

# Predictive studies of solid waste production capacity in fast food restaurants using the bootstrap method and time series

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**Abstract**— Fast food restaurants are responsible for much of the solid waste produced in Brazil. The management of these wastes has a such fundamental importance, because the environmental impact caused by its inadequacy causes incalculable damage to the environment. The performance of the solid waste management system can be determined by evaluating your service level. In restaurants, the level of solid waste service is determined based on the quantity generated. Therefore, the objective of this study was to develop a statistical planning to explore the predictability of the amount of solid waste generated in a fast food restaurant, aiming to develop a monitoring system, based on sustainability indexes, increasing knowledge about the relevant processes and possible internal barriers. Thus, a computational routine was created in the C++ language through the bootstrap statistical method. The results showed that the bootstrap method is a robust statistical tool to predict the amount of solid waste generated in fast food restaurants. The use of time series was important for comparative studies with the data obtained by the bootstrap method, as well as the implementation of a routine predictive analysis of solid waste in a fast food restaurant.

**Keywords**— Nutrition, Commercial Restaurants, Environmental Analysis, Statistical Modeling, Monte Carlo.

## I. INTRODUCTION

The huge increase in solid waste generation worldwide requires the development of waste management strategies for a sustainable environment (1). When examining the impact only on climate, for example, it's seen that the food sector (food industry, wholesale and retail, restaurants and home use) represents about a quarter of the climate impact of consumption, while the impact on the water system is even more pronounced due to excessive fertilization (2).

Comprehensive legislation was built in the European Union, RED 2009/28/EC, with objectives and targets to improve waste management, as well as to reduce toxic gas emissions and adverse health and environmental impacts. Such legislation was developed with the concept of a hierarchy of waste management options, which includes the legally binding prioritization of management activities. In essence, prevention is the most desirable

option, followed by the recovery and recycling of materials (metal, glass, paper recycling or composting of organic waste), recovery of energy from waste (by incineration or digestion of biodegradable waste) and finally disposal (landfill) without recovery of materials and/or energy as the least desirable option (3).

In the case of Brazil, approximately 31.9% of the waste collected is composed of recyclable materials, but just over 1% of the waste is recovered in selective collection programs (4). This fact is the direct object of the National Solid Waste Policy, which brings together the set of principles, objectives, instruments, guidelines, goals and actions adopted by the Federal Government of Brazil, alone or under cooperation with States, The Federal District, Municipalities or individuals, with a view to integrated management and environmentally appropriate management of solid waste (5). This Law allows a model to be made to monitor the amount of solid waste in several instances.

Restaurants are major producers of solid waste (6), which are produced, practically, in all stages of food processing until reaching the final consumer, bringing significant impacts to public health and the environment. Therefore, it's necessary to increase the knowledge of the qualitative and quantitative characteristics that can be generated in these establishments. It's known that the shared responsibility for the life cycle of the product guides for the reuse and recycling of materials, since they have economic and social value, being promoter of work, income and citizenship (7).

Several authors highlight the importance of studying solid waste as a basis for the development of sustainable policies aimed at combating it (8,9). As people become aware of the implications of solid waste, the decrease in environmental impact is almost immediate. Therefore, it's necessary to ensure that awareness of waste becomes a corporate target for restaurant owners, and monitoring is carried out continuously (10). Champions 12.3, a coalition of executives from governments, companies, international organizations, research institutes, groups of farmers and civil society to combat despair, conducted a study in 114 small restaurants in 12 different countries on the analysis and dumping of solid waste. The result indicates that with every dollar invested in reducing food waste, for example, an average restaurant saves \$7 in return (11).

So, the implementation of efficient solid waste management schemes may also be able to reduce environmental impacts such as pollution, global warming and energy deficit, protecting human health and boosting social and economic sustainability (12). Currently, many sustainability researches focus mainly on the application and measurement of ecological efficiency (13). However, in the case of solid waste produced in restaurants, monitoring is of fundamental importance to estimate the quantities produced.

Statistical methods are powerful mathematical tools used to estimate the amount of solid waste produced. Through the results obtained, it's possible to carry out an adequate planning of environmental management. Therefore, based on the assumption of the importance of the large amount of solid waste generated in commercial restaurants, the objective of this study was to use the bootstrap method to estimate the amount of solid waste produced in these establishments, in order to take more effective measures in the prevention and destination of them, thus minimizing the environmental impacts caused in nature.

Bootstrap is a highly efficient computational method for inferential statistical analysis and doesn't

depend on many assumptions. This method was developed by Efron (14), and has been used in different areas of knowledge. The bootstrap method corrects possible deviations from the estimate and achieves more accurate and robust results. It's based on the idea that using only the available data can sometimes give better results than making unjustified assumptions about the populations we are trying to estimate (15).

Conditional efficiency measures are necessary when the production process not only depends on inputs and products, but also can be influenced by external factors. Such measures are estimated by means of a non-parametric calculation of the conditional distribution function of inputs and outputs. For this, procedures and smoothing parameters, bandwidths, basis of bootstrap methodology (16) are involved. Thus, providing a qualitative (compositional) and quantitative (parametric) comprehensive characterization of the total waste generated in fast food restaurants is mandatory for this study.

Time series are important resources used in predictive studies. Time series analysis comprises methods that try to understand such mathematical resources, within the underlying context of the data points or to make predictions. It has many different objectives, depending on the field of application. It includes predicting future values of the series, extracting a hidden signal from noisy data, discovering the mechanism by which data is generated, simulating independent achievements of the series to observe how it can behave in the future (and therefore, for example, to estimate the probability of extreme events) and eliminate the seasonal component of data sets to reveal the underlying trend more clearly (17). Due to its high applicability in mathematical research of predictability, time series can be used to perform predictive studies of solid waste production in fast food restaurants.

## II. METHODOLOGY

### 2.1. Characterization of the site and sampling criterion

The research was conducted in the city of Recife, Brazil. The restaurant chosen for this study belongs to a large fast food chain. In this restaurant, the turnover of food sales is quite intense, being produced large amount of solid waste. Plastic, glass, metal and paper samples were collected. To obtain the data, weighing (gravimetry) of the waste was performed monthly by the cleaning collaborators, and recorded in an Excel spreadsheet, referring to the months of January to December 2019. The data obtained were statistically analyzed using the bootstrap method, aiming to estimate the solid waste

generation capacity of the studied establishment. From then on, it will be possible to suggest sustainability indicators suitable for restaurants, since until then, there is no citation in the literature.

Due to the predictability given by the bootstrap method, it was possible to carry out a planning based on the 3R principle (Reduction, Reuse and Recycling), which allows the economy to stop being linear to be circular (18). The circular model allows solid waste to be significantly reduced, thereby maximizing the use of products.

## 2.2 Sustainability indicators

Management practices require instruments for continuous improvement, so having a performance evaluation system is essential, considering that it's necessary to carry out measurements and evaluation in order to have a control of the studied system (19).

The evaluation systems can be presented in the form of indicators, indexes and rates, representing mechanisms for monitoring trends in reality (20). Such instruments can be used to analyze the efficiency of expenses, improve technical administrative management, in addition to the continuous improvement of systems. Any improvements possibly made from the use of these instruments can assist in planning new projects, in monitoring their implementation, reformulations and adjustments (21).

With the creation of the Advisory Commission on Environmental Statistics at IBGE, a Brazilian governmental institution, in 2001, with a team of experts from other official Brazilian institutions, the construction of IDS-Brasil was carried out, with the validation of 59 indicators (22). Every two years, from 2002 to 2015, IBGE published "Sustainable Development Indicators – Brazil", providing information on the Brazilian reality.

Sustainability indicators cover the environmental, economic, social and institutional areas, as well as allowing the monitoring of the integration of economic and environmental decisions (23). They help decision-making and results follow-up, as well as allow a comparison of results from different scenarios (24). As for the selection of indicators to be used, in general, it should be relatively in small numbers, and reflect the important trends of interest (25).

For Hammond (26), indicators can communicate or inform about progress towards a certain goal, but they can also be understood as a resource that makes a trend or phenomenon that is not immediately detectable.

The limitation in the collection of information about a performance system requires that the system be analyzed by a set of easy measurements, defined by

Stricker *et al.* (27) as indicators. According to this author, these values are used as representations due to the fact that they are measurable, and act as a way of controlling the progress of the strategies and goals established for the development of the process.

There are still no robust studies on sustainability indicators, specifically in commercial restaurants. Although the PNRS is very clear about shared responsibility, which implies that the producer of the waste has responsibility for it until its final destination, but unfortunately there's no inspection enough about it. So, without proper supervision, restaurant managers end up adopting their own parameters that suit their reality. And what you see in restaurants in the city of Recife is that they haven't yet prepared themselves for the circular economy mentioned in this work.

Based on the work carried out by Ayvaz *et al.* (28), a company is considered sustainable, if and only if, it participates in a reverse logistics network through strict planning of environmental management of its solid waste produced. It's recommended that the system operators establish procedures for managing and monitoring the collection of solid waste until recycling, in order to know how much is actually being directed to reverse logistics. Thus, it will be possible to establish efficiency indicators for waste management related to different territorial conditions (29). Also, the evaluation of the main indicators of zero solid waste management should be inserted in this context (30). Due to the high turnover, and consequently, the large amount of solid waste produced in a fast food restaurant, reverse logistics should be mandatory for the sustainable operation of the system (31).

In reverse logistics, the recycling rate is an important indicator of the sustainability of any company that produces high amounts of solid waste. The recycling rate (TR) is defined as the percentage of resources recovered from a solid waste producing unit. Mathematically, TR is defined as the ratio between the amount of materials regenerated during recycling (M) and the total amount of waste produced and collected (Q), as shown in Equation 1 (32).

$$T_R = \frac{M}{Q} \quad (1)$$

## 2.3 Statistical analysis of data

### 2.3.1 The bootstrap algorithm

The basic idea of the bootstrap method is to infer about an estimate (such as sample mean) for a population  $\theta$  parameter (such as population mean) in the sample data. It's an independent sampling resampling method with

replacement of existing sample data with the same sample size  $n$ , and performing inference between this resampled data. Generally, the bootstrap method involves the following steps:

1. A sample of the population of size  $n$  is taken.
2. A sample is drawn at random and with repetition from the data of the original sample of size  $n$ , and replicated until obtaining the  $B$  simulated bootstrap terms. This process is called bootstrap resampling, and each simulated sample is known as a pseudo-sample. In the present study, an algorithm was built in the C++ computational language using the Monte Carlo method, that uses the renu random number generator (33). Figure 1 shows a simplified scheme of the algorithm's operability for the analyses using the bootstrap statistical method.

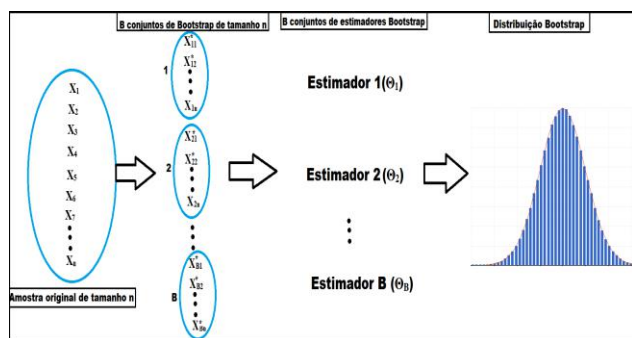


Fig 1. Simplified scheme of bootstrap algorithm.

3. The  $\theta$  statistic is estimated for each bootstrap sample, thus obtaining the arithmetic mean in each resample procedure, until it reaches the simulation value  $B$ .
4. The sampling distribution with the bootstrap means is then constructed, using them to make more statistical inference, such as: estimating the value of the general mean, estimating the standard error of the statistic for  $\theta$ , and obtaining a confidence interval for  $\theta$ .

Thus, it's possible to generate new data through the bootstrap resampling of a given existing sample, and to make statistical inference only with them. The central idea of the bootstrap auto-boot technique is to make certain types of statistical inference with the help of the power of modern computers. When Efron (14) introduced the bootstrap method, he was particularly motivated by assessing the accuracy of an estimator in the field of statistical inference.

### 2.3.2 Bootstrap distribution

To generate the bootstrap distribution by the simulation process presented in item 3.3.1, a random

sample of size  $n$  obtained from a given population was considered. In this case, from the original set formed by the  $n$   $x = (x_1, x_2, L, x_n)$  elements, the bootstrap samples were randomly  $x^* = (x_1^*, x_2^*, L, x_n^*)$  obtained, with replacement, at each stage of the interaction. The value  $x^*$  doesn't indicate the creation of a new dataset, but a set of values resampled with  $x$ . After the simulation, the set of estimators  $\hat{\theta} = (\theta_1, \theta_2, \theta_3, K, \theta_B)$ , who formed the bootstrap distribution, was obtained. In each interaction process, the estimator value equal to the bootstrap arithmetic mean of each sample was obtained, data by  $\bar{x}_1^* = x_3, \bar{x}_2^* = x_8, \dots, \bar{x}_B^* = x_6$ . Since we're dealing with random sweepstakes in the original dataset, not caring about the order to get the bootstrap sample, it's possible to have sequences of  $x_1^* = x_7, x_2^* = x_{10}, x_3^* = x_2, L, x_B^* = x_3$  type. Thus, during the random draw, a number may not appear, others may appear one or more times, etc.

Let  $\hat{F}$  be the bootstrap distribution formed by the estimators of  $\hat{\theta}$ , with  $1/n$  probabilistic mass, then the value of  $F$  was calculated by Equation 2 (14).

$$\hat{F}_{(n)}(x) = \frac{\sum_{i=1}^n I(x_i \leq x)}{n} \quad (2)$$

Where:

$\hat{F}_{(n)}(x)$  - the non-parametric maximum likelihood estimator of  $F$ ;

$I(x_i \leq x)$  - indicator function.

In an orderly way, the elements of the bootstrap distribution can be presented in the sequence below (14):

$$\begin{aligned} x_1^* &= [x_{11}^*, x_{12}^*, L, x_{1n}^*] \\ x_2^* &= [x_{21}^*, x_{22}^*, L, x_{2n}^*] \\ &\vdots \\ x_m^* &= [x_{m1}^*, x_{m2}^*, L, x_{mn}^*] \end{aligned}$$

For each  $\bar{x}_i$ , we will always have an associated estimator  $\hat{\theta}_i$  for each resampling procedure. Similarly, the mean  $\bar{x}_B$  can also be replaced by the estimator  $\hat{\theta}_B$  which

is the arithmetic mean of the bootstrap  $n$  estimators. For both situations, we will have Equations 3 and 4, respectively.

$$\hat{\Theta}_i = \sum_{i=1}^n \frac{x_i^*}{n} \quad (3)$$

$$\hat{\Theta}_B = \sum_{i=1}^B \frac{\hat{\Theta}_i}{B} \quad (4)$$

For the original samples, the population standard deviation estimator was calculated using Equation 5. On the other hand, the standard error estimator  $\hat{\theta}$  was calculated using Equation 6. The bootstrap standard error was calculated using Equation 7.

$$\sigma_m = \sqrt{\frac{1}{m-1} \sum_{i=1}^m (\bar{x}_i^* - \bar{x}_m^*)^2} \quad (5)$$

$$\hat{s}_B = \sqrt{\frac{1}{B-1} \sum_{i=1}^B (\hat{\Theta}_i - \hat{\Theta}_B)^2} \quad (6)$$

$$\sigma_B = \frac{\hat{s}_B}{\sqrt{n}} \quad (7)$$

Where:  $n$  is the original sample size.

In statistics, the representation through a confidence interval shows the amplitude of the values in relation to the probability of containing a certain unknown population parameter. However, if sampling is repeated multiple times for a given significance level, the probability that the confidence interval contains the unknown population parameter increases significantly. Thus, the bootstrap resampling method is an excellent alternative to build confidence intervals for a given statistical parameter. For the present study, the  $z$ -standard bootstrap confidence interval (CI) was used, with a significance level of  $100(1-\alpha)\%$ , estimated using Equation 8, considering that the estimator  $\hat{\theta}$  has normal distribution and standard deviation calculated by Equation 6.

In the present study, the statistical analysis of the data was performed using the empirical bootstrap distribution.

$$CI_{Boot-z}(\bar{x}_m^*, 100(1-\alpha)\%) = \left[ \bar{x}_m^* - z_{\alpha/2} \sigma_{mboot}; \bar{x}_m^* + z_{\alpha/2} \sigma_{mboot} \right] \quad (8)$$

### 2.3.3 Time series analysis

To analyze the predictability of solid waste production in the studied restaurant, time series with moving averages and Holt exponential smoothing were used.

Let the time series  $Z_1, Z_2, L, Z_n$  be stationary and constant, so that you have it for a certain time  $t = 1, 2, \dots, N$ ,  $Z_t = \mu_t + a_t$ , where:  $\mu_t$  and  $a_t$  are respectively, the unknown parameter that varies in time and random noise.

Considering that the group was formed by the  $Z_i$  ones has normal distribution, then: the mathematical hope of  $a_t$  is given by  $E(a_t) = 0$  and its variance by  $Var(a_t) = \sigma^2$ . Thus, in a mathematical procedure that uses simple moving averages of a time series, one should calculate the arithmetic mean of the most recent " $n$ " observations, as shown in Equation 9 (34).

$$M_t = \frac{Z_t + Z_{t-1} + K Z_{t-n+1}}{n} = M_{t-1} + \frac{Z_t - Z_{t-n}}{n} \quad (9)$$

In the case of Holt's exponential smoothing technique,  $Z_t = \mu_t + T_t + a_t$ . The new term  $T_t$  refers to the local trend of the dataset. Thus, the values of the level and trend estimators were calculated by Equations 10 and 11 (34).

$$\bar{Z}_t = \alpha Z_t + (1-\alpha)(\bar{Z}_{t-1} + \hat{T}_{t-1}), 0 < \alpha < 1 \quad e \quad (10)$$

$$t = 2, 3, K, n$$

$$\hat{T}_t = \beta(\hat{Z}_t - \hat{Z}_{t-1}) + (1-\beta)\hat{T}_{t-1}, 0 < \beta < 1 \quad e \quad (11)$$

$$t = 2, 3, K, n$$

Where:  $\alpha$  and  $\beta$  are called smoothing constants,  $\alpha \geq \beta$ . So, it was possible to estimate the value of  $Z_{t+h}$  using Equation 12, originating in " $t$ ".

$$\hat{Z}_t(h) = \bar{Z}_t + h\hat{T}_t, \forall h > 0 \quad (12)$$

## III. RESULTS AND DISCUSSION

### 3.1 Estimation of the amount of solid waste produced

The values of the amounts of plastic, glass, metal and paper from the restaurant studied (Pilot Project) are shown in Table 1. In the calculation of the standard deviation of the statistical analyses used, a 95%



significance level adopted was considered empirical bootstrap distribution, according to Efron (14). Considering the operation of the restaurant, it was observed that there was a selective collection of solid waste that was collected directly by the City of Recife, as no agreement was made with associations of waste pickers. The data presented in Table 1 showed great variability, which really required a robust statistical method for Its analysis.

Table 1. Amount of solid waste produced.

Month	Solid waste (kg)			
	Plastic	Glass	Metal	Paper
Jan	302	65	71	510
Feb	314	73	46	502
Mar	302	47	56	453
Apr	275	28	58	389
Mai	260	44	51	324
Jun	310	49	66	587
Jul	324	60	82	533
Aug	250	53	75	368
Sep	240	58	52	345
Oct	285	43	58	302
Nov	298	42	62	475
Dez	344	62	91	529

Any temporal event can be expressed as a combination on a graph called a periodogram, and you can observe the different periods (how long it takes to complete a full cycle) and amplitudes (maximum/minimum value during the cycle). This fact can be used to examine the periodic (cyclic) behavior of a given event. A periodogram is used to identify the dominant periods (or frequencies) of an event. This can be a useful tool for identifying dominant cyclic behavior in a series, especially when cycles are not related to the monthly or quarterly seasonality commonly found. Figures 2, 3, 4 and 5 showed the periodograms of the amount of plastic, glass, metal and paper produced by the studied restaurant.

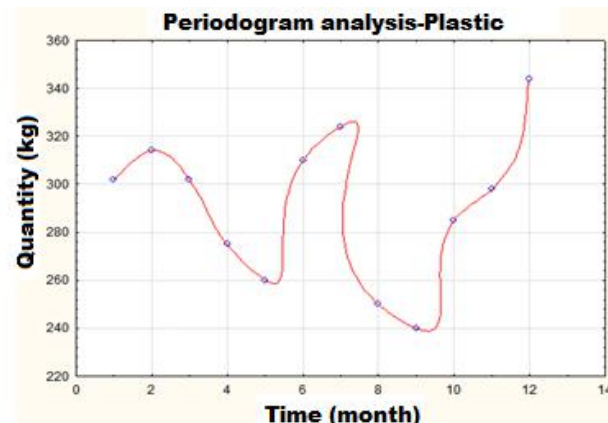


Fig.2: Periodogram of the amount of plastic.

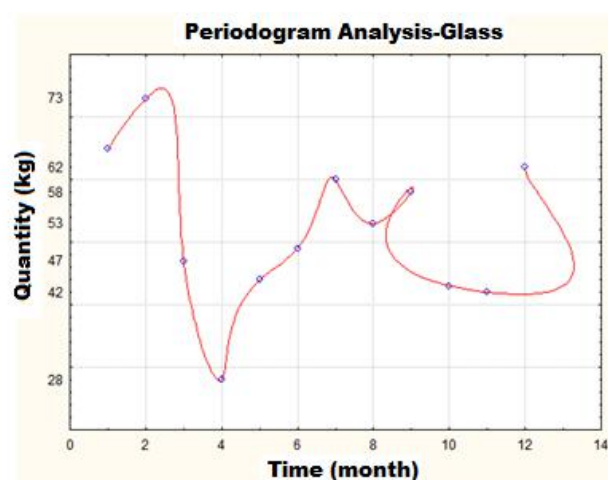


Fig.3: Periodogram of the amount of glass.

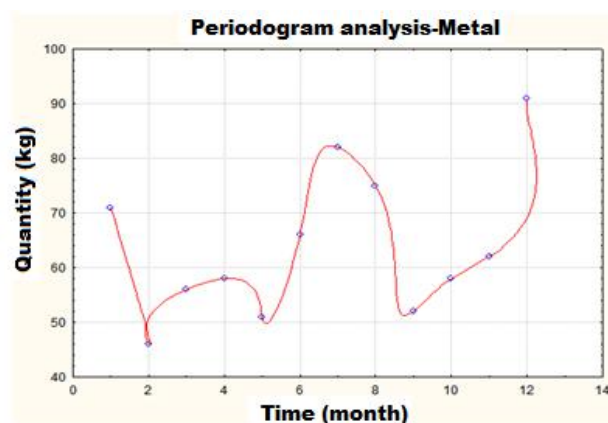


Fig.4: Periodogram of the amount of metal.

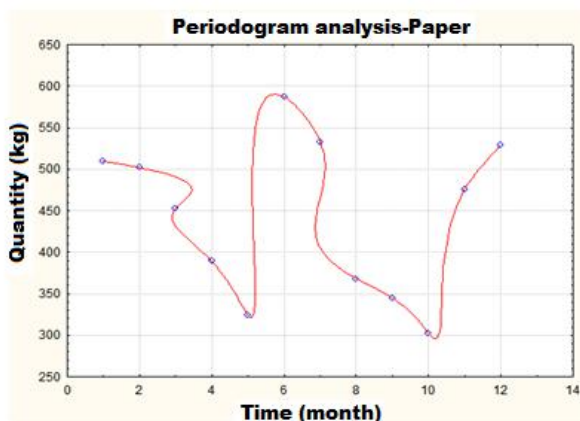


Fig.5: Periodogram of the amount of paper.

Analyzing Figures 2, 3, 4 and 5, great variability is observed in the original quantity of plastic, glass, metal and paper produced by the restaurant. Thus, any statistical study based only on these data would be totally inadequate, as they represent totally unstable systems. In the control graphs shown in Figures 6, 7, 8 and 9, we observed the distribution of the original amounts of solid waste in relation to the arithmetic mean (mean), upper limit (L.S) and lower limit (L.I), with also in relation to the variation within the subgroups, in order to verify the degree of dispersion in the values.

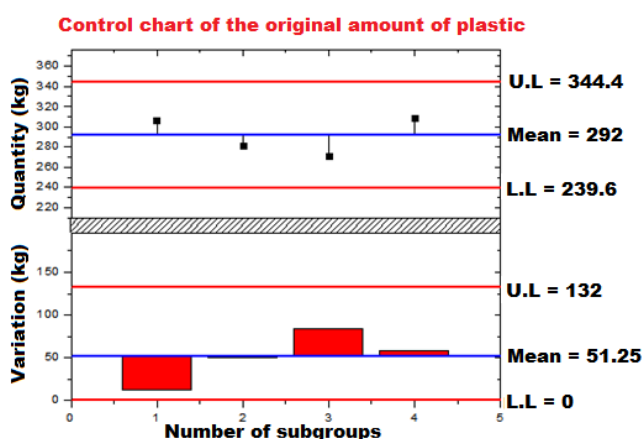


Fig.6: Control chart of the original amount of plastic.

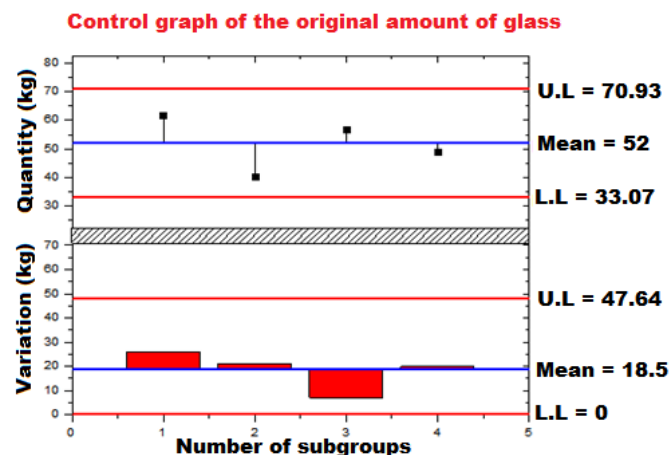


Fig.7: Control graph of the original amount of glass.

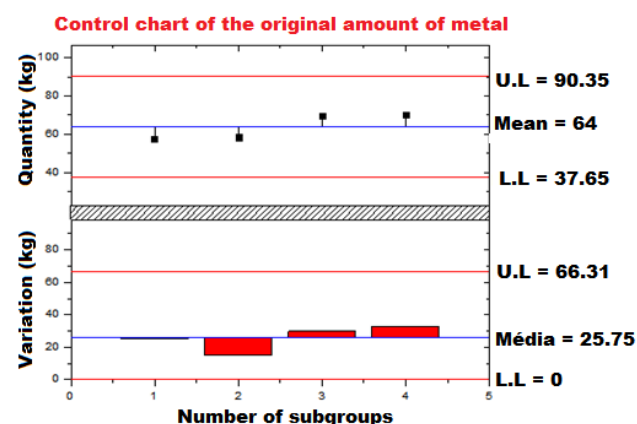


Fig.8: Control chart of the original amount of metal.

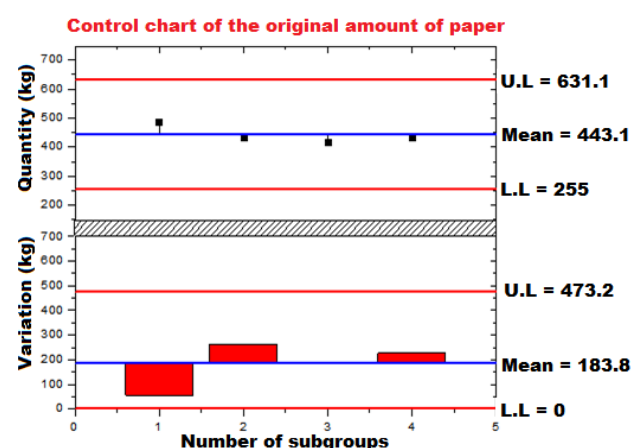


Fig.9: Control chart of the original amount of paper.

Control charts are important statistical quality control tools to improve quality. Quality improvement methods have been applied in the last 10 years to meet the needs of consumers. The product should retain the desired properties with the smallest possible defects, while maximizing profit. There are natural variations in production, but there are also attributable causes that are

not part of chance. Control charts are used to monitor production, and in particular, their application can serve as an “early warning” index in relation to possible “out-of-control” processes (35). To keep production under control, different control charts are established, prepared for different cases, incorporating upper and lower control limits. There are several control charts in use, and they are grouped primarily as control charts for variables and control charts for attributes. The points plotted in the charts can reveal certain patterns, which in turn allows the user to obtain specific information. Patterns that show deviations from normal behavior are raw material, machine configuration or measurement method, human and environmental factors, inadvertently affecting product quality. The information obtained in the control charts helps the user to take corrective actions, opting for specified nominal values, thus improving quality (35).

The use of quality control charts in studies of solid waste production planning in fast food restaurants, such as those shown in Figures 6, 7, 8 and 9, constitutes a very useful statistical tool for instrumental analysis. However, observing these figures, it was verified that the amount of sample was insufficient for an adequate statistical planning. This can lead to gross errors of interpretation, if statistical analyses are performed only with the original data, especially when the purpose of discussing the application of indicators of sustainable local development is intended. Since it's impossible to “create” new samples, the use of the bootstrap method that uses the so-called “pseudo-samples” from the original data set is a very feasible alternative to observe the production behavior of the restaurant, in case there are larger quantities than those presented in Table 1. Figures 10, 11, 12 and 13 show the control charts of bootstrap quantities of plastic, glass, metal and paper, respectively, from the production of the restaurant studied. In obtaining the graphs, 2000 bootstrap interactions were used.

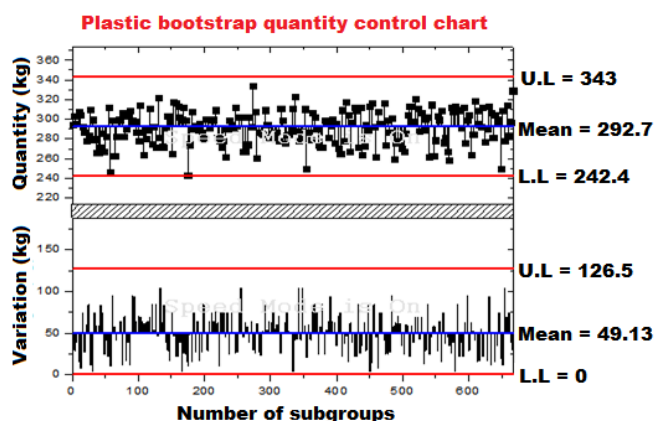


Fig.10: Plastic bootstrap quantity control chart.

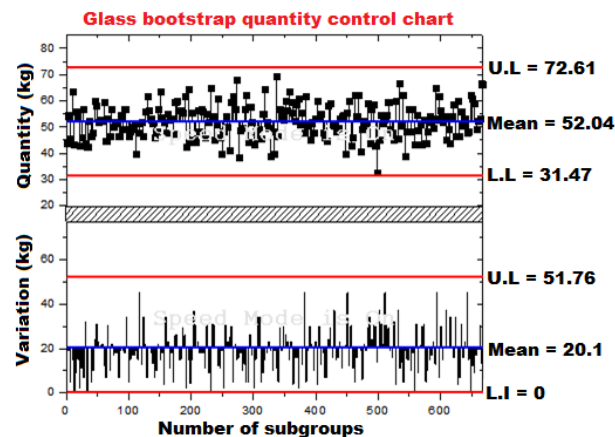


Fig.11: Glass bootstrap quantity control chart.

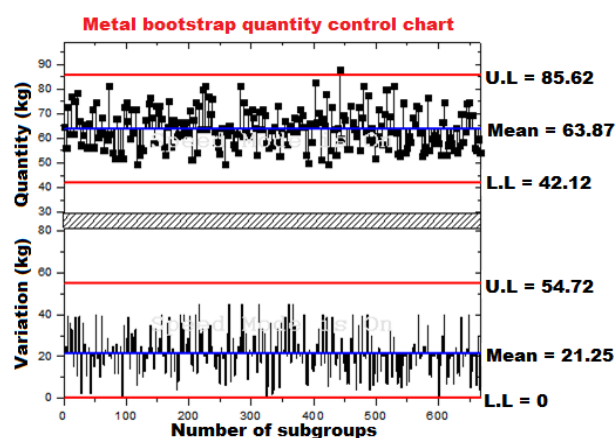


Fig.12: Metal bootstrap quantity control chart.

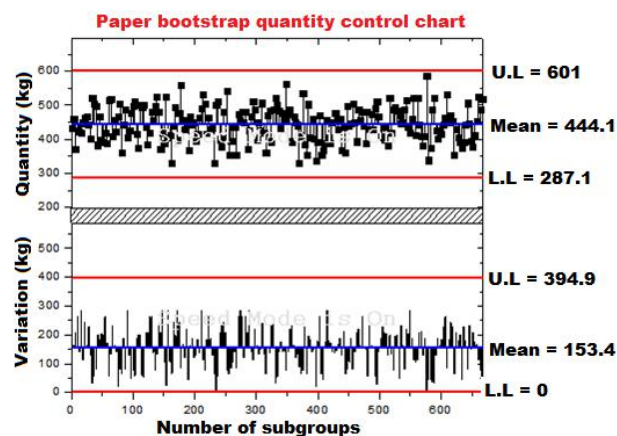


Fig.13: Paper bootstrap quantity control chart.

It's observed in Figures 10, 11, 12 and 13 that the statistical analysis of the original data using the bootstrap method proved to be quite efficient to obtain more stabilized values of the amounts of solid waste produced. Thus, all estimates of central trend measures and dispersion measures should be determined using the bootstrap empirical distribution. However, comparing Figures 6 to



13, it was verified that the arithmetic mean of the original data and bootstrap data didn't differ significantly. According to Efron & Tibshirani (36), the arithmetic mean of the original data and the bootstrap arithmetic mean are robust estimators of the population mean. It's verified in all graphs of Figures 10, 11, 12 and 13, that the dispersion in the original data set (Figures 6, 7, 8 and 9,) was significantly attenuated, resulting in the stabilization of each representative system, which indicated the bootstrap method as an adequate statistical tool to estimate the production capacity of solid waste in commercial restaurants.

### 3.2 Solid waste regenerated by recycling

Brazil doesn't have laws that establish percentages of recycling rates for fast food restaurants. The rate of recycling is an important indicator of environmental sustainability in companies that produce large amounts of solid waste, such as fast food restaurants. To Wen *et al.* (32), the recycling rate is an important indicator of the performance of the recycling system. IBGE (37) presents recycling rate values in its annuals, being described as one of the indicators of sustainable development in Brazil. Certainly, this indicator integrates guiding principles that existed at the United Nations Conference on Environment and Development that was held in the state of Rio de Janeiro in 1992.

When a company adopts sustainable development indicators, it shows that its stakeholders are really concerned with the environment, and not just about making a profit. Using Equation 1 and the percentage of recycling presented in the IBGE's sustainability indicators yearbook (2013), estimates were made of the amount of material that the restaurant studied should regenerate during recycling to be considered a sustainable company that makes systematic use reverse logistics. For that, the bootstrap quantities of the solid residues shown in Figures 10 to 13 were used, and the results obtained are shown in Table 2.

Table 2. Estimation of the amount of solid waste regenerated by recycling.

Type of solid waste	Recycling rate (%) <sup>*</sup>	Regenerated quantity (kg)	
		Variation	Average
Plastic	58,9	143 - 202	172
Glass	47,0	15 - 34	24,5
Metal	97,9	41 - 84	62,5
Paper	45,7	131 - 275	203

<sup>\*</sup>Data obtained from IBGE (2013).

The values presented in Table 2 were the estimated indicators of sustainable development of the studied restaurant. It was observed during the research that the collections of solid waste were carried out by the City of Recife, and there was no interest on the part of the stakeholders for the final destination of the collected material, nor the concern for the reverse logistics process. In fact, if there was a reverse logistics network as suggested by Ayvaz *et al.* (28), the restaurant studied should regenerate, at least, the amount of solid waste presented in Table 3. Thus, it's up to the stakeholders of the studied restaurant to establish performance indicators for the management of the solid waste produced, as suggested by AlHumid *et al.* (38).

Recycling reduces the use of natural resources by reusing materials. Much of the natural resources used by Brazilians are not renewable. The non-renewable use of natural resources is a major environmental problem that has been widely discussed in different areas of human knowledge, always considering that the recycling process avoids new waste, thus saving the environment. Fast food restaurants are potential producers of solid waste, so the environmental awareness of their stakeholders must be the *sine qua non* condition for the creation of a systematized reverse logistics network that's able to integrate recycling into the company's production process. According to Vasconcellos *et al.* (39), reverse logistics deals with the recovery and management of goods, and can add value to an image of the company and the environment. Thus, in order to achieve significant amounts of regenerated materials (Table 2), the operators of the restaurant studied should create strategies to establish a systematized reverse logistics network.

In the current national legislation, there is no parameter of ideal amount of solid waste generated. The state of São Paulo, for example, sanctioned on June 25, 2019 the bill of Law 99/2019 that prohibits the use of disposable plastic cups, cutlery and straws in commercial restaurants, with a penalty of a fine of R\$ 503.6 to R\$ 5,306 for those who break the law. This fact probably considerably decreased the amount of plastic produced in restaurants in the state of São Paulo, however, so far there are no comparative studies on this type of solid waste generated.

In the view of the operators of the system, the lack of adequacy of restaurants as sustainable companies is due to several factors, one of which is the insufficiency of physical space to carry out the selective collection (40). It's evidenced in the literature that this lack of concern with the environmental impact is, in fact, related to the lack of environmental education (41,42). This separation and

quantification of the waste produced is not the concern highlighted in the literature, which focuses on the production of recyclable plastics (43). Solid waste can also be solved with better project planning and employee training.

In the study by Picciafuoco (44) recyclable waste corresponded to only 1% of the total generation of waste in food units. However, in the work of Lafuente Junior (45), the waste from the stock and storage of a commercial restaurant corresponded to approximately 37% of the total waste generation. Despite the literature data, it's recommended that the evaluation of increase or decrease of recyclable waste should always be comparative within the unit itself, allowing to monitor the evolution of waste generation over time, since there's no parameter stipulated by Law (46).

Bartolacci *et al.* (47) defines an indicator that allows defining a maximum value of financial cost for the management of recyclable solid waste, but he considers that this indicator is individual, in view of the variables he predicted in the study between different scenarios. However, in the study by Salguero-Puerta *et al.* (48), the index of reuse of plastic waste produced and the amount that can be sold was defined. Such indicators could not be used in this study due to the lack of information regarding the separation of the types of plastics. But, with demand forecasting, it's possible to avoid waste and establish more accurate planning.

### 3.3 Predictability of the amount of solid waste produced

Studies on the predictability of a given phenomenon is crucial for decision-making, such as it can be used in business practice to predict results of interventions on an interpretable scale and therefore select appropriate procedures (34).

Predictive analytics is the analysis of the data received to identify problems in advance. Unfortunately, many Brazilian companies don't have predictive analyses and don't intend to do it in the near future. Generally, manufacturers are interested in quality control and ensuring that the entire production line is working with the best possible efficiency. With predictive analysis, it's possible to improve the quality of manufacturing and anticipate needs throughout the production line (34).

Manufacturing predictive systems allow users transparency in operations. The basis of a predictive production system is intelligent software, used to control the functionality of predictive modeling. This gives manufacturers the opportunity to proactively implement mitigating solutions to avoid loss of efficiency in manufacturing operations. Forecasting equipment

performance and estimating time to failure will reduce the effects of these uncertainties (34).

According to Ritzman *et al.* (49), the forecast is the evaluation of future events, used for planning purposes. He also states that forecasts are necessary to assist in determining the necessary resources, in programming existing resources and in the acquisition of additional resources, strengthening the idea of sustainability, as this way there will be no waste of products due to excess stock, consequently, the loss of a stopped stock.

Although solid waste is not considered as products of a production line of a fast food restaurant, it's possible to establish predictive studies on the quantities generated in the process. Today's factories and fast food restaurants have many things in common. The backstage of a fast food restaurant are true production lines with high manufacturing efficiency. It's remarkably profitable, and much of this success stems from the innovative methods used in restaurant supply chain management, inventory tracking, and maximizing the speed and quality of delivered food products. Thus, a fast food restaurant is a small factory, with a manager who supervises workers, plans schedules and shifts, tracks inventory and supply chain, oversees an assembly line producing strict quality control on its products. In most cases, the efficiency of the assembly line determines the texture, shape and taste of food, with the main fast food brands making their menu decisions according to what is operationally possible and flavorful. This turns an individual fast food restaurant, in essence, into a miniature factory (50).

Considering that the solid waste generated in a production line of a fast food restaurant behaves as a "product", predictive studies of the quantities produced using time series were performed. For this purpose, the time series with simple moving averages and the exponential smoothing of Holt were used, as suggested by Carlberg (51). Predictive analyses by time series with simple moving averages of plastic, glass, metal and paper quantities for the periods of 3 and 6 months are shown in Figures 14 to 21.

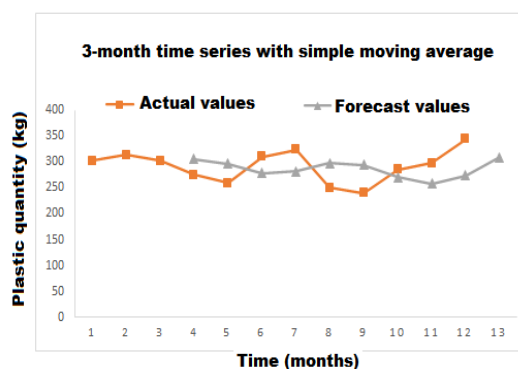


Fig.14: Forecast of the amount of plastic in 3 months with simple moving average.

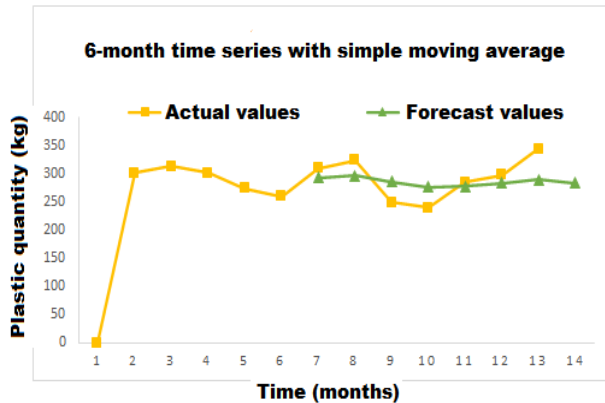


Fig.15: Forecast of the amount of plastic in 6 months with simple moving average.

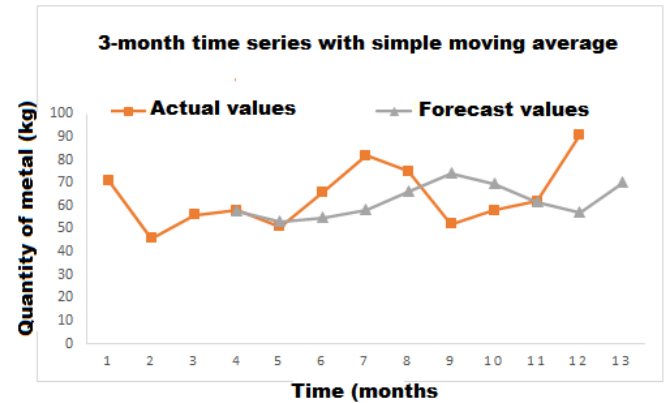


Fig.18: Forecast of the amount of metal in 3 months with simple moving average.

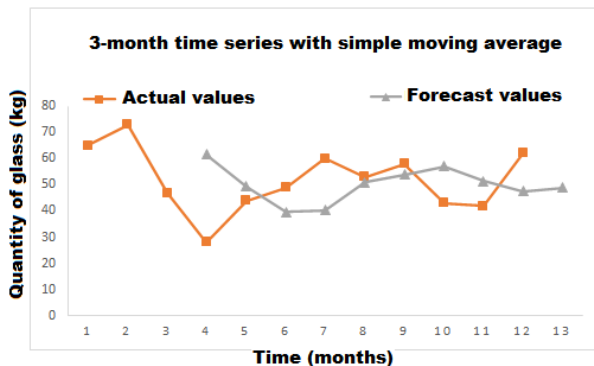


Fig. 16: Forecast of the amount of glass in 3 months with simple moving average.

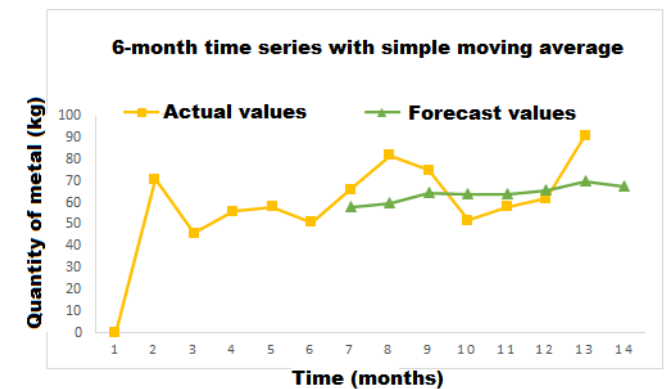


Fig.19: Forecast of the amount of metal in 6 months with simple moving average.

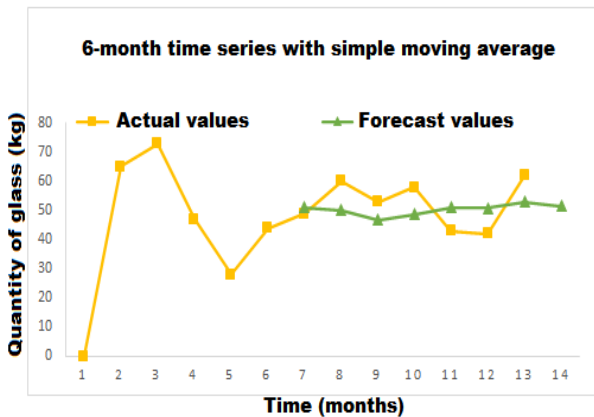


Fig.17: Forecast of the amount of glass in 6 months with simple moving average.

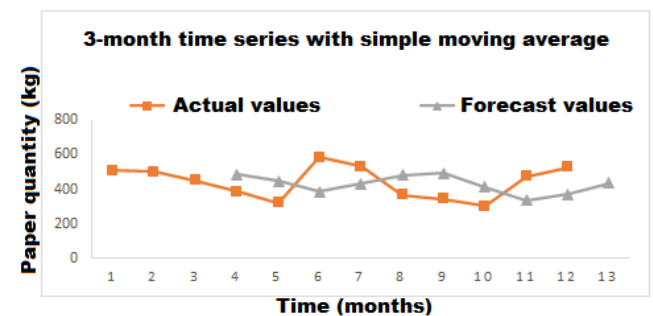


Fig.20: Forecast of the amount of paper in 3 months with simple moving average.

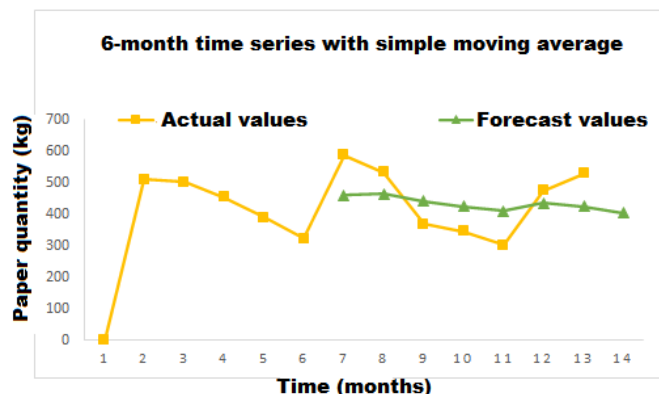


Fig.21: Forecast of the amount of paper in 6 months with simple moving average.

Moving averages may be the best option if there's no other source of information besides the output history of the evaluated product. By averaging your results month by month, quarter by quarter, or year-on-year, you can better visualize the long-term trend that's influencing results. In the analysis of time series with simple moving average, the averages move in time (Figures 14 to 21), and this is due to the entry of new values and output of the old ones (52). In this case, the means are used in the technical analysis identifying trends and assembling the operation strategies.

According to Sanvicente & Mellagi Filho (53) to build a moving average, the duration of the period that the average should be calculated is determined, and then, the average value of the number of observations of the set that was chosen for analysis is calculated. Thus, the average is done regularly with the abandonment of the oldest average and the addition of the newest. On the other hand, the longer the period (time), bigger will be the tendency to linearity. This can be observed for the times of 3 months and 6 months in the time series of the amount of solid waste obtained from the restaurant studied (Figures 14 to 21). In this case, for the 6-month period, the values tended to be more linear than the 3-month period. The forecasts of the quantities of plastic, glass, metal and paper for the period of 6 months tended towards the bootstrap averages presented in Figures 10 to 13. This shows the robustness of the bootstrap method in studies on system's predictability.

To obtain greater stability in predictive analyses of the quantities of plastic, glass, metal and paper, the time series with exponential Holt smoothing was used, the results of which are presented in Figures 22 to 25. According to Samohyl *et al.* (54), this method breaks down the series into its trend and seasonality components and smoothers historical data exponentially, so that old values tend to have zero weight, valuing the most recent observations.

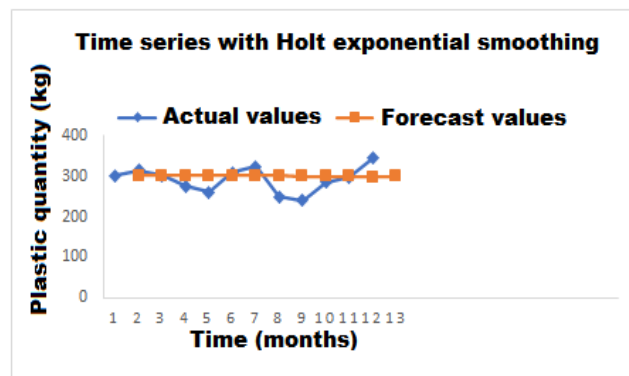


Fig.22: Prediction of the amount of plastic with exponential smoothing of Holt.

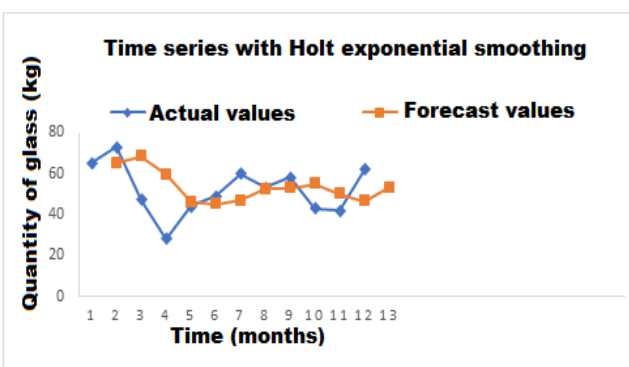


Fig.23: Prediction of the amount of glass with exponential smoothing of Holt.

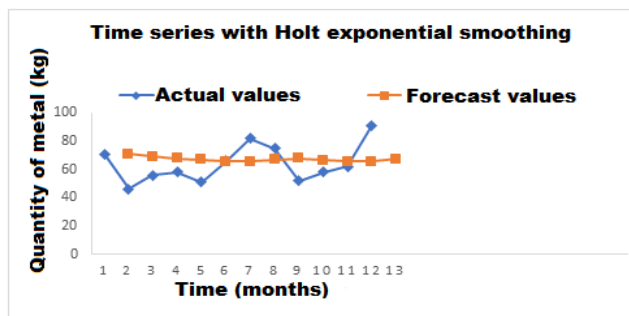


Fig.24: Prediction of the amount of metal with exponential smoothing of Holt.

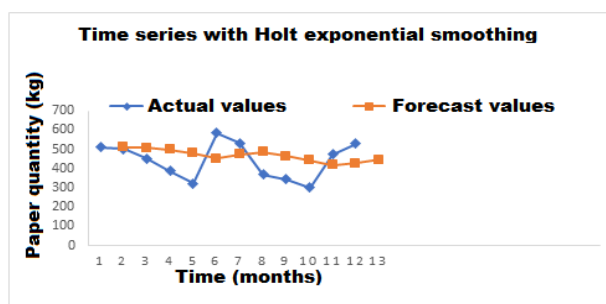


Fig.25: Prediction of the amount of paper with exponential smoothing of Holt.



As can be seen in Figures 22 to 25, the predictability analyses estimated by the time series with exponential Smoothing of Holt tended more rapidly to linearity than the time series with simple moving average (Figures 14 to 21). It's observed in Figure 22 that the forecast values tended linearly to 300 kg, which was not so different from the bootstrap mean value of 292.7 kg presented in Figure 10. Similarly, the trends to linearities presented in Figures 23, 24 and 25 approached the values of the bootstrap means of Figures 11, 12 and 13, respectively. Once again, the bootstrap method proved to be an appropriate statistical tool that can be used in predictive analysis of production system. Silva *et al.* (55) showed that the bootstrap arithmetic mean is a robust central trend measure that is not influenced by anomalous values. This agreed with the works developed by Efron (14).

#### IV. CONCLUSION

The issue of sustainable development in the restaurant studied lacks the support of its Stakeholders to implement a reverse logistics network of systematization of recycling solid waste produced during its operation.

It's necessary to create laws that establish specific indicators of sustainable development for fast food restaurants, because this type of commercial establishment produces high amounts of solid waste.

The bootstrap method and the time series with simple moving averages and exponential Holt smoothing can be used to make predictability studies of solid waste production in fast food restaurants, avoiding its waste.

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