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SUSTAINABLE EFFICIENCY IN THE IMPLEMENTATION OF A DIGITAL SIGNATURE SYSTEM AT A UNIVERSITY

EFICIÊNCIA SUSTENTÁVEL NA IMPLANTAÇÃO DE UM SISTEMA DE ASSINATURAS DIGITAIS EM UMA UNIVERSIDADE

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ABSTRACT

The growing pursuit of operational efficiency and sustainable practices in higher education institutions reflects the need for leadership in promoting a more sustainable future. The shift from analog to digital processes, particularly the implementation of digital signature systems in universities, stands out in this scenario. This article investigates the relationship between sustainability and operational efficiency in the adoption of electronic documents with digital signatures in a university. In addition to addressing compliance with the Ministry of Education's directives, it seeks to understand how this transition contributes to reducing environmental impact and enhancing administrative processes. Focused on Sustainable Development Goal number 12, the article explores strategies for adopting electronic documents, highlighting the competitive advantage in electronic document management. The results reveal not only non-significant costs but also a noteworthy improvement in efficiency, process effectiveness, and sustainable resource use.

Keyword: Sustainability. Digital Signatures. Universities.

RESUMO

A crescente busca por eficiência operacional e práticas sustentáveis nas instituições de ensino superior reflete a necessidade de adoção de estratégias efetivas na promoção de um futuro mais sustentável. A transição de processos analógicos para soluções digitais, especialmente a implantação de sistemas de assinaturas digitais em universidades, destaca-se nesse cenário. Este artigo investiga a relação entre sustentabilidade e eficiência operacional na adoção de documentos eletrônicos com assinaturas digitais em uma universidade. Além de abordar a conformidade com as portarias do Ministério da Educação Brasileiro, busca compreender como essa transição contribui para a redução do impacto ambiental e aprimoramento dos processos administrativos. Com foco no Objetivo de Desenvolvimento Sustentável número 12, o artigo explora estratégias de adoção de documentos eletrônicos, destacando a vantagem competitiva na gestão eletrônica de documentos. Os resultados revelam não apenas custos não significativos, mas uma notável melhora na eficiência, eficácia dos processos e uso sustentável de recursos.

Palavra-Chave: Sustentabilidade. Assinaturas Digitais. Universidades.

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1 INTRODUCTION

The search for operational efficiency and the adoption of sustainable practices are becoming increasingly present in the context of higher education institutions around the world. Universities, as centers of learning and innovation, play a crucial role in leading the change towards a more sustainable future. One area where this convergence between efficiency and sustainability has been most notable is the implementation of digital signature systems in universities (De Andrade, 2020).

The transition from analog processes to digital solutions has been a growing trend in businesses. In higher education institutions (HEIs), this shift is mandatory, due to the regulations of the Ministry of Education (MEC) regarding the digitization of processes, that is, the issuance of electronic documents (with digital signatures) and the digitization of the academic archive. This was established through MEC Ordinances 315 of April 4, 2018, MEC 330 of April 5, 2018, MEC 332 of March 13, 2020, and MEC 360 of May 18, 2022.

These adjustments aim not only at operational efficiency but also at simplifying workflows, reducing paper use, decreasing physical storage space, and lessening environmental impact. The implementation of digital signature systems offers an opportunity to achieve these objectives while simultaneously enhancing the efficiency and accessibility of administrative services (Rossés *et al*., 2017).

This article aims to investigate the relationship between sustainability and operational efficiency in the adoption of electronic documents with digital signatures at a university. In this regard, it seeks to understand how this transition can contribute to the reduction of environmental impact and the improvement of administrative processes. Moreover, it also aims to identify strategies for the adoption of electronic documents and their impacts on operational efficiency, linking the operationalization of the transition to electronic documentation with Sustainable Development Goal number 12. This Goal number 12 seeks to ensure sustainable production and consumption patterns and identify the competitive advantage of the company in adopting electronic document management (Karina; Macêdo, 2023).

This article is divided into five main topics. As an initial part, theoretical considerations about operational efficiency, the use of electronic signatures and electronic documents in companies and universities, and Sustainable Development Goal number 12 were made. In the following session, the methodology and data sources are presented. This is

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followed by the discussion of the results and the final considerations, followed by the references used.

1.1 OPERATIONAL EFFICIENCY AND DIGITAL TRANSFORMATION

Operational efficiency refers to an organization's ability to carry out its operations and processes more productively and effectively, with the help of tools that optimize performance and resource utilization. It involves the automation of administrative processes through digital solutions, which contribute to the faster and more accurate execution of tasks and processes. This leads to an improvement in the functioning of the organization and consequently a reduction in labor costs. By targeting specific tool models to certain sectors, the organization can adapt to the dynamics and demands of the market and the requirements of regulatory sectors, becoming more efficient in terms of structure and functioning (Oliveira, *et al*. 2019).

The impact of digital technologies on the current economy is evident, and across all fields of activity, the dissemination of technological tools has revolutionized business models. However, companies need to analyze and submit to a comprehensive analysis of what technologies can offer, as not every tool will bring benefits or lead to a digital transformation (Carvalho *et al*., 2021).

Digital transformation, according to Abad-Segura et al., (2020), is seen as one of the greatest challenges for sustainable development, especially due to the search for innovative solutions and alternatives for management and the way of thinking of an institution. Abad-Segura *et al*., (2020) also consider that sustainable management should be one of the main strategic objectives within the constitution of educational policies, in line with sustainable management in universities and educational institutions.

It is important to recognize that leveraging the potential related to digital transformation requires organizations to commit to adapting their strategies and generating the capacity to identify value in adopting these technologies, demanding technological and managerial capabilities, still classified as either common or dynamic. Common capabilities support efficiency in the operational and managerial functions of the company, while dynamic capabilities are agents of transformation, reshaping the company's resource base, determining the speed and extent to which such resources can be suited to the demands and needs of the environment.

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In this sense, dynamic capabilities act as a direct link between the internal scenario of the organization and the constantly evolving external scenario. Therefore, we can say that dynamic capabilities play a crucial role in assisting organizations in the continuous improvement of their resources, thus perpetuating the possibility of sustainable competitive advantage (Arantes et al., 2021).

1.2 DIGITAL SIGNATURES AND ELECTRONIC DOCUMENTS.

The concept of a document can be understood as a form of concrete and material proof, something tangible and capable of representing an occurred fact. It also acts as a means of representing the fact one wishes to prove, being a factual representation of the event. Therefore, a document serves to verify the existence or occurrence of this fact, playing an important role in obtaining evidence in various contexts, legal or otherwise (Souza, 2010).

An electronic document, also known as a digital document, is created through the use of a computer. This type of document is stored in digital format and can be accessed and viewed exclusively through a computer, with the aid of appropriate software. The incorporation of a digital signature adds a layer of security and reliability to the data contained in the document, strengthening its integrity (Darmo; Chagas, 2022).

The concept of digital signature can be understood as per Law No. 14.063/2020, where electronic signatures are defined as data in electronic format that are connected to or logically associated with other data in electronic format and are used by the signatory to authenticate authorship, considering the appropriate levels of signatures for the acts provided in the said law. These signatures are classified and characterized as follows:

1. Simple electronic signature: This type of signature is regulated by the entity responsible for the system and does not require the use of a digital certificate. It is suitable for low-risk situations due to its greater vulnerability to fraud.
2. Advanced electronic signature: The advanced electronic signature uses certificates not issued by the Brazilian Public Key Infrastructure (ICP-Brasil) or other means of proving the authorship and integrity of electronic documents, provided that it is accepted as valid by the parties involved or by the person to whom the document is presented. This type of signature has a reduced level of risk compared to the simple signature.
3. Qualified electronic signature: This category of electronic signature employs a digital certificate in accordance with § 1 of Article 10 of Provisional Measure No. 2.200-2, dated August 24, 2001. The qualified signature guarantees both the integrity and the authorship of the document. It presents a high level of security due to the use of a digital certificate and digital signature, which involves encryption in transactions, using private and public keys.

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These definitions and classifications of electronic signatures established by Law No. 14.063/2020 play a fundamental role in the regulation and acceptance of electronic documents, providing security and reliability in digital transactions (Darmo; Chagas, 2022).

1.3 SUSTAINABLE OBJECTIVE

The concept of sustainability is often associated with business practices, however, its model is applicable to institutions of various types, including higher education institutions (HEIs). This concept has become popular in universities and is defined as a policy of improvement for the social mission of universities, as well as in enhancing efficiency, transparency, and accountability in the society where it is embedded (Wallas Pereira Caetano; Leonardo Fabris Lugoboni, 2022).

Given the significant role of universities in the process, it can be stated that education is fundamental in the context of international environmental issues, often highlighted as one of the most effective means to promote the awareness and behavior change necessary to achieve sustainable development. In this perspective, with the adoption of the 2030 Agenda, the 17 Sustainable Development Goals (SDGs) were created, where we highlight for the purpose of this research, SDG 12 (Responsible Consumption and Production), as many HEIs are adopting practices such as the implementation of digital signatures in documents.

This is a change not just bureaucratic, but with the aim of being more sustainable, reducing the use of paper and physical space for storage. This demonstrates the commitment of HEIs to adopt more sustainable practices. By adopting electronic documents with digital signatures, universities also directly influence their stakeholders in pursuit of a more sustainability-conscious society (Di Vaio *et al*., 2022; Guandalini, 2022; Fabiana Pegoraro Soares; Melo; Luiz, 2023).

2 MATERIAL AND METHODS

The research has a mixed-method approach that integrates elements of both quantitative and qualitative methods, aiming to obtain precise data while considering a deep understanding of them. Instead of considering the data as absolute answers, it acknowledges that they are part of a broader context that must be understood in its entirety, as the data analysis converges with the understanding of the relationship between sustainability and

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operational efficiency, due to the adoption of electronic documents with digital signatures in a university (Coelho; Jadson; Silva, 2019).

For the initial data collection, the number of physical documents issued during the year 2022 was obtained through reports from the university's academic system. With these numbers, a quantitative analysis was conducted on the impact of reducing the amount of paper used, as well as the cost of printing them, which had been incurred up to that point. For the qualitative analysis, a meeting was held with a group of university collaborators responsible for issuing and signing documents, composed of four (4) individuals from the Regulatory Processes and Teaching Central departments. In this meeting, those responsible for document issuance were able to list the main operational changes that the adoption of digital signature systems and digital documents brings to the institution. This represents an indirect approach of strategy on the part of the researcher. Additionally, at this stage, a table of processes performed was constructed, allowing for the measurement of changes related to the efficiency and effectiveness of the document issuance and signing process.

The analysis of the results of this research takes an integrated approach, combining both quantitative and qualitative data obtained. Regarding the quantitative analysis, the numbers obtained from the academic system reports were subjected to statistical analysis to identify the impact of the reduction in the issuance of physical documents, as well as the costs associated with printing.

The qualitative analysis, on the other hand, was based on the information collected during the meeting with the university collaborators. The main operational changes identified were analyzed in depth, and the table of processes performed was examined to assess improvements in the efficiency and effectiveness of the document issuance and signing process. From these analyses, conclusions can be drawn regarding the relationship between sustainability and operational efficiency resulting from the adoption of electronic documents with digital signatures at the university.

3 RESULTS AND DISCUSSIONS

A primary data collection was conducted using reports from the academic system of the University to obtain data for the year 2022 from the campus with the highest number of students, prior to the implementation of the system. These data consist of the number of documents requested such as transcripts, course outlines, declarations, and other documents

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that until the present moment required to be printed and physically signed. In addition to these data, the number of class registers (diários de classe) was obtained, and the number of pages required for printing them for archiving purposes was determined, as per the tables below, divided by University units:

Table 1 Number of Documents Requested in 2022

Type of Document	Unity 1	Unity 2	Unity 3	Unity 4	Unity 5	Unity 6
Academic transcript	96	99	55	285	22	19
Lesson plan	120	248	33	963	2	0
Declarations	46	47	37	164	12	9
Total	**2257**					

Source: Developed by the authors.

In the table above, we have the record of requests received by the University for documents requested by students and alumni. These requests are registered within the university's academic system under the function of requested protocols, divided into university units.

Table 2 Number of Class Registers in 2022

Class diary	Unity 1	Unity 2	Unity 3	Unity 4	Unity 5	Unity 6
1º Semester	126	160	75	508	65	46
2º Semester	134	150	74	548	65	46
Total	**1997**					

Source: Developed by the authors.

The number of class registers was collected from the data of the number of courses offered by the University in the 1st and 2nd semesters of 2022, obtained from the academic system.

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Table 3 Number of Printed Pages

Páginas Impressas	Unity 1	Unity 2	Unity 3	Unity 4	Unity 5	Unity 6
Academic transcript	288	297	165	855	66	57
Lesson Plan	600	1240	165	4815	10	0
Declarations	46	47	37	164	12	9
Diary - 1º Semester	1260	1600	750	5080	650	460
Diary - 2º Semester	1340	1500	740	5480	650	460
Total	**28843**					

Source: Developed by the authors.

For the survey of the number of pages generated in the requested documents and class registers, a document-by-document verification was conducted, where we could ascertain the total number of pages printed in issuing these documents throughout the year 2022, understanding the impact of paper usage. This process aligns directly with SDG 12 of the UN's 2030 Agenda, which advocates for sustainable production and consumption. The analysis of paper consumption allows for evaluating the environmental impact on the institution's operations, as well as the ability to promote initiatives to reduce paper usage and printing.

Table 4 Printing Costs per Page

Total Costs per Document	Unity 1	Unity 2	Unity 3	Unity 4	Unity 5	Unity 6
Histórico Escolar	R$26,61	R$38,13	R$15,25	R$79,00	R$6,10	R$5,27
Lesson plan	R$77,04	R$114,58	R$15,25	R$444,91	R$0,92	R$ -
Declarations	R$4,25	R$ 6,03	R$ 3,42	R$15,15	R$1,11	R$0,83
Diary - 1º Semester	R$116,42	R$205,44	R$69,30	R$469,39	R$60,06	R$42,50
Diary - 2º Semester	R$123,82	R$192,60	R$68,38	R$506,35	R$60,06	R$42,50
Total Cost	**R$2,810,68**					

Source: Developed by the authors.

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With this data, it was possible to interpret that the printing cost per page does not represent a significant value. However, from an operational standpoint, all these documents still incur personnel costs, as well as storage costs in some cases, which increases the overall expenses. In this article, we chose not to establish costs with these variables, as they are intangible data at this moment.

Maximo and Ribeiro (2022) conducted a study in which they point out the increase in initial costs in the digital transformation of academic records, which includes the issuance of digitally native documents (electronic documents with digital signatures). This explains that the initial costs of implementing specialized information systems for digital signatures, as well as the transformation of physical files into digital files with reliability and security, require a high investment, as there is not only the cost of the system itself but also the maintenance cost. Despite the presented results, they also emphasize that digital transformation promotes a significant reduction in the costs of printing and storing academic documents, related to academic records, requested documents, and digital diplomas, being more beneficial from a sustainable point of view.

Furthermore, regarding the transformation of archives and the digitization of processes in higher education institutions, we can mention social responsibility, as in addition to teaching, research, and extension activities, they directly influence the relationships among stakeholders (Souza *et al.,* 2015; Pepe *et al.,* 2018). These stakeholders comprise students, employees, the external community, government, and other sectors impacted by university activities, meaning universities must be effective in management, with organizational processes focused on sustainability (PEPE *et al*., 2018; GEORGE *et al*., 2020; GUANDALINI, 2022; PAIVA *et al*., 2023).

With the data obtained, a meeting was held with a group of collaborators from the HEI who are responsible for issuing, signing, and storing academic documents and requested documents. This team consists of four (4) individuals responsible for the Regulatory Processes department and the Teaching Central department. In this meeting, the perceived changes in the digital transformation process of document issuance were discussed, pointing out the changes related to the efficiency and effectiveness of the processes. To list the changes, the tables below were prepared:

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Table 5 Efficiency in Processes

Perceived Changes	Justification
Reduction of Processing Time	Digital signature eliminates the need to print, manually sign, and scan documents, resulting in a significant reduction in processing time.
Workflow Automation	Document issuance processes can be automated, streamlining repetitive tasks and allowing the team to focus on more strategic activities.
Resource Savings	The elimination of paper usage, printing, and physical storage of documents results in resource savings, such as paper, printer ink, and physical storage space.
Ease of Archiving and Retrieval	Electronic documents can be easily archived and retrieved, eliminating the need to physically search for documents in physical files.
Reduction of Manual Errors	Automation and standardization of processes reduce the likelihood of human errors, such as missing signatures or incorrect information.
Greater Visibility and Control	Electronic systems allow greater visibility into the status of documents in real-time, providing better control over the workflow.

Source: Developed by the authors.

Efficiency refers to the ability to achieve the best results using fewer resources, maximizing productivity and minimizing waste. It involves doing things smartly, quickly, and accurately, effectively using time, energy, and money. Whether in business or personal environments, efficiency stands out for its importance, indicating how we can achieve goals more intelligently. Seeking efficiency not only contributes to sustainability, innovation, and competitiveness but also promotes smarter resource management to achieve maximum positive impact (ADILSON PIRES RIBEIRO; MAIA, 2023).

As efficiency is noted in the obtained results as paramount for the transformation of adopted digital processes, it is understood that by simplifying processes, it reduces the time of processing and finalization of them, as well as eliminating physical obstacles, promoting a more agile dynamic from an operational standpoint, and bringing security and reliability to processes, as well as sustainability in reducing inputs, such as paper and printing (LI *et al*., 2023).

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Table 6 Efficiency in Processes

Perceived Changes	Justification
Enhanced Security	Digital signature provides a higher level of security, reducing the likelihood of forgery or unauthorized alteration of documents.
Legal compliance	The adoption of digital signatures in compliance with legal regulations strengthens the legal validity of documents, contributing to compliance with standards and regulations.
Agility in Decision Making	The quick availability of electronic documents can accelerate decision-making processes, especially in situations that require rapid responses.
Remote Access Facility	The ability to access and sign documents remotely is particularly useful in academic environments, where participants may be geographically dispersed.
Environmental Sustainability	The transition to electronic documents aligns the university with sustainable practices, contributing to a more favorable institutional image.

Source: Developed by the authors.

Being effectiveness the ability to achieve established objectives, measured by comparing the results achieved with the defined objectives, we can say that operational effectiveness is enhanced by the use of electronic documents and digital signatures, streamlining processes and reducing bureaucracy. The transition to the digital environment optimizes document management, providing speed in the creation, sharing, and archiving of information.

Additionally, digital signatures ensure authenticity and integrity, eliminating the need for manual procedures and increasing legal security. These technologies foster remarkable efficiency, promoting a more sustainable approach while boosting productivity in modern organizations (Buck *et al*., 2023; Yevheniy Gryshkun *et al*., 2023).

4 CONCLUSION

The implementation of a digital signature system in a university reveals that while cost reduction may not be as significant as expected, competitive advantages and sustainable operational efficiency are notable achievements. The agility in processes, elimination of physical barriers, and legal security provided by digital signatures not only modernize operations but also contribute to a more sustainable approach. The ability to respond quickly, simplicity in document management, and reduction in the use of physical resources

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consolidate the university as an example of operational efficiency aligned with sustainability principles in the contemporary academic environment.

New studies are suggested to deepen the understanding of the factors leading to the implementation of digital signature systems and electronic documents in universities, considering their long-term impacts. Additionally, exploring user acceptance and adaptation to the new system, as well as evaluating the evolution of sustainable practices over time, would be relevant to guide ongoing strategies. Comparative studies between institutions that have adopted different technological approaches could also enrich the understanding of best practices in pursuing operational efficiency and sustainability in academic environments.

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