Revista Brasileira de Administração Científica
Brazilian Journal of Scientific Administration
Jan a Mar 2023 - v.14 - n.1
ISSN: **2179-684X**
This article is also available online at:
www.sustenere.inf.br

Incentive to reduce the use of plastic: an alternative for reducing cost in a public institution

In view of the environmental impact generated by the production of disposable plastic cups and the amount of waste generated by the use of these products, the study reported here aims to present an alternative for the replacement of plastic cups in a higher education institution. The exchange of plastic cups for personal mugs will be simulated. Seeking to justify the study, the financial impact of this measure will be analyzed, which will seek to prove that this alternative will be good for public management. For this, the methodology of system dynamics and scenario planning will be used. The proposal presented showed favorable and interesting results for public management. The article discusses these possibilities and points to future perspectives.

Keywords: System Dynamics; Environmental Impact; Plastic Waste.

Incentivo de redução do uso do plástico: uma alternativa para redução de custos em uma instituição pública

Tendo em vista o impacto ambiental gerado pela produção de copos plásticos descartáveis e a quantidade de resíduos gerada pelo uso destes produtos, o estudo aqui relatado tem como objetivo apresentar uma alternativa para a substituição de copos plásticos em uma instituição de ensino superior. Será simulado a troca dos copos plásticos por canecas pessoais. Buscando justificar o estudo será analisado o impacto financeiro desta medida, que buscará comprovar que está alternativa será boa para a gestão pública. Para isso será usada a metodologia de dinâmica de sistemas e planejamento de cenários. A proposta apresentada demonstrou resultados favoráveis e interessantes para a gestão pública. O artigo discute essas possibilidades e aponta para perspectivas futuras.

Palavras-chave: Dinâmica de Sistemas; Impacto Ambiental; Resíduos Plásticos.

Topic: **Gestão Pública**

Reviewed anonymously in the process of blind peer.

Received: **20/01/2023**
Approved: **15/02/2023**

Marcos Morgental Falkembach
Universidade Federal de Santa Maria, Brasil
http://lattes.cnpq.br/3858285217359039
uchihaconsultoria@gmail.com

Glauco Oliveira Rodrigues
Universidade Federal de Santa Maria, Brasil
http://lattes.cnpq.br/9943217673304581
https://orcid.org/0000-0002-3249-1057
glaucop10@redes.ufsm.br

Luiz Cláudio Dalmolin
Universidade do Estado de Santa Catarina, Brasil
http://lattes.cnpq.br/7393306373465290
https://orcid.org/0000-0003-1501-1629
glaucorodriguesp10@gmail.com

Nilson Ribeiro Modro
Universidade do Estado de Santa Catarina, Brasil
http://lattes.cnpq.br/3985354928735296
https://orcid.org/0000-0002-5765-3382
glaucorodriguesp10@gmail.com

Andréa Oliveira da Silveira
Universidade Federal de Santa Maria, Brasil
https://lattes.cnpq.br/8554631341845429
https://orcid.org/0009-0005-0887-8795
profandreasilveira@gmail.com

DOI: 10.6008/CBPC2179-684X.2023.001.0004

Referencing this:
FALKEMBACH, M. M.; RODRIGUES, G. O.; DALMOLIN, L. C.; MODRO, N. R.; SILVEIRA, A. O.. Incentive to reduce the use of plastic: an alternative for reducing cost in a public institution. **Revista Brasileira de Administração Científica**, v.14, n.1, p.46-59, 2023. DOI: http://doi.org/10.6008/CBPC2179-684X.2023.001.0004

INTRODUCTION

The accelerated process of globalization in the last three decades of the 20th century has unleashed a significant awareness of the global community's responsibility to the environment. The adaptation of the UN to the new demands of the global community regarding environmental, labor and human rights-related risks generated the proposal of the Global Compact, which consists in the adoption of sustainable practices of action against the consequences of globalization (INSTITUTO ETHOS, 2008).

With a market driven by consumerism and convenience, coupled with the comparison with the low price of plastic materials, the demand for plastic is growing. About 299 million tons of plastic were produced in 2013, which represents an increase of 3.9% over 2012 production. In addition, world production continued to grow between the 1970s and 2012, when plastics replaced gradually materials such as glass and metal (GOURMELON, 2015). A study by Geyer *et al*. (2017) estimated that 8300 million metric tons (Mt) of virgin plastics had been produced. According to the authors, in 2015, approximately 6.300 Mt of plastic waste were generated, of which 9% were recycled, 12% were incinerated and 79% were accumulated in landfills or in the natural environment. In addition, they point out that if current trends in waste production and management continue, approximately 12.000 Mt of plastic waste will be landfilled or in the natural environment by 2050.

Thompson *et al*. (2009) believe that immediate considerable reductions in the amount of waste entering natural environments, as opposed to landfills, can be achieved with better waste disposal and material handling. For them, perhaps the increase in recycling capacity will help to reverse this trend, so that we consider end-of-life materials as valuable raw materials for new production, rather than waste.

The first global attitude that showed concern for saving the environment was the United Nations conference that took place in the Swedish capital, Stockholm, in 1972. The Stockholm Conference aimed to raise awareness in society and improve its relationship with the environment and thus meet the needs of the present population without compromising future generations. From this conference, several other actions were taken to decide measures to reduce environmental degradation and guarantee the existence of future generations, resulting in important agreements on climate change, biodiversity and commitment to the principles of Sustainable Development.

Already in 2015, the COP-21 UN climate conference or Paris Agreement where the United Nations defined the Sustainable Development Goals (SDGs) as part of a new sustainable development agenda, called the 2030 agenda, the 193 member states were unanimous in adopting the Sustainable Development Goals, as the objective to protect the planet from degradation, above all through sustainable consumption and production, sustainable management of its natural resources and taking urgent measures on climate change, so that it can support the needs of present and future generations (UNBR, 2015).

Considering meeting the objective of this work, the 12th SDG stands out, which deals with ensuring sustainable production and consumption standards and aims to substantially reduce the generation of waste through prevention, reduction, recycling and reuse. The first advance in this direction in the country was the enactment of Law nº. 12,305/2010, which instituted the National Solid Waste Policy (PNRS), which aims at the non-generation, reduction, reuse, recycling and treatment of solid waste, as well as environmentally adequate final disposal of tailings; encouraging the adoption of sustainable patterns of production and consumption of goods and services and encouraging the recycling industry, among others.

According to data from the National Sanitation Information System (SNIS), in 2016, the total mass collected in Brazil was estimated at 58.9 million tons, with 59% being disposed of in landfills, 9.6% in controlled landfills, 10.3% in dumps and 3.4% sent to sorting and composting units, leaving 17.7% without information, which mainly refers to small municipalities with up to 30,000 inhabitants (BRASIL, 2018a).

In Brazil, the coverage rate of regular household solid waste collection service in relation to the total population reached 93,1% of total households in 2012 and dropped to 91,5% in 2016. (BRASIL, 2018a). The mechanical recycling rate of post-consumer plastic was 19,4% in 2010 according to the report of the Instituto Socioambiental dos Plásticos (2013). Such a situation is not very different from the US, for example, where plastic recycling is largely limited to beverage containers, although local authorities continue to expand the types of plastics collected for recycling (BARNES, *et al*. 2009).

In Brazil, the coverage rate of regular household solid waste collection service in relation to the total population reached 93,1% of total households in 2012 and dropped to 91,5% in 2016. (BRASIL, 2018a). The mechanical recycling rate of post-consumer plastic was 19,4% in 2010 according to the report of the Instituto Socioambiental dos Plásticos (2013). Such a situation is not very different from the US, for example, where plastic recycling is largely limited to beverage containers, although local authorities continue to expand the types of plastics collected for recycling (BARNES, *et al*. 2009).

The tiny percentage of recycled waste corroborates Gourmelon's (2015) statement that recovery and recycling remain insufficient, and millions of tons of plastic end up in landfills and oceans each year. Thus, while recycling is not effective, the idea is to encourage the non-use of plastic or polystyrene cups, to establish substitutes that can be reused to the detriment of the use of disposable cups. The reduction in the use of disposable cups also contributes to cost containment, a problem that has directly affected HEIs, due to deliberate cuts in resources by the federal government.

According to Waste Management (2019), plastic pollution affects the quality of air, soil and water supply systems, as the material absorbs several toxins and can take up to 100 years to decompose in nature, affirming the importance of properly handle the disposal of the plastic.

In this sense, this article aims to evaluate and analyze the amount of plastic cups of coffee (50 ml) and water (200 ml) that are used by a HEI in the central region of the state of Rio Grande do Sul and what would be the impacts in the case of replacing plastic cups with glass mugs.

The article is organized as follows: Section 2 presents the research method used to develop the study. Section 3 presents the theoretical framework. Section 4 demonstrates the development of the computational model. In section 5, the results generated by the model for the experiment are presented. The conclusions are presented in section 6 and the references used are shown in section 7.

THEORETICAL FRAMEWORK

Solid Urban Waste (RSU)

The global generation of solid waste, strongly correlated with gross national income per capita, has been growing steadily over the last five decades. The share of plastics in urban solid waste (by mass) has increased from less than 1% in 1960 to more than 10% in 2005 in middle and high-income countries, driven by the largest plastics market, packaging, an application whose growth has been accelerated by a global shift from reusable to disposable containers (GEYER *et al*., 2017).

Law 12.305/2010 established the National Solid Waste Policy (PNRS), which recognizes solid waste as reusable and recyclable as an economic and social value, with some objectives being to encourage the development of environmental and business management systems aimed at the improvement of production processes and the reuse of solid waste and the non-generation, reduction, reuse, recycling and treatment of solid waste, as well as the environmentally appropriate final disposal of waste (BRASIL, 2010).

According to information from CEMPRE (2017a), from the implementation of the National Policy, considering the aspects related to the improvement in the final disposal of waste and the increase in the recovery rate of the dry fraction of urban solid waste, as of 2012, it was achieved avoid greenhouse gas (GHG) emissions in the order of 7,02 Tg CO2 equivalent per year (7,02M tons CO2 eq per year), considering that around 7% of GHG emissions in Brazil are related to solid waste management.

Jacobi (2006) explains that the fraction of waste that is not re-introduced into the production chain not only increases municipal expenses, but also takes up precious space in already overcrowded landfills and no longer represents energy savings in industrial inputs such as water and Petroleum.

In this sense, it is important to cite Law nº. 12.305/2010, which, by declaring the economic and social value of solid waste, legally going from simple garbage to good, adopts a perspective of environmental protection and social development, capable of effectively transforming the chain productive, often far from worrying about the future, as cited by Granziera (2015).

Waste is typically classified based on its point of generation. Categories include municipal, commercial, industrial, agricultural, and construction and demolition (C&D). However, there is ambiguity in these categories. For example, in the US, solid urban waste (MSW) includes those generated in the residential, commercial, and institutional sectors (eg schools, government agencies), while in other countries, MSW can include anything from residential waste only to all waste managed in the municipal system (eg C&D, non-hazardous industrial) (BARNES *et al*, 2009). In Brazil, they include household waste, those originating from domestic activities in urban residences and urban cleaning waste, originating from sweeping, cleaning of public spaces and streets and other urban cleaning services (BRASIL, 2010).

Regarding selective collection in the municipalities, the 2016 SNIS diagnosis showed that the amount fell for the second consecutive year, it is practiced in 1.215 of the 3.670 participating municipalities, which represents 21.8%, when computing the number of municipalities, no information on collection, and this rate was 22,5% in 2015 and 23,7% in 2014.

The SNIS also assesses the amount of dry recyclables recovered (paper, plastic, metal, glass and others), regardless of whether they come from selective collection or not, sorting activities result, in the 1.361 municipalities that had information considered consistent of the amount of 772.2 thousand tons of recyclables, that is, an average index that is, in 2016, at 7,2 kg/inhabitant/year, 10 percentage points lower than the value calculated in the previous year. % or 600 thousand tons, is recovered in the South and Southeast regions. Another 19% are assigned to the Northeast and Midwest regions and the remainder (less than 4%) is assigned to the North region. The South region stands out as well above the national average, with an average indicator of 15,2 kg/inhabitant/year, more than double the national result of 7,2 (BRASIL, 2018a).

Recycling companies are the main consumers of plastics separated from garbage, which reprocess the material, making it return as raw material for the manufacture of plastic artifacts, such as conduits, garbage bags, buckets, hangers, bleach bottles, and car accessories, it is possible to save up to 50% of energy with the use of recycled plastic (CEMPRE, 2011).

Plastic and its recycling

Plastics are man-made materials, made from polymers, or long chains of repeated molecules (GOURMELON, 2015). They are cheap materials, light, strong, durable, resistant to corrosion, with high thermal and electrical insulation properties (THOMPSON, *et. al*. 2009). Plastics are derived from oil, natural gas (GOURMELON, 2015), and according to Andrady and Neal (2009), these fossil fuels are the preferred raw material, although plastics from renewable resources such as sugar and corn can also be produced. About 4% of the world's oil is used to make plastic and another 4% is used to drive plastics manufacturing processes (GOURMELON, 2015).

Recycling, on the other hand, according to Waste Management (2019), is the process by which waste that is destined for final disposal is collected, processed, and reused. World Business Council for Sustainable (2014) defines recycling as the separation of materials from household waste, such as paper, plastics, glass, and materials, with the purpose of bringing them back to the industry to be benefited. For Middlecamp, *et al*. (2016), recycling is carried out from the collection of plastic and transported to a facility where it can be separated for use as some marketable merchandise and after being separated, the polymers are melted. According to the authors, the cast polymer can be used directly in the manufacture of new products. Mixed polymer (molten polymer blend) is not as valuable as pure polymer, but it can still be used for less noble uses, such as plastic pots, or cheap wood substitutes.

Plastic is the only one to have a recycling industry, because due to its complexity, the recycling industry emerged, responsible for the acquisition of scrap and residues for the manufacture of recycled raw material. This industry manufactures the new raw materials that will once again enter the production process (ABIPLAST, 2017). According to Pivinenko *et al*. (2016) plastics recycling has the potential to partially replace virgin plastics as a source of raw materials in the manufacture of plastic products.

Zanin et al. (2015) suggest a hierarchy to promote the recycling of plastics in a more sustainable way and thus try to take advantage of the inherent qualities of each material. In mechanical recycling, the mixture of different plastics usually leads to the manufacture of a product with lower mechanical properties, whereas chemical recycling involves the controlled depolymerization of the plastic, aiming to obtain products with added value greater than the energy contained in a polymer. In mechanical recycling, plastics are classified, composed by melting and transformed into new products. In chemistry, on the other hand, plastics are depolymerized into their respective monomers and subsequently repolymerized (KIRAN CILIZ *et al*., 2004) or into other valuable chemical products (BREMS *et al*., 2012).

According to ABIPLAST (2017) the apparent consumption of processed plastics in Brazil was 6.5 million tons in 2017, a 4% growth compared to the previous year. More than 90% of raw plastic is produced from fossil fuels (oil or natural gas). Polymers are synthesized by large petrochemical companies such as ExxonMobil, Sinopec and Total. The plastic is then sold to plastic manufacturers to make objects, primarily by injection, blow molding or heat formation. These objects are assembled or sold directly by brand owners through a variety of retail circuits (D'AMBRIÈRES, 2019).

The importance of plastic recycling is highlighted, because for every 1 ton of recycled plastic material produced, the emission of 1,53 tons of Greenhouse Gases into the atmosphere is reduced and 1.1 ton on average of plastic waste disposed in landfills; there is an average energy saving of 75%; 450 L of water are avoided in production; jobs are generated for 3,16 scavengers who collect this volume of material in the month (ABIPLAST, 2017).

Zanin et al. (2015) state that plastic materials cause impacts on the environment whose main forms are at the extremes of their production chain: the depletion of non-renewable raw material and the accumulation of residues that are difficult to degrade. The action of recycling, then, is part of a set of procedures aimed at reducing the environmental impacts associated with them. In this sense, Geyer *et al*. (2017) state that none of the commonly used plastics are biodegradable. As a result, they accumulate, rather than decompose, in landfills or in the natural environment. For these authors, the only way to permanently eliminate plastic waste is by destructive thermal treatment, such as combustion or pyrolysis, and thus, the almost permanent contamination of the natural environment with plastic waste is a growing concern.

It should also be considered that plastics are associated with substantial environmental issues as they are based primarily on non-renewable raw materials (eg oil), are commonly used in short-lived products (eg food packaging) and once discarded, they are predominantly disposed of in landfills or incinerated (THOMPSON *et al*., 2009). Jambeck *et al*. (2015), point out that if not properly disposed of plastic waste can end up in the oceans, thus creating another environmental problem of growing concern (JAMBECK *et al*., 2015). According to them, plastic debris has been found in all major ocean basins, with an estimated 4 to 12 Mt of land-generated plastic waste that entered the marine environment in 2010 alone.

A relevant issue in recycling is the importance of society in the separation of waste, as the main release of plastic to the environment is the result of inadequate waste management and inadequate human behavior, for example, garbage (abandoning waste away from the collection points) (BARNES, *et al*, 2009). A survey conducted by Clicossoft (2016) shows that cardboard and cardboard scraps are the most collected recyclables by municipal selective collection systems (by weight), with 34% and then with 11% are plastics in general and, in first place. Place, the tailings with 35%, which confirms the importance of society in the separation of waste (CEMPRE, 2016).

Another issue that highlights the importance of separation is that, according to Zanin et al. (2015), plastics, if not properly separated, can compromise the final properties of the recycled product due to the physical and chemical variations they present with each other. A study by Luijsterburg et al. (2014) showed that the collection method for plastic packaging waste has practically no influence on the final quality of the recycled material; however, the classification and reprocessing steps influence the final quality of the recycling. This is because there will always be some polymer contamination that will affect the final properties of the recycled ones.

According to ABIPLAST (2017), the estimated mechanical recycling of post-consumer plastic material is 550 thousand tons, with the main resins consumed being polypropylene (PP), with 21,6%, and high-density polyethylene (HDPE) and polyvinyl chloride (PVC), with 13,6%; the polystyrene (PS) of plastic cups ranks ninth, with 6,5.

An important issue with polystyrene cups is that many are sent to waste, remaining in landfills for over 100 years, which is the time they take to decompose. According to Jorge (2015), this problem occurs because, due to its contamination, the price paid for polystyrene scrap is not worth separating, pressing and storing it.

To carry out the analysis and evaluation of the impacts that the use of plastic cups can cause to the environment, the appropriate technique would be systems dynamics, which allows the researcher to test different policies and solutions, evaluating the impact of decisions (BASTOS, 2003).

System Dynamics

The birth of Systems Dynamics (SD), as a formal field of research, takes place after the publication of an article written by Jay Wright Forrester, in the Harvard Business Review, in 1958. This is because the results of the simulation of the article were much commented on in the academic environment, due to the simulation technique created and used by Forrester (MAANI et al., 2000; BASTOS, 2003).

The SD methodology fundamentally proposes the use of a shared vision model, based on the construction of an influence diagram, which serves as a basis for modeling a simulated system. The conditions under which this diagram is constructed are based on empirical procedures (ANDRADE, 2006).

Bastos (2003) states that SD is a methodology that seeks to map structures of organizational or social systems, seeking to examine the interrelationship of their forces and, through simulation, wants to understand how the system in focus evolves over time and how it changes in their parts they affect all their behavior (BASTOS, 2003).

The SD methodology allows the study of the behavior of systems over time, to allow the evaluation of the consequences of our decisions (DAELLENBACH et al., 2005). For this reason and the need to study waste recycling in a future time horizon, it was decided to use it in computer modeling and simulation.

According to Daellenbach et al. (2005), the SD methodology allows the study of the behavior of systems over time, to allow the evaluation of the consequences of decisions.

A SD model can be interpreted as the structure resulting from the interaction of policies. This structure is formed by two main components, which are stocks and flows, so much so that Ford (2009) defines SD as a combination of stocks and flows that use a computational structure to be simulated. Sufian et al. (2007) used this approach to model the solid waste management system in the city of Dhaka-Bangladesh. Other authors who also used this methodology were Abeliotis *et al*. (2009); Dyson et al. (2005); Kumet al. (2005).

For Fernandes (2001), one of the SD applications is the visualization of any human system, through the identification of its structural characteristics, the cause-effect-cause relationships, and the feedback structures, through the construction of the so-called Influence Diagrams. Such diagrams, of a qualitative nature, are used to produce a description of the main elements that cause the behavior of a feedback system and are particularly useful for developing a shared understanding of how a system works, or even for communicating some findings.

RESEARCH METHOD

The methodology used in this research article is based on SD, which aims to understand the basic structure of systems functioning and, in this way, anticipate the behavior they produce. Most of the problems that are analyzed can be computer modeled. SD takes advantage of the fact that computer models can be complex and perform calculations impossible for humans or their conventional investigation methods to perform.

To contemplate the objective of this article, a computational model was developed using the steps generated by Law (2015), which are as follows: (I) Exploratory studies in scientific articles, government brochures, technical reports and observations of the environment in which the data were collected , (II) development of the solution, definition of variables and their relationships, (III) computational implementation of the solution in Vensim software (VENTANA SYSTEMS, 2018), (IV) verification and evaluation (V&A) of the solution through laboratory tests and analysis of the historical behavior.

The model was conceived, verified, and evaluated having as object of analysis an HEI in the central region of the state of Rio Grande do Sul, but it can be applied and extended to other organizations, as long as the specifics of the case are added and dealt with in the model. The stages of development of the model were carried out at the IES due to the ease of access to data and to people who have knowledge about the subject of the study, therefore, the choice of this institution was for convenience. The main justification for applying the developed model takes into account the economic crisis presents at the IES, in addition to presenting a way to generate less environmental impact in the excessive use of plastic.

The primary sources were essentially undertaken through bibliographical research and documental research, in addition to an interview conducted with the person responsible for the area related to the study. The secondary sources used are related to more generic information, such as information about the logistics of purchasing plastic cups purchased directly from the HEI partner in the study. The theoretical study that supports the computational model will be presented in the next section.

Model Components

A System Dynamics model is built with basically four components that we will see next. Stocks are state variables and can be considered as repositories to accumulate or store for other elements of the system (DEATON et al., 2000), its main importance is to provide a view of how the system is at any moment of time, changes in stocks they are not instantaneous, they require a certain amount of time and occur due to the action of flows.

Flows, in turn, are action variables, they can increase or decrease the volume determined in the stock. Produces growth or reduction of stocks, movement of materials and information within the system. Auxiliary variables are components for carrying out algebraic operations, which process information about stocks and flows or represent sources of information external to the system (BLOIS et al., 2008). There are auxiliaries that can also modify other auxiliary variables, they are often used to model information and not the physical flow, and can change instantly without delays (COVER, 1996).

Finally, there are connectors that represent the interrelationships between all components, that is, these interconnections link the components that form the mathematical expression (DEATON et al., 2000). They have the function of information links that describe the relationship between stocks, flows and auxiliaries.

DEVELOPMENT OF THE COMPUTATIONAL MODEL

Higher education institutions have the corporate responsibility to encourage society's awareness of consumption and generation of plastic waste, to minimize the environmental damage caused by them when sent to landfills. Allied to this is the need to reduce costs due to the constant cuts in resources that HEIs have been suffering annually.

In this sense, a model was built to evaluate and analyze the amount of plastic cups of coffee (50 ml) and water (200 ml) that are used by a HEI in the central region of the state of Rio Grande do Sul and what would be the impacts on case of replacing plastic cups with glass mugs.

To perform the simulation and evaluate the financial impacts of the consumption of different plastic cups, three scenarios were generated. The first scenario created is the "Scenario Current" to store the related values purchases that take place in 2018, this scenario will serve as a basis for comparison with the other scenarios developed. The second scenario developed is the “Scenario 50%”, where the purchase of plastic cups will be reduced by 50%, in addition to the purchase of a mug, of 200 ml and another of 50 ml, for each IES server. Finally, the “Scenario 100%” will analyze the zero purchase of plastic cups by IES, intending that each server has its own mug for personal use, trying to reduce the consumption of plastic.

Data on the quantities of plastic cups consumed were taken and collected directly at the HEI, which is the center of the study, which has a total of 4.783 servers. After the established scenarios, the computational model was built, which is shown in Figure 3.

The model is composed of two storage variables ("Cost Plastic 200 ml", "Cost Plastic 50 ml"), four flow variables ("Cup 200 ml", "Cup 50 ml", "Price 200 ml", "Price 50 ml”) in addition to ten auxiliary variables (“Media Purchase Cup”, “Cost 200 ml Cup”, “Cost 50 ml Cup”, “Ceramic Mug Price 200 ml”,”Ceramic Mug Cost 200 ml”, “Ceramic Mug Cost” 50 ml”, “Ceramic Mug Price 50 ml”,”Ceramic Mug 50 ml”, “Ceramic Mug 200 ml”, “Server Quantity”), the interaction of these variables is shown in figure 1.

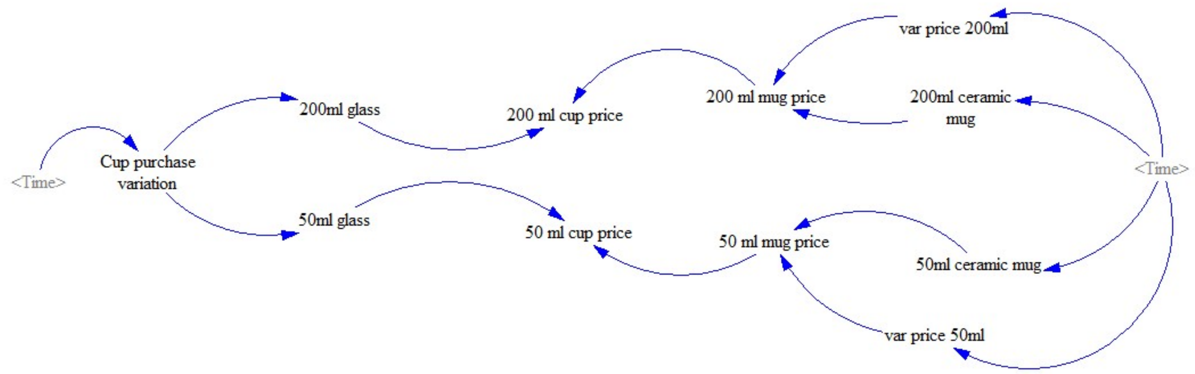

Figure 1: Proposed model and its variables.

The model is divided into two strands, the left side represents the interaction of the variables of the current purchase model, the variable "Media Purchase Cup" was created with the purpose of gradually reducing the purchase of the plastic cup, it is with it that the percentages of scenarios are inserted, which can offer the decision maker the application of other purchase percentages, better reinforcing the decision to purchase plastic cups from the HEI. The right side of the model presents the researchers' proposal, where each server would have the right to a 200 ml mug and another 50 ml mug, and the costs involved in buying the mugs were taken from analyzes in official documents as well as online auctions and refer to R$7,00 and R$4,00 respectively. The model equations are shown in Table 1.

Table 1: The model equations.

(1) 200 ml CUP = 676300*Media Buy Cup
(2) 50 ml CUP = 380200*Media Buy Cup
(3) Plastic Cost 200 ml = CUP 200 ml * Price 200 ml
(4) Plastic Cost 50 ml = CUP 50 ml * Price 50 ml
(5) Cost Ceramic Mug 200 ml = Ceramic Mug 200 ml*Price Ceramic Mug 200 ml
(6) Ceramic Mug Cost 50 ml = Ceramic Mug 50 ml*Ceramic Mug Price 50 ml
(7) Cost 200 ml Cup = Cost Ceramic Mug 200 ml+Cost Plastic 200 ml
(8) Cup Cost 50 ml = Ceramic Mug Cost 50 ml+Cost Plastic 50 ml

Equations 1 and 2 show the average annual purchase value of cups multiplied by the average annual purchase, making it possible to verify the financial impact of purchasing different quantities of cups. The other equations refer to the costs in Reais of purchasing plastic mugs and cups. The following section presents the simulation results of the computational model.

COMPUTATIONAL SIMULATION RESULTS

After defining the three scenarios, the simulations were run in the Vensim simulator (VENSIM, 2018) on a computer with a Pentium Core i3 processor and 8 Gb of RAM memory. The simulation execution time was in the order of millionths of a second. The time horizon simulated in the experiment was 15 (fifteen) years, but the configuration of this variable is up to the designer / user, as it depends on the analysis to be carried out.

Decisions, based on the results generated by the model, may involve the adoption or not of the purchase of ceramic mugs. Figure 2 shows the cost of the 50 ml cup for the HEI. The 100% scenario, where IES will no longer buy 50 ml cups, showed the best result, being able to total savings of approximately R$586.219,00 to the public coffers at the end of the simulation. The 50% scenario, where half of the demand for cups will be purchased, will yield a lower cost from 2026, presenting in 2038 savings of approximately R$66.000,00.

Figure 2: Cost and scenarios for the 50 ml cup.

The analysis of the 200 ml cups, shown in Figure 3, also presented the 100% best-performing scenario, totaling an expense of R$53.502,00 considering that each server will earn only two mugs, exempting the IES from the responsibility of replacing the same. This scenario has a higher cost than the current one, although in just two years of simulation, that is, from 2028 onwards, this scenario will present a lower cost, allowing the HEI to invest the expenses with plastic cups in other sectors or products. In 2035, the 100% scenario could present savings of approximately R$ 2.427.000,00, a considerable amount that could represent an excellent opportunity for a strategy to reduce the costs of the IES. This economy corroborates the research by Thompson *et al*. (2009), where researchers claim that the use of waste with greater durability, instead of disposable waste, will generate greater savings for the organization.

The 50% scenario until 2023 represents a greater investment for the institution, but from 2029 onwards, it may present savings of BRL 36,000.00 per year, when compared to the current scenario and in 2035, adding all the different scenarios. 50% may present financial savings of up to approximately R$744.000,00.

It can be seen that from 2029 onwards, the difference between the current scenario and the 50% scenario starts to gain a greater proportion, reinforcing the importance of reducing the purchase of plastic cups, which seems to be something negligible but may offer great financial savings for Higher Education Institutions, enabling the investment of this reduction in other areas of education. Gourmelon (2015) and Geyer *et al*. (2017) define that the use of resources with a longer life cycle can generate financial and environmental savings for world institutions.

Figure 3: Cost and scenarios for the 200 ml cup.

CONCLUSIONS

The debate on the environmental crisis has given the population in general greater awareness regarding the change in attitude that must be taken to minimize the negative impacts caused to the environment.

HEIs can and should be transforming agents in the communities they are part of to boost environmental awareness in the face of conscientious consumption and correct disposal of plastic waste. In addition, HEIs need to identify ways to face the budget cuts for education, which have been running annually by the federal government.

The various possibilities for reusing waste are related to Sustainability, as they cover the economic factor, the social factor, and the environmental factor. When in contact with the environment,

The proposed model showed that, even with the purchase of two mugs for each server, the costs are compensated within a maximum of 4 years. The best results are shown by the "100% Scenario", considering the 50ml cups, which can save approximately R$466.519,00 to the public coffers at the end of the simulation. Even the "50% scenario", for both cups, which considers the purchase of half of the current demand, in a few years is compensatory, exceeding resources to be invested in the other activities of the IES. The model, which can be reconfigurable and open, can be improved with new scenarios to assess the insertion of new variables that help in the process of reducing the use of plastic cups, among which the use of mugs stands out.

Through the results generated by the model, the end users (environmental managers) of the model can, for example, define incentives to reduce the total generation of solid waste, incentives to increase green consumption rates, produce campaigns valuing the reuse and recycling of materials and assess the economic benefits of recycling.

Thus, as shown by the research results, the reduction or extinction of the use of plastic cups at the HEI, contributes both to the reduction of impacts on the environment that cups can cause, as well as to the reduction of expenses with the consumption of this material, allowing the surplus resources to be invested in other more needy areas.

Having such satisfactory results in this study, the importance of other studies on recycling, the use of other products not derived from plastic and the reuse of solid waste is highlighted, which may contribute to decision-making regarding the most relevant initiatives in which concerns the management of urban solid waste.

This experiment carried out makes it clear that, despite the cost of acquiring new mugs, reducing the use of plastic cups reduces the annual cost of purchasing them. The results point to a strategy, which can be applied by any institution, to reduce the accumulation of residues and waste of raw materials, enabling a healthier alternative for the environment.

As future work we intend to analyze the environmental issue of plastic recycling. Plastic recycling also leads to significant reductions in atmospheric CO2 emissions, because the use of recycled plastic avoids the emission of an amount equivalent to that generated during the production of raw plastic..

REFERENCES

ABELIOTIS, K.. Decision support systems in solid waste management: a case study at the national and local level in Greece. **Global NEST Journal**, v.11, n.2, p.117-126, 2009.

ABIPLAST. Associação Brasileira da Indústria do Plástico. **Perfil 2017**. São Paulo, 2017.

ANDRADE, A. L.; SELEME, A.; RODRIGUES, L. H.; SOUTO, R.. **Pensamento Sistêmico**: caderno de campo: o desafio da mudança sustentada nas organizações e na sociedade. Porto Alegre: Bookman, 2006.

ANDRADY, A. L.; NEAL, M. A.. Applications and societal benefits of plastics. **Phil. Trans. R. Soc. B**, v.364, n.1526, p.1977-1984 2009. DOI: http://doi.org/10.1098/rstb.2008.0304

AZEVEDO, L. V.; COSTA, D. R. T. R.; SANTOS, J. R.. **Desenvolvimento sustentável e políticas públicas de educação ambiental**. 2018

BARNES, D. K. A.; GALGANI, F.; THOMPSON, R. C.; BARLAZ, M.. Accumulation and fragmentation of plastic debris in global environments. **Phil. Trans. R. Soc. B**, v.364, n.1526, p.1985-1998. DOI: http://doi.org/10.1098/rstb.2008.0205 , 2009.

BRASIL. **Lei nº 12.305 de 02 de agosto de 2010**. Institui a Política Nacional de Resíduos Sólidos. Brasília: DOU, 2010.

BRASIL. Ministério das Cidades. Sistema Nacional de Informações Sobre Saneamento. **Diagnóstico RS 2016: diagnóstico com o texto de análise dos dados**. Brasília: SNIS, 2018a.

BRASIL. Ministério das Cidades. Sistema Nacional de Informações Sobre Saneamento. **Planilhas**: conjunto das tabelas com as informações e os indicadores, disponibilizadas em Excel. Brasília: SNIS, 2018b.

BREMS, A.. Recycling and recovery of post-consumer plastic solid waste in a european context. **Thermal Science**, v.16, n.3, p.669-685, 2012.

CEMPRE. **Compromisso empresarial para a reciclagem**. São Paulo, 2011.

CEMPRE. **Compromisso empresarial para a reciclagem**. São Paulo, 2016.

CEMPRE. **Compromisso empresarial para a reciclagem**. São Paulo, 2017a.

CEMPRE. **Compromisso empresarial para a reciclagem**. São Paulo, 2017b.

DAELLENBACH, H. G.; MCNICKLE, D. C.. **Management science decision making through systems thinking**. New York: Palgrave Macmillan, 2005.

D'AMBRIÈRES, W.. Plastics recycling worldwide: current overview and desirable changes. **Field Actions Science Reports**, v.19, 2019.

DYSON, B.; CHANG, N. B.. Forecasting municipal solid waste generation in a fast-growing urban region with system dynamics modeling. **Waste Management**, v.25, n.7, p.669-679, 2005.

FERNANDES, A. C.. **Dinâmica de sistemas e business dynamics**: tratando a complexidade no ambiente de negócios. 2001.

FORD, A.. **Modeling the environment**. 2 ed. Island Press, 2009.

FORRESTER, J. W.. **Dinâmica industrial**. Buenos Aires: El Ateneo, 1972.

GEYER, R.; JAMBECK, J. R.; LAW, K. L.. Production, use, and fate of all plastics ever made. **Science Advances**, v.3, n.7, 2017. DOI: http://doi.org/10.1126/sciadv.1700782

GOURMELON, G.. **Global Plastic Production Rises, Recycling Lags**. Vital Signs, 2015.

GRANZIERA, M. L. M.. **Direito ambiental**. 4 ed. São Paulo: Atlas, 2015.

PLASTIVIDA. Instituto Socioambiental dos Plásticos. **Monitoramento dos índices de reciclagem mecânica de plásticos no Brasil**. 2013.

INSTITUTO ETHOS DE EMPRESAS E RESPONSABILIDADE SOCIAL. **Responsabilidade social das empresas**: a contribuição das universidades. São Paulo: Peirópolis, 2008.

JACOBI, P.. **Gestão compartilhada dos resíduos sólidos no Brasil**: inovação com inclusão social. São Paulo: Annablume, 2006.

JAMBECK, J. R. R.. Plastic waste inputs from land into the ocean. **Science**, v.347, n.6223, p.768-771, 2015 DOI: http://doi.org/10.1126/science.1260352

JORGE, L. M.. **A cadeia de reciclagem do plástico pós-consumo na região metropolitana de Porto Alegre**. Dissertação (Mestrado em Engenharia) – Universidade Federal do Rio Grande do Sul, Porto Alegre, 2015.

KIRAN C.. Pyrolysis of virgin and waste polypropylene and its mixtures with waste polyethylene and polystyrene. **Waste Management**, v.24, p.173-181, 2004.

KUM, V.; SHARP, A.; HARNPORNCHAI, N. A.. System Dynamics Study of Solid Waste Recovery Policies: In Phnom Penh City. In: INTERNATIONAL CONFERENCE OF THE SYSTEM DYNAMICS SOCIETY, 23. **Proceedings**. Boston: SDS, 2005.

LAW, A. M.. **Simulation modeling and analysis**. 5 ed. McGraw-Hill, 2015.

LUIJSTERBURG, B.; GOOSSENS, H.. Assessment of plastic packaging waste: material origin, methods, properties. **Resources, Conservation and Recycling**, v.85, p.88-97, 2014.

MIDDLECAMP, C. H.. **Química para um futuro sustentável**. 8. ed. Porto Alegre: AMGH, 2016.

O GLOBO. **Brasil é o 4º maior produtor de lixo plástico do mundo**. 2017.

ONUBR. **Nações Unidas do Brasil**. Rio de Janeiro, 2015.

SUFIAN, M. A.; BALA B. K.. Modeling of urban solid waste management system: the case of Dhaka city. **Waste Management**, v.27, p.858-868, 2007.

THOMPSON, R. C.; MOORE, C. J.; SAAL, F. S.; SWAN, S. H.. Plastics, the environment and human health: current consensus and future trends., **Phil. Trans. R. Soc. B**, v.364, n.1526, p.2153-2166, 2009. http://doi.org/10.1098/rstb.2009.0053

VEIGA, J. E.. **Desenvolvimento sustentável**: o desafio do século XXI. 3 ed. Rio de Janeiro: Garamond, 2008.

WASTE MANAGEMENT. **Recycling Facts and Tips**. 2019.

WBCSD. World Business Council for Sustainable Development. **Towards a sustainable paper cycle**. Genebra, 2014.

ZANIN, M.; MANCINI, S. D.. **Resíduos plásticos e reciclagem**: aspectos gerais e tecnologia. 2 ed. São Carlos: EdUFSCar, 2015.