Computer Modeling for Evaluation of Logistic Cost Scenarios in a Higher Education Institution

Modelagem Computacional para Avaliação de Cenários de Custo Logístico em uma Instituição de Ensino Superior

Modelado Computacional para la Evaluación de Escenarios de Costos Logísticos en una Institución de Educación Superior

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Abstract
Objective: To analyze the management of logistical transport costs in a Federal Higher Education Institution in Rio Grande do Sul, through the simulation of scenarios to reduce these costs, considering the variations that make up the system.
Methodology: A computer simulation model was used with the System Dynamics methodology. The research is characterized as exploratory, with a quantitative approach, examining the institution's travel process. The data was found in the institution's computerized system, in current transport service contracts and in consultation with the university's competent sector. The computational implementation of the solution was carried out using the Vensim simulator.
Results: The results demonstrate the financial importance of the transport area in the organization and its potential for optimization. Simulations of new plans contributed to the analysis of results, narrowing down paths to reducing logistics costs.
Conclusion: The study highlights the significant impact of transport operational costs on organizations' budgets and highlights the possibility of optimizing these costs through computer modeling and scenario simulation.

Keywords: Transport, Scenarios, Logistic Cost, Computational Modeling, Operational Research.

Resumo
Objetivo: Analisar a gestão do custo logístico de transporte em uma Instituição Federal de Ensino Superior do Rio Grande do Sul, através da simulação de cenários para redução desses custos, considerando as variações que compõem o sistema.
Metodologia: Utilizou-se um modelo de simulação computacional com a metodologia System Dynamics. A pesquisa é caracterizada como exploratória, com abordagem quantitativa, examinando o processo de viagem da instituição. Os dados foram encontrados no sistema informatizado da instituição, nos contratos vigentes de serviço de transporte e na consulta ao setor competente da universidade. A implementação computacional da solução foi realizada através do simulador Vensim.
Resultados: Os resultados demonstram a importância financeira da área de transporte na organização e seu potencial de otimização. As simulações de novos planos contribuíram para a análise dos resultados, diminuindo caminhos para a redução de custos logísticos.
Conclusão: O estudo evidencia o impacto significativo dos custos operacionais de transporte no orçamento das organizações e destaca a possibilidade de otimização desses custos através da modelagem computacional e simulação de cenários.
Palavras-chave: Transporte, Cenários, Custo Logístico, Modelagem Computacional, Pesquisa Operacional.

Resumen
Objetivo: Analizar la gestión de los costos de transporte logístico en una Institución Federal de Educación Superior en Rio Grande do Sul, a través de la simulación de escenarios para reducir esos costos, considerando las variaciones que componen el sistema.

Metodología: Se utilizó un modelo de simulación por computadora con la metodología de Dinámica de Sistemas. La investigación se caracteriza por ser exploratoria, con enfoque cuantitativo, examinando el proceso de viaje de la institución. Los datos fueron encontrados en el sistema informático de la institución, en los contratos vigentes de servicios de transporte y en consulta con el sector competente de la universidad. La implementación computacional de la solución se realizó mediante el simulador Vensim.
Resultados: Los resultados demuestran la importancia financiera del área de transporte en la organización y su potencial de optimización. Las simulaciones de nuevos planes contribuyeron al análisis de resultados, acotando caminos para reducir los costos logísticos. *Conclusión:* El estudio destaca el impacto significativo de los costos operativos del transporte en los presupuestos de las organizaciones y destaca la posibilidad de optimizar estos costos a través de modelos informáticos y simulación de escenarios.

Palabras clave: Transporte, Escenarios, Coste Logístico, Modelización Computacional, Investigación Operativa.

Introduction

The efficient use of public resources is a recurring and growing demand in all spheres of government, with society as its main concern so that innovative actions that stimulate the economy and the optimization of services are implemented in organizations.

Logistics in Public Administration represents one of the opportunities for improvement in its use, considering the new technologies that emerge as a facilitator for such measures to occur. For Cavanha Filho (2001), logistics is defined as the part of the supply chain process that plans, implements and controls the stock flow of goods, services and related information, aiming to meet consumer requirements.

According to Arbache (2011) the control of logistics costs is fundamental to the activity management process. In addition to the accounting need itself, the control and monitoring of these costs allows a better evaluation by the manager for decision making. Faria and Costa (2008) state that the management of logistics costs has as its main objective to establish policies that allow companies to simultaneously reduce costs and improve the level of service offered to customers.

Reducing logistics costs certainly favors the fiscal maintenance of an organization, however, the question arises of how to implement reduction measures without compromising the quality of service provided to customers. Scenario projection, therefore, contributes to the answer to this question, assisting in strategic decision making.

The institution object of this case study is the Federal University of Pampa (Unipampa), founded in 2006, with campuses in ten cities of the western border and Rio Grande do Sul campaign region. It currently has 118 undergraduate and postgraduate courses, approximately 10,000 students enrolled and more than 1,800 active servers, according to information published in the institution's 2017 Census.

The distance between cities has always been a logistical challenge for the university (Figure 1), with a distance variation where the shortest distance between campuses is 75 km (Bagé to Dom Pedrito) and the longest is 740 km (São Borja to Jaguarão).

Figure 1
Geographic distribution of campus

Source: Unipampa Website (2023).

This feature has caused a concern since the beginning of the university's implementation to organize this activity in a minimally satisfactory way for the plaintiffs, which led to the implementation of an official transportation system, currently with 58 vehicles distributed among the units and drivers hired for this function.

The need to promote more efficient transportation management in Public Administration meets the growing use of new technologies for remote conversation using free or proprietary software for virtual meetings. Using these tools can significantly reduce the need for face-to-face meetings, thereby reducing the demand for passenger transportation within the organization.

Given the above, the objective of this paper is to analyze the logistics cost of passenger transportation between Unipampa campuses, simulating the reduction of these costs through computer modeling, using the System Dynamics methodology, considering the variables that make up the system. The result is expected to contribute to practical effects on the rational use of transportation systems, as well as awareness of the financial volume applied to these services in organizations and their potential for optimization.

In addition to the introduction, this paper is organized in five more sessions, starting with the theoretical framework that underlies this study, following the methodology used for the research. Subsequently, we present the development of the research, divided into two sections, the first discussing the development of the computational model and the second with the analysis of the results. Finally, we conclude with the final considerations about the research.

Bibliographical review

Logistics goes back to wartime, being associated with the military field for a long period, because it was widely used to coordinate warships, soldiers and the transport of heavy weapons. Past this time, the term logistics has long been associated only with transport action until it is understood that "logistics is a dynamic and practically endless process" (Castiglioni, 2013). Similarly, Christopher (2018) reports the importance of wartime logistics and defines the time taken to recognize the "vital impact that logistics management can have on gaining competitive advantage".

Initially there is a reluctance to understand that logistics is directly linked to the profit realized by the company and only those who are dedicated to understanding it properly can enjoy all its benefits. Quirino, Brito and Steppan (2010) believe that logistics would have reduced relevance in the case of proximity between raw material, final product and consumer public, but this is not the current situation. Local production develops as possibilities permit and logistics take action so that goods or services reach their destinations satisfactorily with minimal expenditure for the organization.

And he adds that the importance of logistics is such that it makes it possible for a company to stand out ahead of the competition in its customer preference. Almeida et al (2017) point out that logistics systematization can also include negative attributes and must be identified to define their limitations and gain control.

Likewise, Santo (2010) speaks of the positive repercussion of the implementation of a logistics system when expressing that “many Brazilian companies see logistics as a management tool capable of solving problems and establishing a competitive differential” and that the harmonization between services and The flow of urban transport leads to promising gains.

The concept of logistics that considers customer delivery as the end point of the process is already outdated, as other issues such as reverse logistics, green logistics, related to the environmental impact, and the study on solid waste shipments have already entered the scene. (Castiglioni, 2013).

Although logistics is not just about the transport of people and cargo, this situation has considerable participation in the process and as Santo (2010) reported, “the evolution of transport followed the evolution of man”, because the development of societies is linked to displacement ability. Pozo (2015) complements treating transport as a major influencer and responsible for development by crossing the barrier of a society by taking its production and defines it as “various methods for moving products”, the most common being road, rail and the airway. Almeida et al (2017) define that the logistic modal should be adequate to the convenience of the situation and mainly in accordance with the time and cost required for a satisfactory level of service.

According to Pettersson and Segersted (2013), knowing their logistics costs, companies can focus on reducing them to increase profitability and knowledge of their business. To achieve logistic al excellence, it is necessary to obtain the best relationship between reducing these costs and improving the level of customer service (Fleury, Wanke and Figueiredo, 2000).

According to the authors Goulart and Campos (2018) the effectiveness of the logistics sector can be measured in different ways and may be specific to the type of activity performed, including aspects that are most important to the business. Performance measurement ensures that the manager will always be evaluating his activity against a static reference, seeking to achieve the best possible situation considering the scenario of his organization.

Methodology

In this article, the research method adopted for the computational model development was based on the methodology presented by Law (2015), for modeling and simulation of systems, which consists of the following steps:

I. Exploratory study on scientific articles, technical reports, stakeholder interviews and observations of the environment where the data were collected. Through this data, the research problem was specified and structured;
II. Computational implementation of the solution through the Vensim simulator (Ventana Systems, 2019) from the System Dynamics area;
III. Verification and evaluation (v & a) of the solution, through laboratory tests and historical behavior analysis (with the possible data), to verify if the obtained results represent part of the observed reality, as well as through the simulation of an experiment using nine scenarios for such; e,
IV. Simulation analysis.

The research is also characterized by being an exploratory research, with quantitative approach, which aims to investigate the travel process of a HEI in the state of Rio Grande do sul. According to Gil (2010), the exploratory research aims to broaden the knowledge about a given phenomenon by exploring a certain reality.

Data regarding the travel processes were collected from the computerized system of the research institution. The contracts in force related to the transportation service were also considered, as well as consultation with the competent sector of the university.

To achieve the goal proposed by the research, it uses the System Dynamics study, defined by Ford (2009) as a combination of stocks and flows using a computational framework to be simulated.

System Dynamics (DS) studies the behavior of systems over time. It has roots, among others, in systems theory, general systems theory and control theory. These theories underpinned holistic thinking, cited in some areas of literature. The first publication on General Systems Theory (TGS) was in 1945 by biologist Ludwig Von Bertalanffy, in which he states that TGS treats living systems as always open systems, as opposed to Systems Theory which deals with of closed systems, focused on automation, systems engineering, cybernetics and computer technology (Rodrigues, et al 2021).

In the next session will be exposed the development of the computational model.

Developing the computer model

The growing search for lower financial costs of higher education institutions means that public managers invest resources in new techniques for a future with greater financial sustainability.

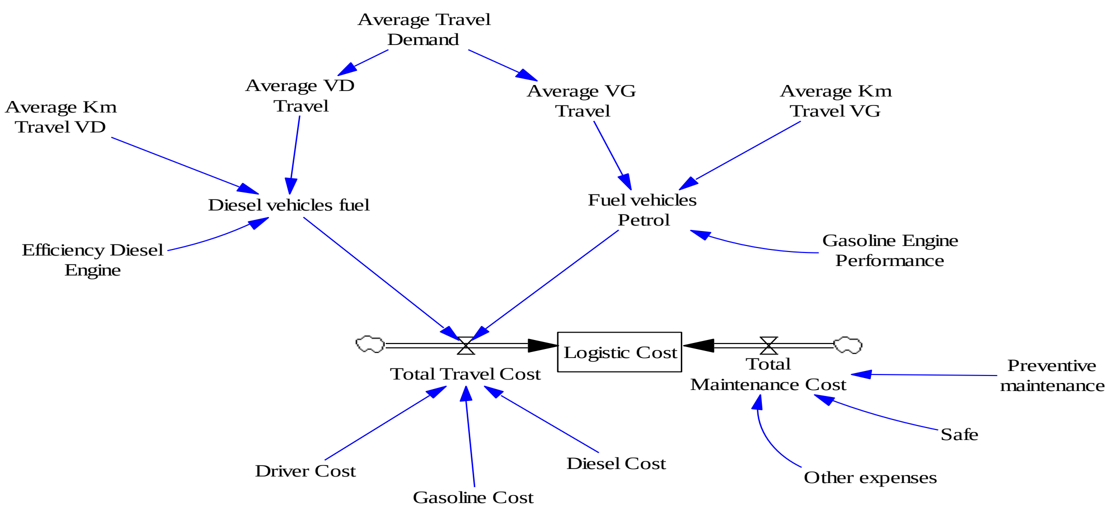
To implement economic policies without compromising the services already offered, it is therefore necessary to have an overall view of the expenses generated over the years, with scenarios of reduction at different levels, considering all its variables, thus obtaining an overview of the system and its optimization potential.

The developed model consists of eighteen variables. Auxiliary variables “Average Travel VD” and “Average Travel VG” are responsible for dividing the amount of trips by petrol or diesel powered vehicles, the data entered in these variables are modified according to the input values entered in the auxiliary “Travel Average Demand”. ”, Which varies as the years go by.

The auxiliary variables "Fuel Diesel" and "Fuel Diesel" represent the mathematical logic for calculating the amount of fuel spent (in liters) to transport the users. The input data of these variables are auxiliary: "Average Travel VD", "Average Travel VG", "Average Travel KM VD", "Average Travel KM VG", "Rend Diesel Engine" and "Rend Gasoline Engine".

In addition to auxiliary variables, the model has two flow variables ("Total Travel Cost" and "Total Maintenance Cost"), they store the data of auxiliary variables "Driver Cost", "Gasoline Cost", "Diesel Cost", "Maintenance Preventive", "Insurance" and "Other Expenses". Finally, to store the model result, an inventory variable called "Logistic Cost" was generated, which receives input values through the two flow variables mentioned above. Figure 2 represents the developed model.

Figure 2
Developed Model



The three types of variables used in the model have different explanations. Auxiliary variables are components for performing algebraic operations that process information about stocks and flows or represent sources of information external to the system (Blois and Souza, 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.

Stocks and flows are the central points of one of a System Dynamics, stocks are levels or accumulators, they characterize the state of the system and provide them with memory. It is in this component that delays occur with the accumulation of the difference between flows. Inbound flows and outflows, only through these flows can the accumulated quantity in stocks be changed. Time in systems is pre-established, so stocks are only altered through their flows, flows are determined by stocks because it is the main structure of information. For this simulation the pre-set time was ten years.

The data entered in the model were collected directly from the HEI. To analyze the fuel cost issue, data available in the annual bulletin of the National Agency of Petroleum, Natural Gas and Biofuels (ANP, 2018) were used. Regarding the average engine performance of 58 IES vehicles, the spreadsheet of the National Institute of Metrology, Quality and Technology INMETRO (2019) was used. The data used in modeling are shown in Table 1.

Table 1
Data used in the modeling

Car appointments	**Value**	**Unit**
Year 2017	1.171	Approved orders
Year 2018	1.431	Approved orders
Year 2019	1.483	Approved orders
Annual Average	1.361,67	Approved orders
Km traveled	**Value**	**Unit**
Year 2017	415.550	Km
Year 2018	561.889	Km
Year 2019	606.713	Km
Annual Average	528.051	Km
Average annual km per vehicle	9.104	Km
Average km per order	388	Km
Other variables	**Value**	**Unit**
Number of vehicles (light)	58	Vehicles
Estimated driver cost (monthly)	2.000	Real
Preventive maintenance (estimated annual average)	300	Real
Insurance (estimated annual average)	1.100	Real
Other expenses (estimated annual average)	1.200	Real

Source: UNIPAMPA (2020).

The mathematical logic inserted within the variables is represented in Table 2, where are the main equations used in the model.

Table 2
Model of equations

Equation (1): Diesel vehicle fuel = (Average Km Travel VD * Media Travel VD) * Rend Diesel Engine **Equation (2):** Fuel gasoline vehicles = (Average Km Travel VG * Average Travel VG) * Performance Gasoline Engine **Equation (3):** Total Travel Cost = (Diesel fuel * Diesel cost) + (Gasoline vehicle fuel * Gasoline cost) + Driver cost **Equation (4):** Total Maintenance Cost = Preventive Maintenance + Other Expenses + Insurance **Equation (5):** Logistic Cost = Total Maintenance Cost + Total Travel Cost

Source: UNIPAMPA (2020).

The experiment and analysis of the model results is exposed in the next session.

Experimental analysis and results

To execute the model and enable the insertion of a proposal, the scenario technique was used. Prospective techniques, such as scenario generation, originated among the military during the period of World War II. Used systematically, mainly by the United States of America, to support mechanisms of war strategy formation (Marcial and Grumbach, 2005). For the modeling developed in this study three scenarios were generated:

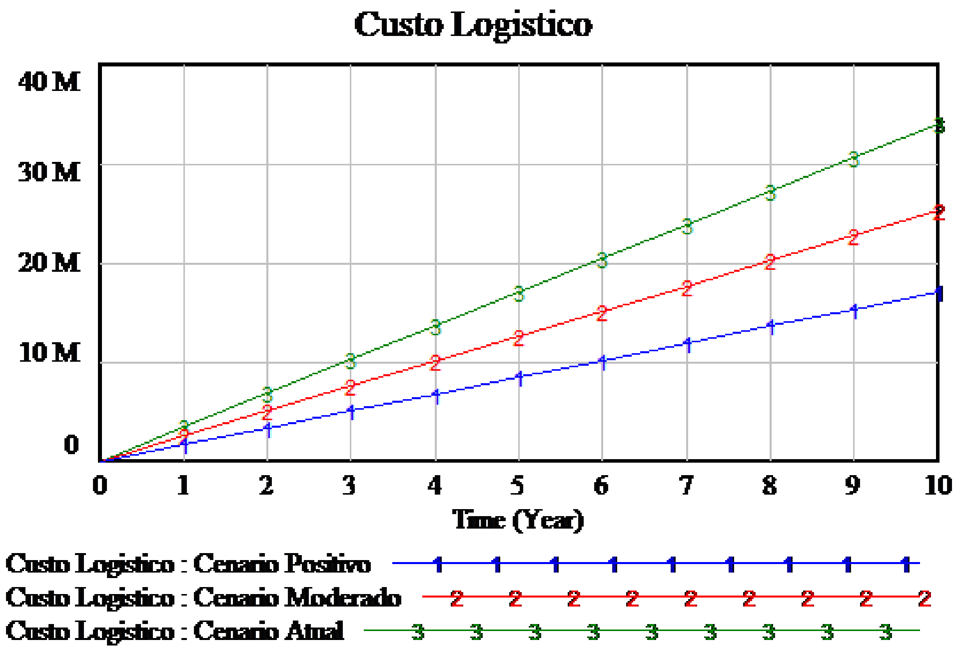
a) Current Scenario: Responsible for maintaining the current logistics of HEI;
b) Moderate Scenario: Proposes to reduce travel by 20%;
c) Positive Scenario: Proposes to reduce travel by 50%.

The reduction of trips will be carried out through the better division of passengers in each vehicle, organizing the logistics of trips with 4 people per vehicle.

After defining the three scenarios for the experimentation of the developed model, simulations were performed in the Vensim simulator (Vensim, 2019) on a computer with Pentium Core i5 processor and 8 Gb of RAM. The simulation execution time was in the order of millionths of seconds. The time horizon simulated in the experiment was 10 (ten) years, but the configuration of this variable is up to the designer / user, because it depends on the analysis to be done.

After the execution of the scenarios, the result shown in Figure 3 was reached. The scenario that presents the best financial performance is the positive scenario. In this scenario, spending on 10 years of travel will reach a maximum of 16 million reais, with an average spending of approximately 1.6 million reais per year

Figure 3
Search Result



The moderate scenario will spend around R $ 2.5 million per year. If the manager invests in this scenario, he will have a better financial return than the current scenario, since he spends around 3 million reais per year, totaling approximately 33.987 million reais in year 10. The positive scenario shows savings of around 1.4 million per year when compared to the current scenario, and 900 thousand reais compared to the moderate scenario.

Decisions, based on the results generated by the model, may involve the adoption of the model obtaining a greater financial return. Other analyzes and observations of interest to organizational managers, as long as they can be performed in the simulation model, can be performed, because the model was conceived seeking to simplify the user-model interaction, so that what-if analyzes are of simple execution.

Conclusion

This work aimed to elaborate scenarios of reduction of passenger travel between the campuses of a university over a period, obtaining the savings generated and thus contributing to the strategic decisions about the optimization of this service.

For the development of the simulation model it was considered the concept that System Dynamics models are composed by stock variables, flow, both endogenous variables. One of the central objectives of the System Dynamics methodology is to have a model that can simulate real behavior. That is, the source of problems in a system is an inherent part of the developed model.

The System Dynamics methodology helped to map the structures of the developed system, trying to examine their interrelationship in a broad context. Through the developed simulation, the applied dynamics aims to understand how the system in focus evolves over time and how changes in its parts affect its behavior over time. From this understanding, it was possible to diagnose and predict the system, as well as to simulate more scenarios in time.

Three scenarios were generated using data collected through stakeholder interviews and literature review. The results obtained are consistent with reality. The rates used were developed by the model designer for this study. It is noteworthy, however, that the scenarios were generated for this experiment, but the model can be configured according to the needs of those who will use it, that is, it is a reconfigurable and open model. As future work, we intend to expand the model to other HEIs that were not considered in the study, beyond the environmental analysis, verifying the environmental impact caused by the reduction of travel.

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