518<br>DMINUS=0,0166044<br>Estimated overall statistic DN=0,0166044<br>Approximate P-value = 0,945608 |
| ***Population from normal distribution with outlier*** | |
| Chi-square = 44,9777 with 8 d.f.<br>P-value = 3,71602E-7 | DPLUS=0,0447609<br>DMINUS=0,0420354<br>Estimated overall statistic DN=0,0447609<br>Approximate P-value = 0,0363728 |
| ***Population from skewed distribution*** | |
| Chi-square = 278,334 with 8 d.f.<br>P-value = 0,0 | DPLUS=0,120744<br>DMINUS=0,116339<br>Estimated overall statistic DN=0,120744<br>Approximate P-value = 0,0 |

**Task 4 outputs**

On Figure 4 autocorrelation function (ACF) for autocorrelated and independent data can be seen respectively.




ACF for independent data

ACF for autocorrelated data

Figure 4 - Autocorrelation functions

## 5 APPLICATION OF THE LEARNED KNOWLEDGE

Knowledge and information obtained through the exercise for complex statistical one variable analysis are applied by students on the individual program "Complex data Analysis" where meeting data preconditions is verified on the real data sample. In addition to exploratory data analysis next step of data analysis must be done in the program – statistical inference and defining tolerance limit connected with determined maximal defect rate.

## 6 CONCLUSIONS

At the Department of Quality Management at the Faculty of Metallurgy and Material Engineering a big stress has been put on the statistical thinking. Statistics does not mean only huge of formulae but it is considered to be an effective tool for understanding and reducing variation of processes increase of quality of the processes outputs cutting costs and process lead time.

## REFERENCES

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