Analysis of service quality indicators in telecommunications using control statistical methods and fuzzy logic

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Abstract

Brazil's telecommunications, in the last years, have faced deep changes with the creation of ANATEL – the National Bureau of Telecommunications - in 1997. ANATEL is a telecommunications regulation bureau whose mission is to keep up the quality levels of services by Telecommunication Companies acting in Brazilian territory, so that they are compatible with international standards. The quality control is performed by indicators [3], which are collected monthly from companies. Those companies that do not achieve the goals may have their contracts cancelled. This work takes care of some methodologies for ANATEL quality control, analysing performance indicators and presents Brazil's telecommunications services performance. Traditional Statistical Quality Control graphs (CUSUM) are used and the results are analysis by fuzzy logic. The results are presented in a graphical interface that allows the user to analyse the whole indicator set. The results show that fuzzy logic allows the implementation of soft thresholds to trigger alarms before the indicators reach forbidden levels.
Keywords: quality services telecommunication, control statistical methods, fuzzy logic indicators, quality indicator.

1 Introduction

The Regulating Agency Telecommunications in Brazil - ANATEL, monthly receives from the operators of public services (service providers), fixed and mobile telephony, indicators that show the quality of services. Control limits for the indicators are established to guarantee specified standards of quality in the



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concession. The prompt analysis does not have to predict trends that would anticipate problems, to make decisions that correct such possible problems or to prevent that bigger shunting line comes to occur. The present work uses Statistical Control Process methodologies (SCP), taking in to consideration the historical series of the indicators, aiming to raise shunting line problems of averages - CuSum methods [1] and Fuzzy Logic [2] to be able to get a qualitative indicator evaluation.

1.1 Soon historical

The opening of telecommunications sector made possible to the transfer of companies control, which belonged to the former TELEBRÁS (State Company), to free competition. To there was also the entrance of new companies (mirror and little mirror companies - "E*spelhos and Espelhinhos"*), that modified complete the telecommunication services market, tariffs and prices, resulting in a significant improvement of quality. These changes were possible because the laws of federal constitution of Brazil - CF/1988 authorized the creation of the regulating agency (ANATEL). The function of ANATEL is to guarantee and control the competitive quality, prices and telecommunications for all people *(universalização*). Were defined to guarantee the quality indicators for fixed telephony (PSTN – Public Switch Telephony Network), and later for mobile service (SMC - Commuted Mobile Service). These indicators are party of the contract of grant that was signed with the current service providers.

2 The indicators of quality

The indicators are divided in groups of goals and in each group indicators and goals were established in function of years 2000 to 2005. The uses of services are sufficiently changeable all day long, with distinct tariffs. The following Most Movement Periods (MMP) in day were created:

1) Period 09:00 to 11:00am
2) Period 02:00 to 04:00pm
3) Period 08:00 to 10:00pm

The groups of GOALS are divided as the following:

I. Goals of quality service;
II. Goals of attendance to repair requests;
III. Goals of attendance address changes;
IV. Goals of attendance for telephone to the user;
V. Goals of quality of telephone of public use – TUP;
VI. Goals of information area code;
VII. Goals of attendance the correspondence;



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VIII. Goals of personal attendance to the user;
IX. Goals of emission of accounts;
X. Goals of updating net.

The first step of this paper is the Goals of Quality Service (table 1) using the first group of GOALS and INDICATORS of Brazil (consolidated). The others indicators, which are available in ANATEL's site [3], will not be analyzed.

Table 1: Goals of quality service.

• To get signal to dial - MMP, in the maximum of 3 seconds in 98% of the cases [fig.3].
• Completed Local Calls (LC) [fig.4] and Long National Distance (LND) [fig.5] in the MMP: -65% from 31/12/2001 and 70% from 31/12/2003
• Calls not completed – Engaged lines - LC [fig.6] and LDN [fig.7] - MMP:-5% from 31/12/2001 and 4% from 31/12/2003.
• The calls have to be carried through with good quality of transmission, in adequate levels and without noise or interference, with low incidence of fall of linking, in the terms of the telecommunication regulation.

2.1 ANATEL´s indicators evaluation

The process can be summarize as the following

- The operators monthly send the indicators to ANATEL using electronic system, which receives them and compares with the goals established in contract. For indicators that are out of the standard, the operators have to justify, otherwise they will be punished;
- After that, the indicators Brazil are calculated, and these are the indicators used in this paper to develop the methodology.

The ANATEL's control can be defined

I. indicators monitored by the Agency - Internet;
II. auditorship carried through by the Agency;
III. research opinion of quality services with the users;
IV. monitoring evaluation of quality service by users or group of users;

Table 2 present correlations between quality service indicators. It is noticed a weak relation between the indicators, only inverse relation between group III and group IV. Then it will be used all quality indicators in analysis. The process analysis show that there are much little variations from one month to other [3].

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Table 2: Correlation matrix - quality indicators.

	GROUP I	GROUP II	GROUP III	GROUP IV	GROUP V
GROUP I	1	0,182393	-0,32795	0,279461	-0,18143
GROUP II	0,166719	1	-0,41307	0,382815	-0,18143
GROUP III	-0,31392	-0,41307	1	-0,871176	0,407841
GROUP IV	0,279461	0,382815	-0,87118	1	-0,523454
GROUP V	-0,15224	-0,18143	0,407841	-0,523454	1

This work uses tools of Statistical Control Process (SCP), combined with computational intelligence methods Fuzzy Logical to visualize the indicators behavior for long time and diagnosis problems before the same ones come to happen and to exceed the limits (goals) established for ANATEL. These methods can be used as support DSS Systems –Decision Support System.

2.2 Overview - SPC methodologies

Process control graphs usually have the following elements:

- CL - CONTROL LIMIT - Expected value on which the variations of process must occur. They can be an average value, standard deviation, and others;
- UCL - UPPER CONTROL LIMIT - value upper which if exceeded the process will indicate to be outside of control;
- LCL - LOW CONTROL LIMIT - value low which if exceeded the process will indicate to be outside of control;
- USL - SUPERIOR UPPER LIMIT - superior maximum control limit of the process. This value could not be exceeded;
- LSL - LOW SUPERIOR LIMIT - inferior maximum control limit of the process. This value could not be exceeded;

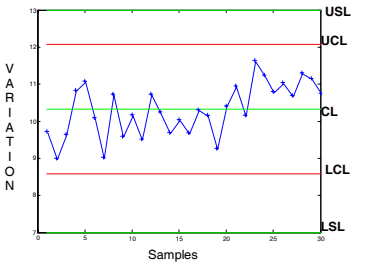


Figure 1: Shewhart graph.

One example used by Montgomery and Douglas [1] be used to facilitate understanding of SCP:

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- In a determined process a set of 30 values is extracted, which the 20 first ones possess average $\mu_0 = 10$ and standard deviation $\sigma_0 = 1$, and last the 10 samples possess average $\mu_1 = 11$ and standard deviation $\sigma_1 = 1$.

The values are around the action limit CL - the average of the values of all the samples. None of the values are out of the control limits, and the visualization of the process are a trend of variation in the average. However, it is not easy to notice that the process is out of control.

2.2.1 Method CuSum – cumulative sum control chat

The CuSum method is used to detect small alterations in the process, which cannot be well visualized by the traditional methodologies; therefore, it accumulates these small variations before an established point. Assuming samples $n \geq 1$ are collected and x_j is the average of sample "j".

- If μ_0 is the average of the main process CuSum is formed by the locate of:

$$Ci = \sum_{j=1}^{i} (x_j - \mu_0) = (x_i - \mu_0) + \sum_{j=1}^{i-1} (x_j - \mu_0) \quad (1)$$

  - $\mu_1 > \mu_0$: a positive add will be developed
  - $\mu_1 < \mu_0$: a negative add will be developed

$$Ci = (x_i - \mu_0) + C_{i-1} \quad (2)$$

  where . x_i – sampling . μ_0 - average
  . C_{i-1} - previous value of C_i (initial value $C_0=0$)

- Tabular CuSum: Definition: C_i^+ - upper side
  C_i^- - low side
  - $C_i^+ = \max [0, x_i - (\mu_0 + k) + C^+_{i-1}]$
  - $C_i^- = \max [0, (\mu_0 - k) - x_i + C^-_{i-1}]$, where:
    - Start value: $C_0^+ = C_0^- = 0$
    - k - value of reference or how much that it will go to vary in function of average (μ_0).

The CuSum graph, figure 2, shows previous example of the 30 samples, register the removals the average making the accumulation of these values, to each sample. With this observe that the process from sample 23, trends to out of the control, being exceeded the UCL.

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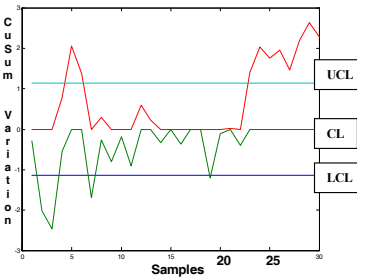


Figure 2: CuSum Graph.

2.3 Fuzzy logic

A fuzzy set is an extension of the classic concept of sets through a membership function:

$$m_A(u):U \quad [0,1] \tag{3}$$

it determines how much object "*u*" belongs to the set A.

The membership function used will be TRIANGULAR:

$$Tri(x;a,b,c) = \max[\min[(x-a)/(b-a), (c-x)/(c-b), 0\ ] \tag{4}$$

The Diagnosis of the indicators, using the fuzzy logic can be seen on tree aspects:

a) Traditional Analysis (2 outputs)

- OK or Not OK (Alarm)

b) Fuzzy Analysis -(3 outputs)

- OK - Value inside of goal

Not-OK - Alarm

Fuzzy Ok/Not-Ok, with membership degree.

c) Fuzzy Possibility Analysis (4 outputs)
Where consideration possible errors in the proper e measured, therefore:
- Ok / Not- Ok : The value measured and the result of the measure.

The methodology used will be Fuzzy Analysis (b) with 3 outputs using how input CuSum result data, where it obtains to detect the small variations in the average of the process.

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3 Methodology analysis indicators

All the indicators values are considered in the MMP, for periods Morning, Afternoon and Night. The programs and graphs was made by MATLAB [5], following the routine.

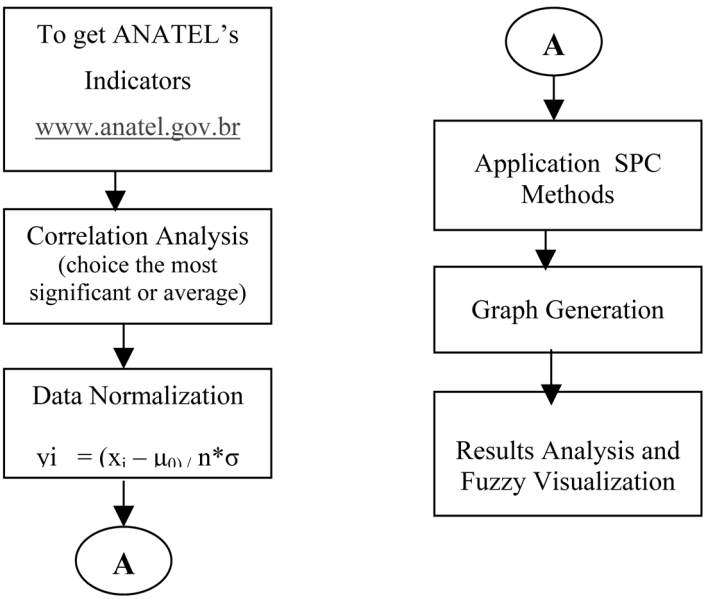


Figure 3: Implementation routine.

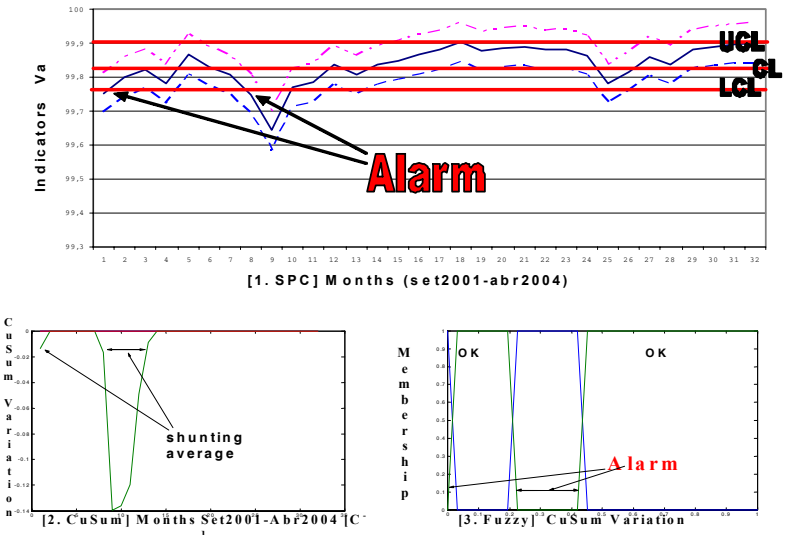


Figure 4: To get signal to dial – MMP.

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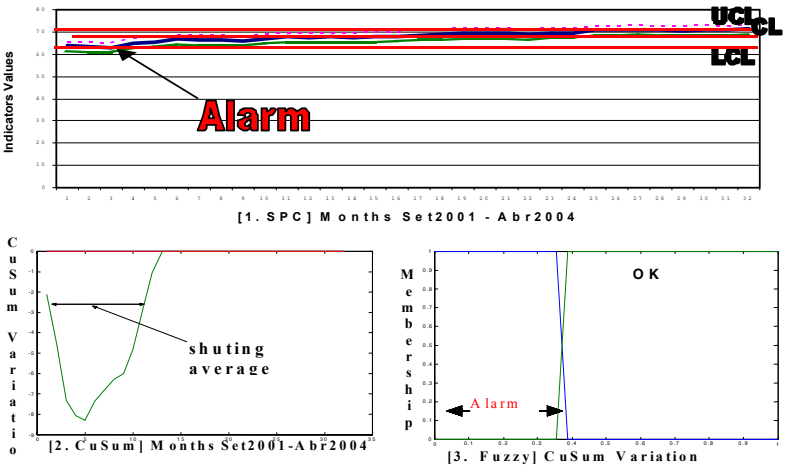


Figure 5: Connected local calls - MMP.

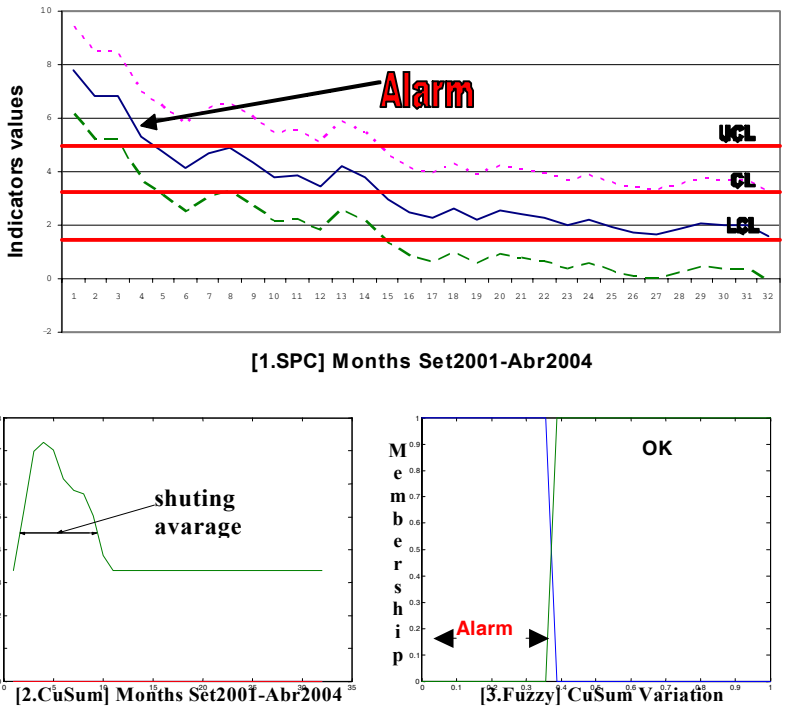


Figure 6: Connected long national distance calls (LND) in the PMM.

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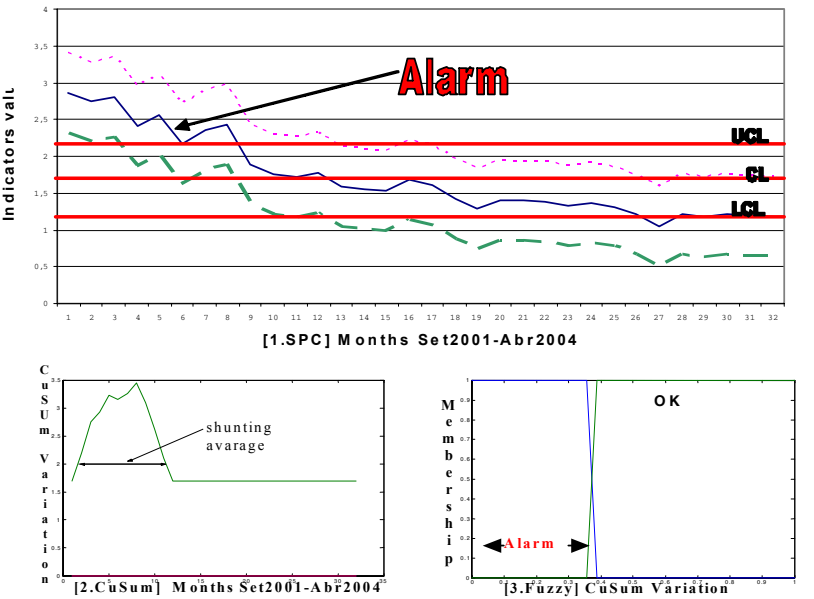


Figure 7: Not connected calls - congestion LND – MMP.

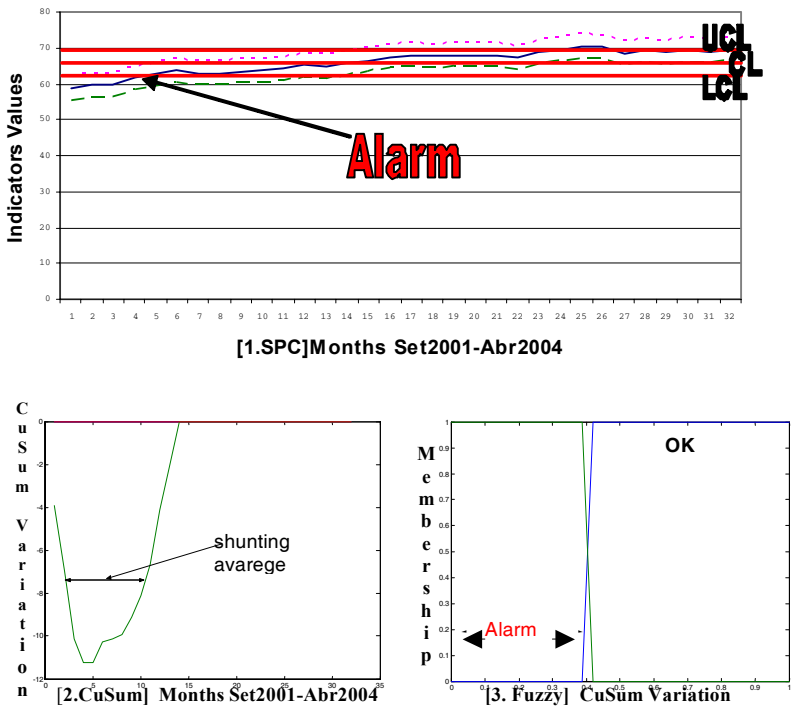


Figure 8: Not connected calls - congestion LC – PMM.

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4 Results

All the graphs were generated with information of Set-2001 until the most recently (Abr-2004) in ANATEL´s site [3]. Algorithms in MATLAB had been developed, with options of generation of the graphs in each one of the periods (M/A/N) or with average values of all the periods. The graphs are
(1.) The SPC graph; (2.) The CuSum graph; (3.) The Fuzzy Control graph.

5 Management tolls

As observed, the logical fuzzy introduction, it was created an analysis tolls with regions of alarms (NOK) and not-alarms (OK) it will be an acknowledgment that has variation in direction of alarm that is less than one standard deviation. The way that the graphs are presented, a simultaneous analysis are need in all of then so that possible variations are found. Therefore it would be interesting if we created only one graph, with coloration that could be changing from a state to another passing through diverse tonalities, function of the membership degree of values at a color or to another one. Doing so, if call the not-alarm – GRAY (color graph GREEN), and the alarm BLACK (color graph RED), it could be made a management fuzzy graph where intermediate degree of gray (or green colors) it represents the membership degree: the alarm, not alarm and regions of previously alarm, would be created - figure (9).

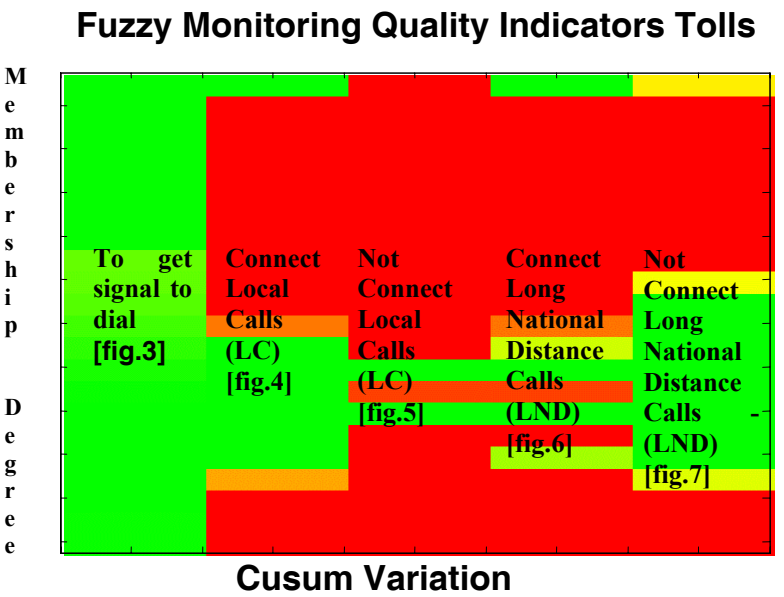


Figure 9: Management quality panel.

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6 Conclusion

The CUSUM method works with variations in the average of the values, make an analysis of behavior of the process and a prompt analysis, presenting trends that the indicators are presenting. Therefore with this type of analysis we could anticipate the problem and being able to act preventively.

With entrance CUSUM in a graph of Fuzzy Diagnosis, were capable to mount an efficient way of management, where it will be had previously, through ALARMS and PREVIOUS-ALARMES, information that indicating determined one changed its behavior, presenting a trend to run away the established goals before.

The next steps will be to search in the base with all the 35 indicators which the possible correlations, and as to create an efficient and preventive methodology of diagnosis and prevention of problems in the quality of the rendering of services.

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