Systems & Management 14 (2019), pp 257-268

SYSTEMS & MANAGEMENT
Electronic magazine

THE USE OF SYSTEM DYNAMICS TO EVALUATE PRINT OUTSOURCING SCENARIOS IN A PUBLIC EDUCATIONAL INSTITUTION

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ABSTRACT

Information and Communication Technologies (ICT) emerge as a strategic tool, indispensable for the survival of any organization. However, excessive use of ICT can lead to drawbacks such as equipment dependency, rapid obsolescence, and rising maintenance costs. Inefficient use of ICT can result in higher costs for organizations, which may cause them to lose important competitive advantages. In this context, outsourcing printing may be an alternative for institutions to reduce their costs and become more competitive. The aim of this paper is to evaluate scenarios about the financial viability of printing outsourcing in a Federal Higher Education Institution (*Instituição Federal de Ensino Superior* - IFES). To this end, an exploratory research was conducted, with a quantitative approach, using computational modeling, and using the System Dynamics methodology, with simulation and evaluation of three different scenarios: current scenario, likely scenario, unlikely scenario. The results obtained indicate that the unlikely scenario (100% of leased printers) resulted in lower printing costs over the period of the experiment, totaling R$ 637,828.00; the probable scenario (50% of leased printers) totaled R$ 1,000,480.00; while the current scenario (20% of leased printers) resulted in costs of R$ 1,603,060. With the simulations, it was found that printer leasing (outsourcing printing) is the best financial alternative for IFES, which served as a reference for the study, resulting in lower printing costs compared to printer acquisition. The use of systems modeling to evaluate scenarios has been used to support managers in the decision making involving ICT; however, there were no studies in the literature focused on the financial viability simulation of printer outsourcing. Thus, this work sought to bridge this gap by developing and validating a simulation model that can be applied in different scenarios and types of organizations, and work as a reference for future studies.

Keywords: Outsourcing; Modeling; Print Outsourcing.

PROPPI / LATEC
DOI: 10.20985/1980-5160.2019.v14n3.1544

Electronic Journal of Management & System
Volume 14, Number 3, 2019, pp. 257-268
DOI: 10.20985/1980-5160.2019.v14n3.1544

1. INTRODUCTION

The use of Information and Communication Technologies (ICT) in people's lives is a reality, given the widespread use of personal computers, portable devices, smartphones, tablets, printers, and communication devices such as fiber optics, communication cables, and equipment (Simonetto *et al.*, 2016). The evolution of these tools boosts the creation and enhancement of equipment that assists in troubleshooting and automates tasks, while facilitating communication and entertainment.

In the field of management, administrative automation, as a phenomenon induced by the use of informatics, and information processing technologies in the exercise of the administrative function are present and irreversible aspects (Saddy, 2014). However, according to Saddy (2014), the use of ICT can bring many drawbacks, such as dependence on equipment, their rapid obsolescence, rising equipment maintenance costs, or dehumanized treatment. In this sense, maintenance costs, equipment upgrades and operation, and ICT tools cannot be ignored, especially in organizations that have large amounts of IT equipment, which generates a great quantity of resources allocated to maintaining the daily operations of these technological tools. The inefficient use of IT can both damage the environment and result in higher costs for organizations, causing them to lose important competitive advantages. (Melville, 2010).

One alternative to trying to lower operating costs is outsourcing computer services, such as printer leasing. According to Preusler et al. (2005), the administrative practice of outsourcing could be a great alternative to solve the waste problem, besides having a low cost. These services can be considered an option in organizations where printing equipment is often scrapped, unusable, generating rework, high fixed costs, toner and cartridge purchase, and replacement costs. (Silveira *et al.*, 2012).

At the Federal Higher Education Institution (IFES) under analysis, according to the Sustainable Logistics Plan (*Plano de Logística Sustentável* – PLS) (UFSM, 2016), the inventory of movable goods indicates that there are 3,127 printers in the institution, including dot matrix, inkjet, laser, copiers, and multifunction printers. These machines require the maintenance, refilling or purchase of new print cartridges and toners, and their disposal when they become obsolete, resulting in electronic waste. The institution also uses its printer outsourcing service, including technical assistance, preventive and corrective maintenance, with replacement of parts and supplies, which is provided by an outsourced company. However, there are no studies identifying which alternative is more financially viable: the purchase of printing equipment or the outsourcing of printing services (printer leasing).

The use of systems modeling and operational research to simulate and evaluate scenarios has been used to support managers in decision making involving ICT, more specifically electronic equipment, in higher education institutions, such as electronic waste disposal (Schneider *et al*., 2015), computer remanufacturing (Simonetto, *et al*., 2016), and reuse of toner and printer cartridges (Costa Filho *et al*, 2006; Huang and Sartori, 2012; Moura *et al*, 2012). However, no studies were found aimed at the simulation of financial viability for outsourcing printers (leasing printers), the so-called printing outsourcing.

The objective of this paper is to evaluate scenarios regarding the financial viability of print outsourcing in an IFES by developing a computational simulation model. Through the construction of this model, it is expected to assist managers in the decision-making process regarding the lease or not of printers, in order to minimize the costs generated by the use of such equipment. To validate the model, simulations were performed in different scenarios, using real data collected in an IFES located in the state of Rio Grande do Sul.

The paper is organized as follows: section 1 contains the introduction with the context and objectives of the paper; Section 2 presents the theoretical framework, with the topics that provided the basis for analysis and discussion; Section 3 presents the research method used for the development of the study. Section 4 contains the development of the simulation model; Section 5 contains the experiment and the results, with the simulation scenarios and the experiment using the model; and finally, section 6 contains the conclusions, limitations, and suggestions for future studies.

2. LITERATURE REVIEW

At this stage, the issues outsourcing and costs, which provided theoretical basis in the analysis and discussion of the results obtained, will be presented.

2.1 Outsourcing

Outsourcing currently spans many industries and is a rapidly spreading phenomenon worldwide, being a recent phenomenon that emerged in the United States before World War II (Serra, 2011). According to Prado (2005), outsourcing is characterized as a management

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Volume 14, Number 3, 2019, pp. 257-268
DOI: 10.20985/1980-5160.2019.v14n3.1544

technique that leads to structural and cultural changes in the organization, meaning more than simply cutting costs. It represents an important and topical theme that adds value to the organization's business and is a key strategy for top management.

The concept of outsourcing is defined by Pagnoncelli (1993, p.10) as "a planned process of transferring activities to be performed by third parties". The author explains that it is a "process" because it is continuous, permanent; it is planned because implementing an outsourcing program without considering strategic planning is a mistake that could compromise the program; activities refer to activities that are not the core of the company's mission; and it is performed by third parties because they are performed outside the company. To Oliveira (1998), it is called outsourcing the link that connects a borrowing company to the service provider company, by means of a contract regulated by civil, commercial or administrative law, whose purpose is to perform supporting activities of the core activity. Similar definition is given by Giosa (1997, p. 14), who sees outsourcing as "the tendency to transfer to third parties activities that are not part of the company's core business".

Serra (2011) cites advantages and disadvantages of outsourcing. Among the advantages, the author mentions the improvement of the quality of services, the possibility of technology transfer without extra costs, the reduction of fixed and variable costs of the company, the greater ease of cost control by the contractor, the focus of the business of the company in its area of expertise, the reduction of the risk of equipment obsolescence and the reduction of inventory costs. Regarding disadvantages, Serra (2011) cites the difficulty of finding an ideal partner, the difficulty of formulating partnership contracts, the difficulty of controlling contracts, the difficulty in controlling the internal cost with the partner company, and the choice of unqualified suppliers that reduce product/service quality.

Organizational decision making by outsourcing has many reasons and motivations. Bergamaschi (2004) mentions that the motivators for outsourcing may be diverse, but they are fundamentally of economic, technical or strategic origin. Among the main motivations presented by the author are cost reduction, improvement of service quality, and focus on activities related to the organization's core competencies. The reasons for outsourcing can be explained by the advantages offered by external suppliers, who have more efficient equipment and technologies, specialization and focus on their activities, and the early obsolescence of equipment and technologies.

The growth of outsourcing agreements, in terms of size and importance, has generated a growing concern about the risks involved in the process. Prado (2005) lists the main risk factors involving outsourcing: drafting incomplete contracts, allowing for passive management by the supplier, failing to build and maintain skills and capabilities internally, building agreements with little flexibility to adapt to the rapidly changing technological and business environment, managing total outsourcing agreements, having little process experience, and outsourcing to short-term financial restructuring.

For Preusler et. al (2015), outsourcing can be used by both private and public organizations. According to the authors, in the same way that private companies outsource in search of greater efficiency in the middle activities, enabling them to dedicate themselves harder to the end activities, public organizations have also started to use this form of administration, which also contributed to the reduction of the state bureaucracy.

Serra (2011) points out that outsourcing is present throughout the production process, not being restricted to services, reaching the condition of joint participation in the core activities of the production process of companies from several countries, including Brazil. For that reason, it is important that Brazilian law adapts to this reality. In his study, Prado (2005) found that, regarding the degree of formality of contractual arrangements for information technology outsourced services (IT), 81.3% of the arrangements are implemented through formal contracts, while the remaining 18.7 % of arrangements are implemented without formal contracts. These contracts without formalization and without definition of obligations and rights, generally adopted in the contracting of services on demand, such as hardware maintenance, show that the alliances and partnerships made more intensely by companies with culture of outsourcing are more based on trust than on formal contracts.

Nevertheless, hiring outsourced services requires special care. According to Cristofoli (2011), the process of preparing and creating an IT services outsourcing contract must be exhaustive and complete and, in some cases, it can be extremely complex because it involves aspects such as the provision of services, transfer of hardware and software infrastructure, as well as that of employees. Contracts shall specify the agreements and terms signed between the parties for the fulfillment of economic exchanges and shall not be complete if they do not cover the obligations of the parties involved in all situations (Cristofoli, 2011).

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DOI: 10.20985/1980-5160.2019.v14n3.1544

2.2 Costs

Knowing costs is a prerequisite for running any organization, regardless of type and size, as well as better control over finances. The cost is embedded in the life of every individual from birth to death, since all the goods and services necessary for their consumption or use come at a cost. (Dutra, 2009). In the case of organizations, costs result from a combination of several factors, including technological and productive process-related training and qualification of labor. Overall, it reflects in costs a number of variables, both internal and external. Internal variables include mode of operation, behaviors and attitudes, and external variables include level of demand and input prices (Megliorini, 2007).

The concept of cost is defined by Dutra (2009, p. 17) as "the portion of expenditure that is applied to production or any other cost function, whether disbursed or not. Cost is the value accepted by the buyer to acquire a good or is the sum of all the values added to the good from its acquisition until it reaches commercialization". For Bruni (2010), costs correspond to expenses related to goods and services used in the production of other goods and services. Therefore, they are associated with the products and services used by the entity and represent a transition from an investment that targets the value of inventories. As examples, the author cites expenses with raw materials, packaging, labor, rents, insurance, etc. Similarly, Megliorini (2007) states that costs correspond to the share of expenditures consumed in the manufacturing environment for the manufacture of the product, for the purchase of goods for resale and for the performance of services.

Dutra (2009) cites the diversity of cost classification, which varies according to the nature of the object, the calculation, and the formation, among other classifications. As for nature, the main types are raw materials, labor, electricity, fuels, insurance, social charges, rents, and maintenance. As for the calculation, the costs are classified between direct costs (those that can be directly appropriated to each type of good or organ at the moment of its occurrence) and indirect costs (those that cannot be appropriated directly to each type of good or function at the time of its occurrence). In relation to formation, costs are classified as fixed (structure costs that occur in one period after another without variations, or whose variations are not the result of changes in the volume of activities in the same period) and variable costs (they vary depending on variation in the volume of activity, that is, the variation in the quantity produced in the period). Another type of cost present in the administrative activity that should be considered by managers is the opportunity cost. According to Bruni (2010), opportunity costs correspond to implicit expenses, inherent to the decision, but which usually do not have actual disbursements. They are presented as costs of the deprecated alternative and should be formally considered, even if there is no actual disbursement.

Considering that one of the main factors that interfere in the decision of organizations to "buy" or "do" is the economic factor, as mentioned by Bergamaschi (2004), the study of transaction costs has been widely used in outsourcing work. Transaction Cost Theory (TCT) represents the view in which members of an organization make outsourcing decisions based on economic reasons. Williamson (1975), TCT author, states that costs originate from two sources: (1) production costs, which are related to material, capital and labor; and (2) the coordination costs, which are related to planning, adaptation and monitoring of activities. TCT presents a model based on transaction types. In this model, for each type of transaction, the more efficient alternative is indicated, that is, outsource market or internally-making hierarchy (Prado, 2005).

Transaction costs are related to the costs of maladaptation, when the transactions are not aligned with the contractual terms; negotiation costs, in situations where customers and suppliers make efforts to resolve issues that are not aligned; the costs of setting up and running governance structures through which disputes are resolved; and the costs of linking the effectiveness of the commitments made by the actors (Williamsom, 1996). TCT considers that the behavioral characteristics of the agents involved in the transactions may affect the types of existing contracts and the decision by one or another type of governance structure used. Among the characteristics of economic agents involved in economic transactions, TCT highlights limited rationality and opportunism (Williamsom, 1996).

3. METHOD

The research is characterized by being an exploratory research that uses a quantitative approach. According to Gil (2008), the exploratory research aims to broaden the knowledge about a given phenomenon by exploring a certain reality.

To achieve the objective proposed by the research, computational modeling, characterized by prescriptive models, is used. This prescriptive model is based on the representation of objectives and constraints of a process for which optimal solutions are sought, and it can be ac-

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curately or roughly solved (Goldbarg and Luna, 2005). From models, it is aimed to represent the real world in an abstract and simplified way, allowing explanations or behavior tests in whole or in parts. Also according to Goldbarg and Luna (2005), a model is not identical to reality, but sufficiently similar so that the conclusions obtained through its analysis and operation can be extended to the real world. Model building and execution serve to understand the consequences of making one decision or another, where it is sought to predict events that cannot be controlled to better adapt to them (Simon, 1990).

Through the modeling process, one can simulate and mimic the behavior of virtually any type of real-world operation or process (Law and Kelton, 1991). Simonetto and Löbler (2014) report that one of the main stages of a simulation study is the creation of a logical model consisting of a set of assumptions and approximations, properly quantified and structured, that aim to represent the behavior of the real system under certain conditions.

One of the techniques used for computer simulation is the System Dynamics (SD) methodology. Ford (2009) defines SD as a combination of stocks and flows that use a computational structure to be simulated. Inventories refer to model variables that are accumulated in the system and flows are decisions or policies. These components may be organized in the form of cause and effect relationships, called balance or reinforcement feedback, and are subject to time lags in the system under analysis.

According to Serra et al. (2000), what system dynamics tries to do is to understand the structure of systems functioning and, thus, to try to predict and anticipate the behavior that systems produce. The authors state that, according to the existing literature, systems can be modeled both qualitatively and quantitatively, which differs in the instruments used, since "verbal descriptions and causal diagrams are more of the qualitative type, whereas the stock diagrams, flow and equations are quantitative ways of representing system dynamics".

Law (2015) presents the SD methodology from four stages, which were followed for the development of this work:

1. Specification and structuring of the research problem, based on studies in scientific publications and technical reports, stakeholder interviews and observations of the environment where data are collected. For this work, from bibliographical surveys in scientific and technical literature, and interviews with those responsible for contracting printer outsourcing services, and with contract managers, in the institution that served as the basis for the study, the problem was identified and its variables were raised.

2. Construction of formal models for the representation of the problem. In this stage, the relationships between the variables were structured, and the equations for the generation of each one of them were defined.

3. Computational implementation of models and simulators can be used. The implementation was performed using Vensim software (Ventana Systems, 2016), a computer simulator that supports the needs of the model as well as SD.

4. Verification and evaluation of the presented solution through simulated tests. Prior tests were performed before running the full simulation to verify that the data generated in each variable was as expected from the input information.

Thus, the system dynamics methodology, through stock, flow and equation diagrams, allows quantifying the relationships between the system elements and studying the behavior of these systems over time, helping to make decisions. The model was developed, verified and validated, having as its object of analysis a higher education institution in Brazil, but it can be applied and extended to other organizations of different types and sectors, provided that case specificities are added and dealt with in the model.

3.1. Simulation Model Development

ICTs are indispensable tools for the survival of any organization. However, the excessive use of ICT can lead to drawbacks such as rapid equipment obsolescence and rising maintenance costs, which can lead to significant losses in competitiveness. In this sense, outsourcing printing may be an alternative for institutions to reduce their costs, as mentioned earlier. In this paper, a simulation model is developed and validated in order to evaluate the financial viability of IFES's print outsourcing that served as the basis for the study. The results obtained in the model will help managers in their decision to outsource or not to print materials.

Figure 1 presents the structure of the model, with the components used and their interrelations.

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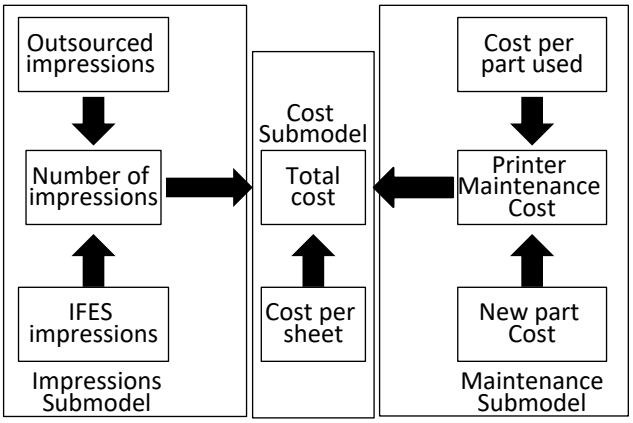

Figure 1. Structure of the developed model
Source: The authors (2018)

In order to facilitate understanding, the model was divided into three submodels: (i) the impressions submodel; (ii) the maintenance submodel; and (iii) the costs submodel. The developed model has computational and mathematical characteristics widely used in management situations, whose quantities are represented by decision variables, and the relationships between variables are demonstrated by mathematical expressions/equations (Lachtermacher, 2018). Next, the three submodels are described.

The Impressions submodel was developed with the objective of measuring and estimating the amount of annual impressions of the analyzed institution. The submodel consists of two inventory variables, *Impressions* and *ImpressionsAI*, which store the number of annual impressions divided into impressions by the institution's printers, and third-party printers responsible for providing the printer's leasing service to the institution, respectively. Both are supplied by input information from two flow variables, called *Impressions* (number of copies printed on own machines) and *ImpressionsAI* (number of copies printed on leased machines).

The submodel still has eleven auxiliary variables: *Average AI Impressions* (average number of copies made by leased machines), *AI Impressions* (number of copies made by leased machines), *AI Average* (average number of leased printers), *AI Printers* (quantity of printers), *Total Printers* (total amount of printers leased plus own printers), *Printers* (number of own printers), *Average Printers* (average amount of printers own), *Impressions To Printer* (number of copies made by own machines), *average Impressions* (average number of copies made by own printers), which are responsible for representing the variation by scenario. A shadow variable called "Time" is the input of these auxiliaries, enabling the storage of temporal data, making the model more accurate for a ten-year analysis. The Impressions Submodel is shown in Figure 2, and its equations (1 to 4) can be seen in Chart 1.

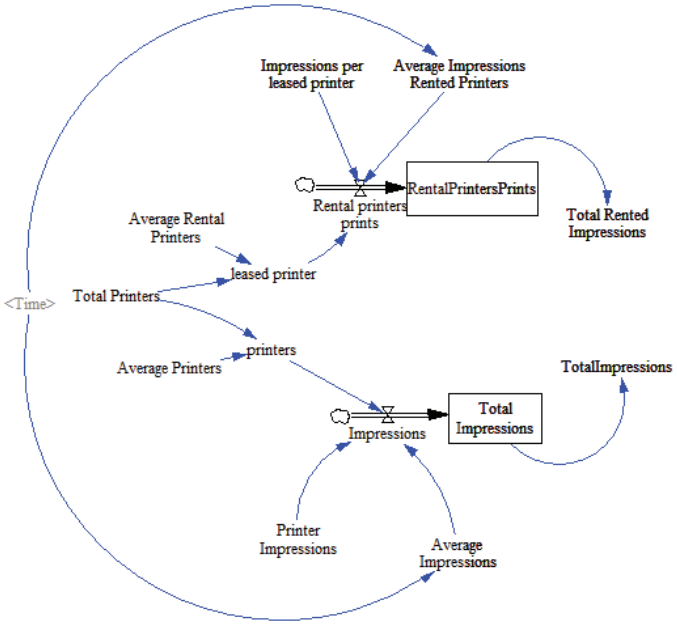

Figure 2. Impressions submodel
Source: The authors (2018)

The submodel also completes two auxiliary variables called *Total Impressions* (total number of copies made by leased printers), *Total AI* (total number of copies made by leased printers), responsible for linking to the Cost Submodel. Through them, the data generated by this submodel will be entered into the input variable responsible for representing the cost per impression.

Maintenance (corrective or periodic) of printers is performed in the computer maintenance laboratory of a teaching unit of the institution itself. Through data collected directly in this laboratory, it was identified that the types of maintenance performed in the institution's printers are: Internal and external cleaning of the equipment (except cleaning contacts only); Heavy or chemical cleaning (washing); Plate capacitor exchange; Power supply repair; BIOS battery; IDE or SATA cable, and basic settings.

Through this analysis, the Maintenance Submodel, composed of seven stock variables (*Int/Ext Cleaning*, *Chemical Cleaning*, *Capacitor Replacement*, *Power Supply Repair*, *BIOS Battery*, *IDE/SATA Cable and Adjustments*), responsible for storing the cost by type of maintenance, was generated. The stock variables have as input the data stored in the flows *Total Cleaning*, *Total Chemical*, *Total*

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Capacitors, *Total Power Supply*, *Total BIOS*, *Total Cable*, and *Total Adjustments*, which represent the total costs by maintenance type. The flows, in turn, are responsible for absorbing the data generated by the auxiliary variables, which are composed of annual data, designed through bibliographic and laboratory studies, where the behavior of printers in the last five years made it possible to have a maintenance average by printer type. The Maintenance submodel is represented in Figure 3, and its equations (5 to 12) can be seen in Chart 1.

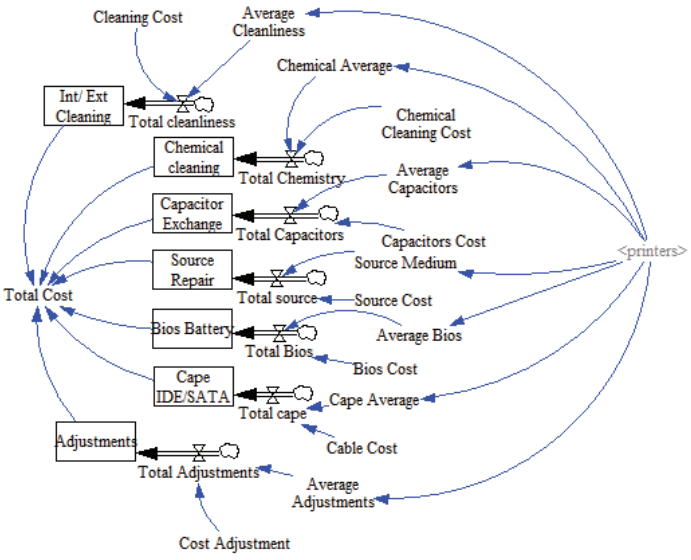

Figure 3. Maintenance Submodel
Source: The authors (2018)

Auxiliary variables are *Cleaning Cost*, *Chemical Cleaning Cost*, *Capacitors Cost*, *Power Supply Cost*, *BIOS Cost*, *Cable Cost*, and *Settings Cost*. Inventory variables are the input data for the auxiliary variable Total Cost (sum of all maintenance costs), which in turn is responsible for linking to the Cost Submodel, which will be explained below.

The Cost Submodel is the central part of the analysis of this paper as it is responsible for storing the financial viability of all scenarios applied in the study. The central variable of this submodel is an inventory variable called *Cost*. The *Impressions Cost* and *Maintenance Cost* flows enter the input data for analysis into the inventory variable. The *Average Sheet Cost* (average value of A4 sheet costs) and *Reload Cost* (value of printer refill costs) variables measure the total cost of prints in Reais (R$). The Cost submodel is shown in Figure 4, and its equation (13) can be seen in Table 1.

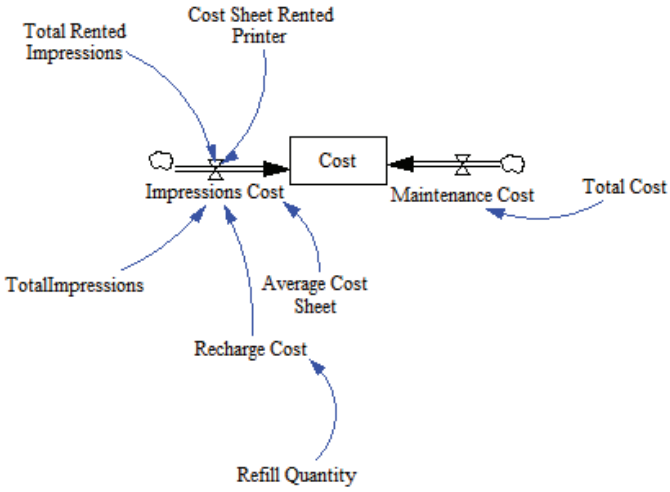

Figure 4. Costs Submodel
Source: The authors (2018)

The submodel equations and the values assigned to the variables are presented in Chart 1.

With the equations it will be possible to execute the logic of the model, allowing performing the modeling, leaving the model closer to reality. The purpose of building models is to represent the real system in an abstract and simplified manner, with which to explain or test its behavior, in whole or in part.

4. ANALYSIS OF RESULTS

For the execution of the model it was necessary to develop different scenarios. Three scenarios were developed: current scenario, likely scenario, and unlikely scenario.

The scenarios were designed based on data from an IFES: some of its variables were calibrated with fixed values for all scenarios, while others have changed in each scenario to verify their financial impacts over a 10-year period. Only laser printers for personal use were considered, that is, inkjet printers, dot matrix, plotters and other larger printers were excluded because most of these have their life cycle ending, and are usually discarded by the institution. The number of scenarios (three) was chosen based on Andrade (2006), and are as follows:

- Current Scenario: In this scenario, the current print outsourcing rate used by IFES, which is 20%, will be maintained. This means that 20% of the

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Chart 1. Equation Model

(1)	IA Printers = Total*Average AI Printers
(2)	Printers = Total Printers*Average Printers
(3)	Impressions = Printers*(Impressions To Printer*Average Impressions)
(4)	AI Impressions = AI Printers*(Impressions Per AI*Average IA Impressions)
(5)	Total Cleaning = Cleaning Cost*AverageCleaning
(6)	Total Chemical = Chemical Cleaning Cost*Average Chemical
(7)	Total Capacitors = Cost Capacitors*AverageCapacitors
(8)	Total Power Source = Power Supply Cost*MediaPower Supply
(9)	Total Bios = Bios Cost*AverageBios
(10)	Total Cable = Cable Cost*AverageCable
(11)	Total Adjustments = Adjustment Cost*AverageAdjustments
(12)	Total Cost = Adjustments+Bios Battery+IDE/SATA Cable+Power Supply Repair+Int/Ext Cleaning+Chemical Cleaning+Capacitor Replacement
(13)	Impressions Cost = (AI Sheet Cost*Total AI)+(Total Impressions*Average Sheet Cost)+Reload Cost

Source: The authors (2018)

printers used by the institution are leased. Data for the year 2018;

- Likely Scenario: This scenario represents the first modelers' proposal, where 50% of printers will be leased;

- Unlikely Scenario: In this scenario, 100% of printers will be leased. Here the scenario would identify the financial impact if all IFES printers under study were leased. This scenario was established even knowing the difficulty of its application, as this would result in a large accumulation of electronic waste, and would require new strategies for the environmentally correct disposal of printers already used in the institution.

After defining the scenarios for the experiment, the simulations were performed. To perform the simulations the Vensim simulator (Ventana Systems, 2016) was used in a computational structure with Intel Core processor (i5 2450) of 2.5 Ghz, 4 Gb of RAM. The simulation execution time of the three scenarios was in the order of hundredths of a second. The model will enable interested parties to generate other simulations and can create different scenarios, since the model was built with the purpose of assisting managers in decision making, and in choosing the most financially viable alternative(s).

The initial number of printers in all scenarios was set to 1,816. This amount refers only to laser printers present in the institution, with data obtained in the equity survey reports. Although the institution has more printers, most of them are inactive. This number was also used as the total refills available as there is no data on how many times each printer's cartridges have been refilled. Given that the number of servers and students of the institution has not undergone significant changes, it was determined that there is no need to increase the number of equipment, that is, it was defined that the initial number of printers of the institution is sufficient to meet university demand, and that new printers can be purchased just to replace defective equipment.

Bousquin *et al.* (2012) indicate that the lifetime of printers varies from two to eight years, while Stobbe (2007) *apud* Bousquin *et al*. (2011) indicates a time of five years. Thus, it was decided to fix the life span of all study printers at five years, agreeing with both studies and facilitating the understanding of the model. Defect rate was defined as 0.2 (⅕), obtained from the consultation with technical specialists of the institution that work in the maintenance of computational devices. The same experts, IFES technical-administrative servers, also contributed to the definition of the printing cost.

To estimate the number of impressions performed each year, historical data from A4 sheets used by the institution between 2008 and 2017 were used. It was defined that the behavior of the 10 years of simulation would be similar to that found in the previous 10 years (from 2008 to 2017). The initial value defined for the number of impressions was based on estimates of the number of sheets used in IFES during the first half of 2017. Similarly, the recharge price change was based on the behavior from 2008 to 2017. For this case, data from

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the most consumed toners in the institution were used. Finally, the amount of refills for each toner was set to three for all scenarios, and the amount of toner prints was set at 3000 copies. These variables were determined based on technical information from manufacturers. Table 1 summarizes some of the variables in the simulation scenarios.

The decisions, based on the results generated by the model, may involve the adoption or not of outsourcing of printing (printer leasing) in the IFES under study. Table 2 presents the expense generated by the impressions, by scenario, showing the difference generated by the choice of each of the studied scenarios. The managers of the institution may establish new simulation scenarios, according to the need, possibility or strategy adopted.

Table 1. Constant variable values in scenarios

VARIABLE	VALUES
Copy Value (Rent)	R$ 0.0043
Copy Value (Without Rent)	R$ 0.004938
Impressions P / Month	12,000
Average Recharge Cost	R$ 65.00
Printers Quantity	1,812
Internal and external equipment cleaning (except contact cleaning only)	R$ 20.00
Heavy or chemical cleaning (washing)	R$ 40.00
Plate capacitor replacement	R$ 30.00 (up to 3) to R$ 50.00 (more than 3)
Power supply repair	R$ 30.00
BIOS battery	R$ 5.00
IDE or SATA cable	R$ 5.00 (IDE) and R$ 10.00 (SATA)
Settiings (printers)	R$ 15.00

Source: The Authors (2018)

The current scenario, where 20% of the printers used by the institution are leased, and 80% are printers purchased and owned by the institution, has the worst performance, accumulating an expense of approximately R$ 1,603,060.00 with printing over 10 years, which represents an annual average of approximately R$ 160,000.00. The unlikely scenario, where 100% of the printers will be leased, will spend a maximum of R$ 627,828.00 over 10 years, a difference of more than R$ 975,000.00 from the current scenario. This is a significant difference, since the accumulated spending on impressions over 10 years, in the current scenario, represents a value 155.33% higher than the accumulated spending in the unlikely scenario. In the likely scenario, where 50% of the printers would be leased, there is an intermediate situation, where the printing costs would be lower than the costs of the current scenario, and higher than the costs of the unlikely scenario, reaching R$ 1,000,480.00 in the tenth year. Figure 5 shows the cost variations over time of the three simulated scenarios.

Table 2. Accumulation of impression cost

	Unlikely scenario	Likely Scenario	Current Scenario
Year 1	R$ 9,370.00	R$ 18,054.00	R$ 28,922.00
Year 2	R$ 28,111.00	R$ 54,164.00	R$ 86,766.00
Year 3	R$ 57,160.00	R$ 108,392.00	R$ 173,636.00
Year 4	R$ 97,453.00	R$ 180,798.00	R$ 289,633.00
Year 5	R$ 149,929.00	R$ 271,445.00	R$ 434,860.00
Year 6	R$ 215,523.00	R$ 380,396.00	R$ 609,421.00
Year 7	R$ 295,173.00	R$ 507,713.00	R$ 813,419.00
Year 8	R$ 389,815.00	R$ 653,457.00	R$ 1,046,960.00
Year 9	R$ 500,388.00	R$ 817,691.00	R$ 1,310,130.00
Year 10	R$ 627,828.00	R$ 1,000,480.00	R$ 1,603,060.00

Source: The Authors (2018)

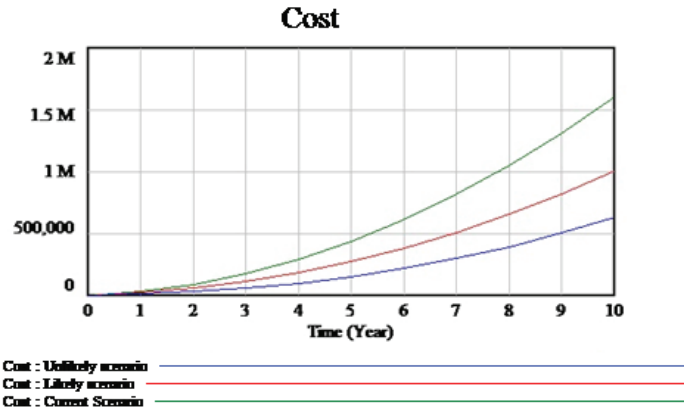

Figure 5. Costs of simulated scenarios
Source: The Authors (2018)

It can be seen that from the first year onwards, the costs of using 100% leased printers are lower than the costs of the other two scenarios, and this holds true for the remaining years until the end of the tenth year of the

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DOI: 10.20985/1980-5160.2019.v14n3.1544

experiment. Considering the average costs in the period analyzed, the average annual cost of the unlikely scenario was R$ 62,782.80, the likely scenario was R$ 100,048, while the current scenario is R$ 160,306.00 per year; thus, leasing 100% of the printers in the institution that was the basis for the study proved to be the most financially advantageous option.

However, considering the difficulty of applying the unlikely scenario, as it would generate accumulation of electronic waste due to the large number of printers that the institution has (1,816), among other factors, the possibility of applying the likely scenario is more favorable, in view of the possibility of remanufacturing printers that are near the end of their life cycle, generating new products such as the 3D printer (Simonetto *et al.*, 2016). If the decision maker chooses to apply the probable scenario, where half of the printers would be leased, the expense will be R$ 1,000,480.00 in the tenth year, resulting in a reduction of R$ 602,580.00 compared to the current scenario, as can be observed in Table 2. It is noteworthy that the adoption of either scenario also depends on other factors, such as the materials procurement policy, e-waste disposal policy, objectives and goals contained in the Institutional Development Plan (PDI), Reverse logistics plan and organizational culture change, which were not considered in this study, as it was restricted to financial aspects.

5. CONCLUSIONS

The use of ICT in people's lives is an irreversible reality due to the large amount of equipment, devices and artifacts that facilitate communication and expedite both personal and professional tasks. However, according to Saddy (2014), the use of ICT can bring many drawbacks, such as dependence on equipment, their rapid obsolescence, and rising equipment maintenance costs or dehumanized treatment. Inefficient use of IT, in addition to damaging the environment, can result in higher costs for organizations, which may cause them to lose important competitive advantages. In this sense, outsourcing printing (printer leasing) can be an alternative for institutions to reduce their costs, as well as reduce the environmental impacts caused by electronic waste.

The purpose of this paper is to evaluate scenarios about the financial viability of print outsourcing in an IFES. For this, a computational simulation model was built, with simulation and evaluation of three different scenarios, through the SD methodology.

Regarding the results obtained, the unlikely scenario (100% of leased printers) presented the best results, saving approximately R$ 975,000.00 on printing expenses at the end of the tenth year, compared to the current scenario. The likely scenario (50% of leased printers) would allow a financial savings of R$ 372,652 at the end of the tenth year. In the comparison of the three scenarios, the current scenario (20% of leased printers) presented the worst performance, with the highest costs, totaling R$ 1,603,060.00 over 10 years. Thus, it was found that outsourcing printing (printer leasing) is the best alternative, in financial terms, for the institution that served as the reference for the study, resulting in lower costs than the acquisition of printers.

The main practical contribution of the developed model is to obtain a tool capable of evaluating the viability and financial impacts of printing outsourcing, thus helping managers in the decision making regarding the leasing or not of printers. In addition, as it is an open model, it can be changed for application in other cases, different scenarios, and types of organization, making possible further research from this study.

One of the limitations of this investigation refers to the fact that the model was developed to analyze a public institution, because the process of buying equipment and contracting services in these institutions is usually performed through bidding, unlike private institutions. Another limitation was not considering other aspects, such as organizational culture and institutional policies, such as materials procurement policy and reverse logistics policy. Toners were also not explored in modeling due to the lack of hard data.

As future work, it is suggested to add other variables to the model, such as the ideal number of printers that should be leased to minimize costs and identify ways to reuse electronic waste. The new model generated will help in planning printer purchases and disposals to minimize ICT costs as well as contribute to environmental sustainability through Green IT initiatives.

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Received: May 25, 2019

Approved: June 3, 2019

DOI: 10.20985/1980-5160.2019.v14n3.1544

How to cite: Negrini, F.; Simonetto, E. O.; Rodrigues, G. O., et al. (2019), "The Use of System Dynamics to evaluate print outsourcing scenarios in a public educational institution", Sistemas & Gestão, Vol. 14, No. 3, pp. 257-268, available from: http://www.revistasg.uff.br/index.php/sg/article/view/1544 (access day month year)