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THE APPLICATION OF A STATISTICAL APPROACH FOR THE COMPARISON OF AIR POLLUTION BETWEEN CASABLANCA MOROCCO AND ISTANBUL/TURKEY

Souad Laaroussi[1], Taoufik Cherradi[2] and Soulhi Aziz[3]
[2]Laboratory Civil Engineering, CEDOC EMI, Rabat, Morocco
[2]Mohammadia School of Engineers, Rabat, Morocco
[3]Superior National School of Mines, Agdal Rabat, Morocco
E-Mail: s.laaroussi@hotmail.de

ABSTRACT

The major concerns of the policy and management of cities around the world is the reduction of emissions of air pollutants. The main challenges facing local decision-makers are climate change, population growth, pollution and rising energy costs. It should be noted that air pollution is one of the most complex environmental problems. Given the limited financial resources of most municipalities, the main objective of this paper is to provide a less costly decision support model for the assessment of air pollutant concentrations, particularly SO2. In our article "Using a statistic Approach: An Application for Assessing Concentration of Air Pollutants" published in 2019, we used the Six Sigma approach, in its "analysis" section, for the evaluation of the daily average of SO2 concentrations measured during the one-year period. The application of statistical tests made it possible to evaluate the compliance of this pollutant with the limit value set by the standards for the protection of the environment. In this article, we will propose as well a decision support approach based mainly on the statistical tools of the Six Sigma approach. The work is divided into two parts, in the first the SO2 indicator of the city of Casablanca is analyzed using superior capability, control charts, Bote à moustache. In the second part, we also used the six-sigma approach to compare the daily SO2 pollutant averages found in the city of Casablanca / Morocco and the city of Istanbul.

Keywords: air pollutants, Moroccan standards of the environment, so_2, Casablanca, istanbul, six sigma, normality test, box-cox transformation, statistical tests.

1. INTRODUCTION

Air pollution is undoubtedly a critical environmental problem that cannot be neglected. Given its paramount importance, clean air is considered to be one of the main UN Sustainable Development Goals [1]. It is therefore necessary to ensure the quality of the air in the cities to improve the health and well-being of the inhabitants. The World Health Organization's cancer agency, in its project "Health Risks from Air Pollution in Europe", has officially classified air pollution as a carcinogen to humans [2]. Due to sustained urbanization in recent years, levels of air pollutants in urban areas and megacities are becoming very high, which decreases the quality of the air. Among the main sources of emission: road traffic, maritime transport emissions, industrial emissions [3], domestic heating and other anthropogenic actions.

The city of Casablanca is the dynamic commercial and industrial metropolis of the country with many international commercial establishments and high technology industries and the largest city of the Maghreb by its population. It is now confronted with major urban problems while the rate of motorization continues to increase, which poses serious ecological problems. Indeed, the problems of pollution and congestion highlight the need to change the management of the city and to propose new feasible and sustainable solutions to assess the concentrations of air pollutants, in order to meet the global requirements for the protection of the environment. Therefore, the use of efficient and reliable estimation methods is mandatory. The following questions will help to establish a thorough understanding of the following factors: Which of the statistical tests is applicable to the assessment of air pollutants? And how can local authorities use the results obtained to ensure compliance with the regulations in force in order to comply with the requirements of the protection of the environment?

In our article "Using a statistic Approach: An Application for Assessing Concentration of Air Pollutants" [4], we used the Six Sigma approach, in its "analysis" section, for the evaluation of the daily average of SO_2 concentrations measured during the one-year period. The application of statistical tests made it possible to evaluate the compliance of this pollutant with the limit value set by the standards for the protection of the environment. In this article, we will propose as well a decision support approach based mainly on the statistical tools of the Six Sigma approach. The SO_2 concentrations of the city of Casablanca in Morocco are compared with those of the city of Istanbul in Turkey.

Values on the concentration of SO_2 for the city of Casablanca come from the Direction of the National Meteorology / Morocco. That of the city of Istanbul comes from an article on air pollution in the city of Istanbul / Turkey [5].

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Figure-1. Direction of the national meteorology / Morocco.

1.1 Methodology

In the section "Results", we adopt the IMRAD methodology. We will begin by describing the problem of air pollution. Afterwards, we will present the Moroccan environment standards. Then, the main concepts of Approach Six Sigma are presented. In the case study part, we will try to verify the conformity with the Moroccan norms in force regarding the concentrations of the SO_2 [6], a) by carrying out the test of normality, b) if the distribution of the data is not normal, a transform will presents the normal law with the indices, c) then, in the assessment of the conformity of the concentrations with the requirements in force, two tools will be used: the X-bar cards and the calculation of the higher capacity. In a second part we will use the statistical tools of the Six Sigma approach to compare the Sulphur dioxide SO_2 concentrations of the city of Casablanca in Morocco to that of the city of Istanbul in Turkey. We ends with the discussion of the results of the statistical evaluation (step "M": measures). In the "Conclusion" section, the merits and drawbacks of the proposed solutions will be presented, including perspectives.

2. RESULTS AND DISCUSSIONS

2.1 Notion of Atmospheric Pollution

The phrase "atmospheric pollution" is relatively old. It covers several phenomena driven by distinct processes and are sometimes coupled. They are presented as follows [7]:

- The additional greenhouse effect caused by the greenhouse effect (carbon dioxide, ...) and its consequences on the climate;
- The destruction of stratospheric ozone (especially at the poles) by compounds such as chlorofluorocarbons (CFCs);
- Air quality with the problems of photochemical pollution (ozone, nitrogen oxide and volatile organic compounds) or particulates, acid rain (linked to sulfur dioxide and sulphate aerosols), more generally transboundary pollution multi-pollutant;
- The impacts of accidental releases (chemical, biological or nuclear) into the atmosphere.

Atmospheric pollution manifests itself in the form of a thick suffocating fog called smoke. Smoke is a mixture of air pollutants composed of ozone, particulates, carbon monoxide, nitrogen oxides and volatile organic compounds. It is a yellow-brown fog that is visibly present in large cities, but there are also high concentrations of smoke in the periphery and in the countryside, mainly because of the wind. Smoke irritates the eyes, the respiratory and cardiovascular systems, which exacerbates heart and lung diseases, as asthma damages the mucous membranes of the lungs. This can increase the risk of lung cancer and premature death. Seniors, children, asthmatics, people with lung diseases and heart problems, smokers, and people who exercise outdoors are even more sensitive to toxic gases forming the smoke.

2.2 Source of Atmospheric Pollution

The origin of atmospheric pollution is either anthropogenic (produced by human activities) or natural (emissions by vegetation, soil erosion, volcanoes, oceans, etc.). All sectors of human activity are likely to emit atmospheric pollutants: industrial activities, transport (road and non-road), domestic activities (heating in particular), agriculture, and forestry. They are emitted into the atmosphere as gases or particulates (PM) from different sources, then transported and / or processed in this compartment, and then removed by means of dry or wet deposition aerosols ~~that~~ are incorporated in rain or clouds. Pollutants observed in the atmosphere are not all emitted directly from these sources. They also result from physico-chemical reactions between chemical components, primary pollutants and other constituents of the atmosphere, governed by weather conditions. Table-1 shows the emission sources of the main air pollutants.

Table-1. Sources of air pollutants [8].

Pollutants	emission sources
Nitrogen dioxide (NO_2)	NO_2 comes mainly from the combustion of fuels and incineration plants.
Ozone (O_3)	There are no sources of emission: ozone (O_3) is a secondary pollutant that is formed at a low altitude by chemical reactions produced under the effect of sunlight, from atmospheric pollutants - said precursors - such as nitrogen oxides (NOX) and volatile organic compounds (VOCs).
Sulphur dioxide (SO_2)	SO_2 comes mainly from the combustion of fuels and fuels containing sulfur (fuel oil, diesel, coal, etc.). Sulfur impurities in fossil fuels are oxidized by oxygen in the air (O_2) to sulfur dioxide (SO_2).
Carbon monoxide (CO)	CO is formed during the incomplete combustion of fuels. Traffic is responsible for most of the carbon monoxide emissions followed by industrial and domestic heating.
Primary Particles (PM)	The largest anthropogenic sources of particulate matter are road transport, energy production, agriculture, industrial combustion, non-road transportation, residential heating and industrial processes.

2.3 Presentation of the Six Sigma Approach

The German physicist Johann Carl Friedrich Gauss (1777-1855) [8] laid the foundation stone of the Six Sigma method from its concept of normal distribution [9]. Walter A. Shewhart (1891-1967) developed statistical process control (SPC) around 1920. He kept the scientific basis he kept in his book, Economic Control of the Quality of Manufactured Product published in 1931. The pioneer of quality management, William Edwards Deming (1900-1993), created the process-oriented vision of a company's activities and tasks around 1940. Its development is now an integral part of quality standards and management lessons. Six Sigma has become today a philosophy of process improvement in five phases. It is based on the DMAIC [9] principle (Design, Measurement, Analysis, Improvement and Control):

- **Define:** Set the goal
- **Measure:** Measuring customer expectations
- **Analysis:** Analyze problems, strengths and weaknesses
- **Improve:** Differentiate, innovate
- **Control:** Guarantee long-term quality

This philosophy is aimed primarily at minimizing errors to achieve world-class performance (3, 4 errors per million opportunities) that is usually expressed as a Six Sigma measurement or simply a Sigma value. For our study, we will only apply the "Measure" part of the six sigma approach.

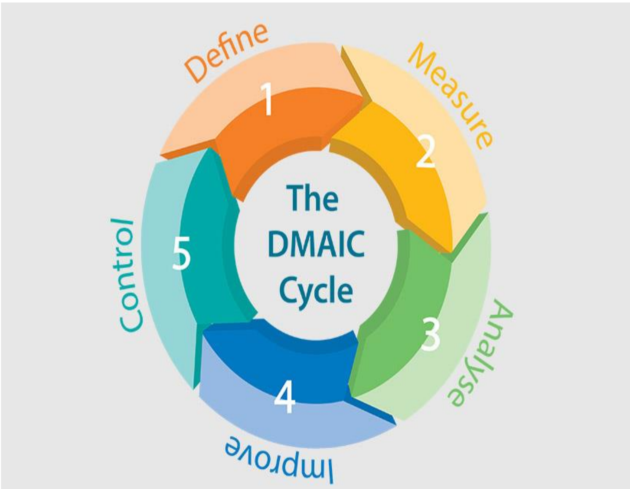

Figure-2. DMAIC principle [9].

2.4 Moroccan Standards on Air Quality

Morocco is paying conspicuous attention to the problems of air pollution, due to the accelerated industrial activities and heavy road traffic. This clearly has a direct and dangerous impact on the health of inhabitants, and in particular children. To remedy this situation, the government has decided to fight against the deterioration of air quality. It is in this context that the government has taken measures to monitor the quality of the air and reinforce the legal arsenal.

In accordance with the provisions of the law n°13-03 [10] relating to the fight against the air pollution, and its decree of application n ° 2-09-286 on December 8th, 2009 fixing the norms of air quality air monitoring modalities. A National Committee for Monitoring and Surveillance of Air Quality has been created, namely the secretariat and the chairmanship of which are provided by the Ministry of the Environment. This committee is very useful for federating and harmonizing air quality and monitoring actions, as well as strengthening measures to fight against air pollution. At the regional level and in

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accordance with Decree No. 2-09-286 on December 8th, 2009, in each region where an air quality monitoring network is set up, and a permanent committee for the monitoring and surveillance of the quality of the air is instituted.

The air quality monitoring started in 1997 with the first campaigns of this kind in Morocco conducted by the Ministry Delegate for the Environment in the urban areas of Rabat, using a mobile laboratory. These campaigns have made it possible, on the one hand, to evaluate the extent and intensity of pollution in the city by comparing measured concentrations with different standards, and on the other hand, to make public authorities aware of the need to have fixed stations for continuous measurement of air quality.

2.5 Case Study and Discussion

Casablanca is a city located in the center-west of Morocco. It is the dynamic commercial and industrial metropolis of the country with many international business establishments and high technology industries and the largest city of the Maghreb by its population [12].

Figure-3. The geographic location of Casablanca [11].

It is located on the Atlantic coast, about 80 km south of Rabat, the administrative capital, its area is 219 km23. Its population is estimated at more than 5 million [13], representing a demographic concentration of more than 21.65% of the Moroccan population (Sbai, 2001).

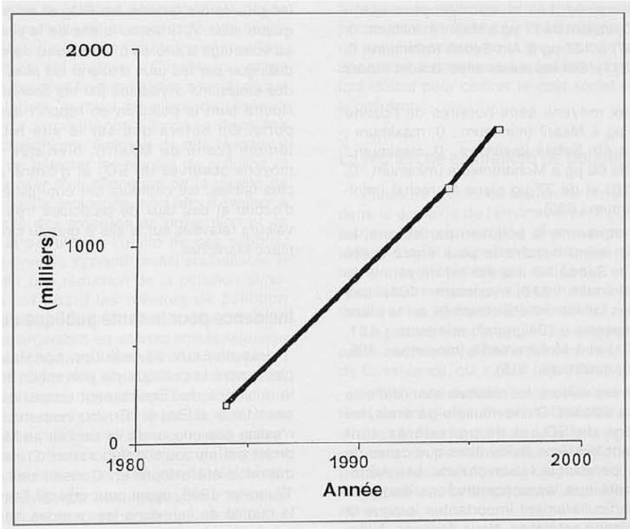

Figure-4. Nombre de véhicules en circulation au Maroc.

Dense urbanization merges with sparsely populated interior areas reflecting the long-term processes of rural-urban migration. Result of strong demographic and economic pressures, more and more important, which affect its environment. As a result, anthropogenic pollution and industries with high pollution potential have had adverse effects on the environment and human health. One of the major problems is air pollution. Indeed, 80% of the Greater Casablanca industry discharges its effluent0s directly into the atmosphere and the number of passenger cars which is constantly increasing, raises concerns as to the impact of these discharges on the quality of the air.

Increasing urbanization places high demands on infrastructure, such as transportation. This causes the increase of different pollutants (CO, SO_2, NO, NO_2, O_3 and PM10) in the atmosphere. In actuality, the city of Casablanca desperately demands more intelligent solutions in to control and inspect air quality. One should know that the aim of this study is to use the six sigma approach in the evaluation of concentrations of atmospheric pollutants, in particular SO_2.

The monitoring of the air quality of the city of Casablanca is carried out with the help of a unit responsible for collecting the concentrations of the main pollutants. This unit is presented under the supervision of the team of the National Laboratory for Studies and Monitoring of Pollution (LNESP). Directorate of National Meteorology is responsible for marketing the collected data. According to Moroccan standards, the average annual limit value of SO_2 for air quality is 20 µg / m3 (Source National Metrology Direction / Morocco). In the case of the city of Istanbul, observational data were collected from the Istanbul Metropolitan Municipality (Istanbul Metropolitan Municipality Department of Environment Protect 2007). The critical value of SO_2 is also set at 20 µg / m^3, (Ministry of Environment and Forests of the Republic of Turkey, 2007).

The work is divided into two parts, in the first part the upper capacity control charts and the X-Bar diagrams will be used. In the second part, the SO_2

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concentrations of the city of Casablanca in Morocco are compared with those of the city of Istanbul in Turkey.

Part 1: An application for assessing concentrations of SO_2 : Cas Casablanca

3.5.1 Normality test

This test verifies the normality of the data distribution according to two hypotheses:

Equality Assumption H_0, Actual Data Distribution Follows Normal Law

Difference Hypothesis H_1, Actual Data Distribution Does Not Follow Normal Law

P is the propensity to make the mistake of accepting the H1 difference hypothesis, which is wrong to consider a risk of $\alpha = 5\%$

- If P > 0,005: H_0 is correct, the data distribution is normal
- If P < 0,005: H_1 is correct, the data distribution is not normal

The probability density of the normal distribution is given by [15]:

$$P(x) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right) \quad (1)$$

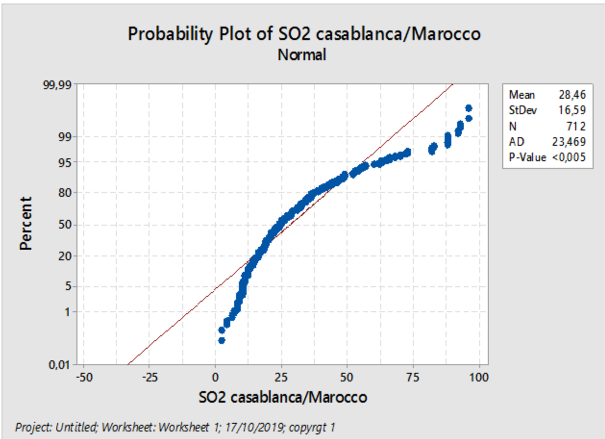

Figure-5. Probability Plot of SO_2 concentration.

The value P < 0,005, H1 is correct; the actual distribution of the data is not normal.

3.5.2 Control charts for standardized data

The use of an X-Bar chart is to monitor the average of a process and determine its stability. It represents the average of the measurements in each subgroup. The center line indicates the average of all subgroup averages. The control limits, which are plotted at a distance of 3 standard deviations above and below the center line, show the expected variation in the means of the subgroups. The data is transformed using the Box-Cox Transformation [16] by the tools of a statistical software.

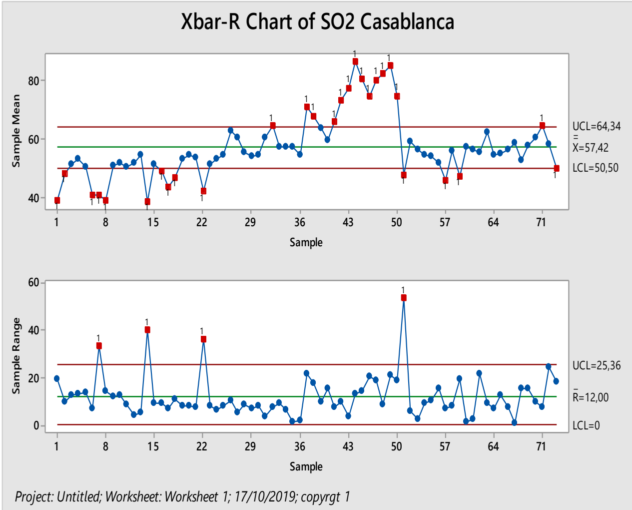

Figure-6. Chart for individual value.

Several points are beyond the control limits on the first graph while only 2 are beyond the limits on the second graph. These points indicate that the process cannot be stable. The process also does not respect these natural limits (+ 3σ, -3σ). It is then declared out of control at the 95% confidence Interval.

3.5.3 Capability calculation for standardized data

By following the capability $C_{p,upper}$ [17] which is calculated with respect to the upper limit . In our case the limit value is 20 µg /m^3 for SO_2 (Moroccan standards). Descriptive statistics have been determined for SO_2 values. These statistics are shown in Table-2. The capacity characteristics indicators are presented in Figure-5.

$$Cp, upper = \frac{UCL - \bar{x}}{3\sigma} \quad (2)$$

$$\sigma = \frac{1}{365} \sum_{i=1}^{365} (x1-\bar{x})(x1-\bar{x}) \quad (3)$$

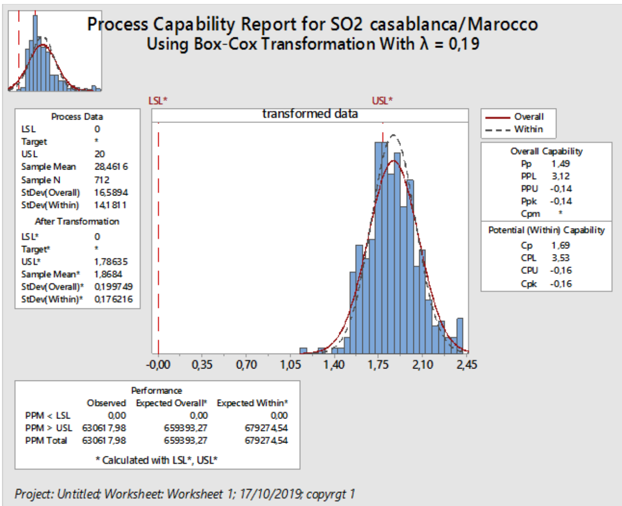

Figure-7. Capability for standardized data.

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Table-2. Descriptive statistics.

Statistic	SO_2
USL	0
Sample Mean Sample N	28.4616 712
StDev (Overall) StDev (Within)	16.5894 14.1811
C_p	1.69
P_{pk}	-0.14
C_{pk}	-0.16

The capability index $C_{p,upper}$ is calculated to summarize the comparison of the adjusted distribution of the specifications.

Since $C_{p,upper}$ = 1.69 > 1.33, we can say that the process is centralized. But The same calculates give 26, 29%, which is impossible to correspond to 93 overruns per year. This shows that it is not in conformity with the standards in force, and hence it does not allow any overtaking.

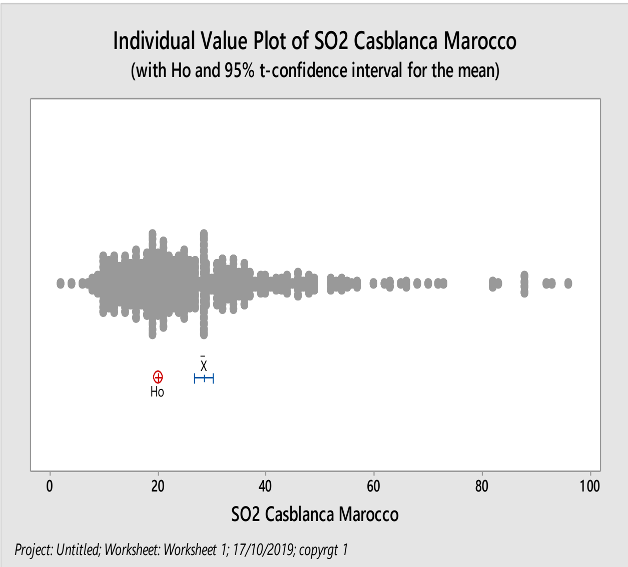

Figure-8. Individual Value Plot of SO_2 Casablanca.

Most data is below the average x-bar. In addition we find values that exceed 80 mg / m^3, which requires a study to identify the causes that produced these extreme factors.

3.5.4 box-and-whisker plot:

A box-and-whisker plot is, in statistics, a graphical representation. Typically, it allows, for a dataset, to represent the median, quartiles and percentiles (5th and 95th) or deciles (1st and 9th). Aberrant data (outliers) are also often represented.

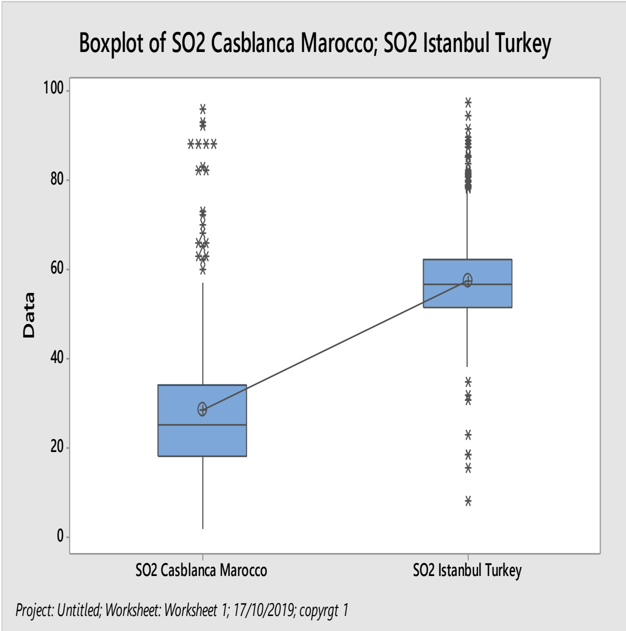

Figure-9. Boxplot of SO_2 Casablanca, SO_2 Istanbul.

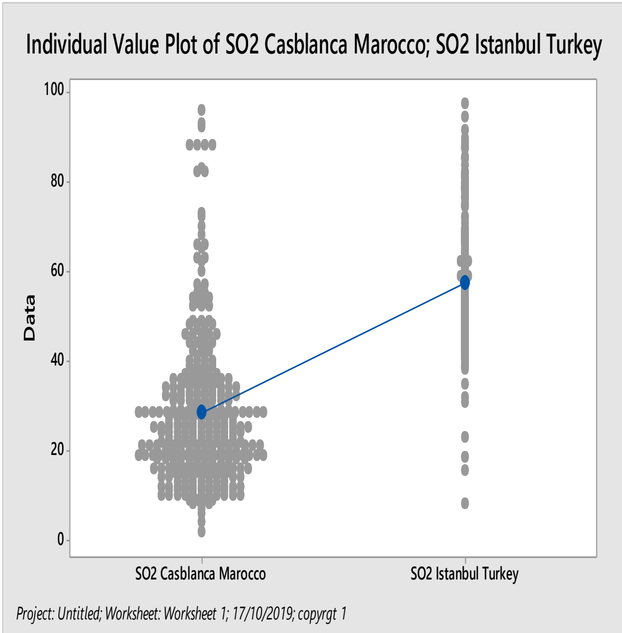

Figure-10. Individual Value Plot of SO_2 Casablanca, SO_2 Istanbul.

The box-and-whisker plot represents the daily average of SO_2 concentrations for both cities. The median values seem different.

The majority of data for the city of Casablanca are on the upper side, the opposite for the city of Istanbul. This asymmetry indicates that the data may not be normally distributed.

For the city of Istanbul there are no bad values. In the case of the city of Casablanca, the outliers are large, indicating that there are problems with data collection or unusual behavior of a process.

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3.5.5 Sub-sample control cards

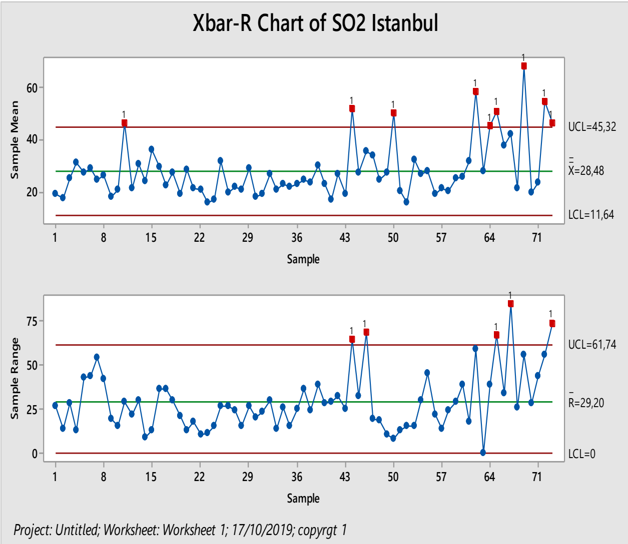

Figure-11. Chart for individual value.

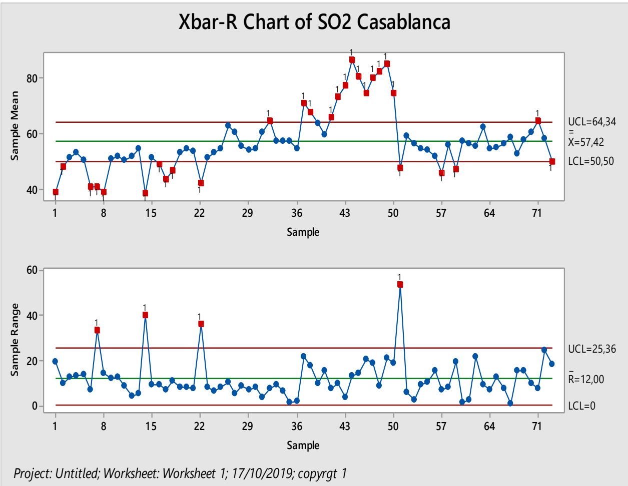

Figure-12. Chart for individual value.

The Xbar-R-Chart of the city of Casablanca and Istanbul indicate that the variation of the process is not under control, several points are out of control line, they are not included in the control limit randomly. The X-Bar for both cities indicate that the tests failed at several points. The process also does not respect these natural limits (+ 3σ, -3σ). It is then declared out of control at the 95% confidence Interval.

The average value of SO_2 pollutant concentrations for Casablanca city is 28 mg/m^3. That of the city of Istanbul is 57 mg/m^3. This means that the city of Casablanca is less polluting than the city of Istanbul.

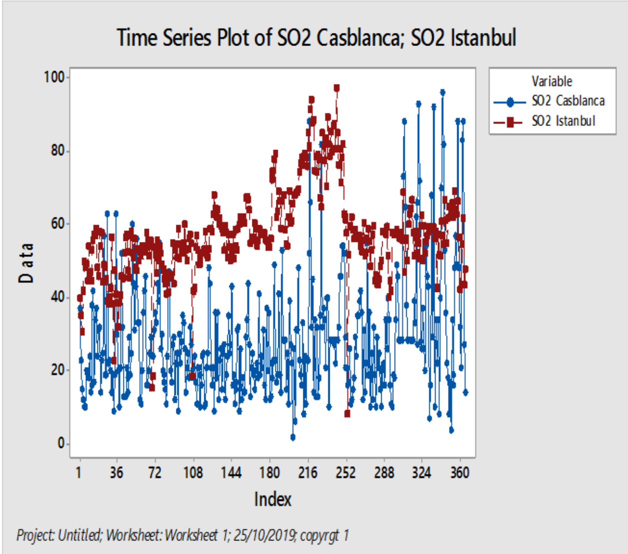

Figure-13. Time Series Plot of SO_2 Casablanca; SO_2 Istanbul.

According to the graph, the average value of SO_2 pollutant concentrations in the city of Casablanca is lower than that of Istanbul, which again means that the city of Casablanca is less polluted than city of Istanbul.

CONCLUSIONS

In this article, we presented the six-sigma approach. The analysis of the results showed that the city of Casablanca is less polluting than the city of Istanbul. For the city of Istanbul, there are no outliers. In the case of the city of Casablanca, outliers are important, indicating problems of data collection or unusual behavior of a process. This requires a study to identify the factors that led to these extreme values.

In the same way, other components of atmospheric pollutants can be analyzed by comparing them with the limit values fixed by the standards in force. Six-sigma is a structuring and very effective, but it can create concrete problems out of abstract ones. It should be known that the six-sigma approach allowed us to analyze the concentrations of the atmospheric pollutant SO_2 measured over a period of time, on a daily average.

In a future work, we will lead a study to identify the factors that led to outliers values in the case of the city of Casablanca.

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