



Original Research Article

Sustainable Digital Transformation in Public Administration: A Framework for University Enrolment

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ABSTRACT

The increasing pressure on public institutions to adopt digital solutions has raised new questions about the actual sustainability of such transformations, particularly in administrative systems that remain resource-intensive despite partial digitalisation. While digitalisation is widely promoted as a path to greater efficiency and environmental responsibility, its sustainability outcomes are far from guaranteed. This study critically examines these assumptions through the case of a university enrolment system, identifying inefficiencies and exploring how digitalisation can optimise resource use and improve performance. The widely assumed link between digitalisation and sustainability is not universally valid, as outcomes depend on context, implementation, and infrastructure. The economic, environmental, and social impacts of digital transformation are assessed using process mapping, a conceptual sustainability framework, and estimates of paper and processing efficiency. Digital workflows are shown to reduce administrative workload, lower paper waste, and enhance accessibility, while underscoring the need to avoid unnecessary information technology practices, redundant communication flows, and poorly structured information management that may offset sustainability gains. For example, annual carbon dioxide emissions were reduced from 85,926 kg to 85,006 kg when transitioning from a hybrid to a fully digital enrolment process, primarily by eliminating paper-related emissions and reducing electricity use. The study provides a policy-oriented sustainability indicator framework to guide decision-makers in evaluating public sector digitalisation efforts, while also offering a structured approach to assess trade-offs and implementation conditions. The research contributes methodologically by combining process modelling with sustainability indicators – a rarely integrated approach in public administration – and lays a foundation for future computational optimisation models focused on institutional governance and sustainability-oriented digital transformation.

KEYWORDS

Digital transformation, Public administration, Process optimisation, Sustainable development, University enrolment, CO₂ reduction, Sustainability assessment, Administrative efficiency.

INTRODUCTION

The digitalisation of public services and institutions is gaining increasing significance in modern societies [1]. The rapid development of information and communication technologies

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(ICT) has fundamentally transformed public administration, where digital solutions play a key role in improving efficiency, transparency, and sustainability [1]. At the governmental level, there is a growing recognition that the transition from traditional paper-based administrative systems to digital platforms is imperative not only from a technological perspective but also from sustainability and economic standpoints [2]. While digitalisation is often accompanied by sustainability narratives, its actual environmental and social impacts depend heavily on the implementation context and the institutional environment. Nevertheless, the assumption that digitalisation inherently equates to sustainability continues to dominate public policy discourse, despite the lack of empirical, system-level research on this relationship. In higher education administration, it is particularly common that, despite the introduction of digital tools, background processes (such as student enrolment) remain partly paper-based, resource-intensive, and often inefficient. Hybrid operations not only lead to increased operational costs and environmental burdens but also negatively affect institutional transparency and public trust. This study addresses this contradiction by analysing the student enrolment process at Széchenyi István University from a sustainability and process management perspective.

The goal of this research is to develop a structured evaluation framework for administrative digitalisation in public higher education by combining process modelling, sustainability analysis, and scenario-based simulation. The study aims to quantify the impact of digital transformation on environmental, economic, and social performance through an applied case study of university enrolment.

The methodology combines process modelling (Business Process Modelling and the P-graph method), CO₂ emission calculations, estimates of paper usage and workforce efficiency, and policy recommendations. The literature offers numerous examples of optimising digital public services, particularly through Business Process Management (BPM) [3], Lean [4], and P-graph [5] methodologies. However, most studies do not integrate process management tools with sustainability assessment. It is infrequent for a higher education administrative process, such as student enrolment, to be analysed through a multidimensional sustainability framework. This study aims to fill that research gap by evaluating the enrolment process not only from the perspective of process optimisation, but also in terms of its economic, environmental, and social impacts. In doing so, it assesses not only the efficiency of institutional digitalisation, but also its long-term sustainability consequences.

This research contributes to the field of study by merging a three-dimensional sustainability model with a process-based modelling approach modified for public administration. The methodology differs from previous research in that it either focuses on qualitative stories of digitalisation or specific environmental indicators. A quantifiable and reproducible approach is introduced in this study to assess trade-offs among administrative burden, resource usage, and process productivity. Furthermore, the use of scenario analysis enhanced by a hybrid BPMN–P-graph setup is an original methodological contribution allowing for a more in-depth understanding of sustainability in digital public sector workflows.

The application of P-graph-based process modelling in this context is particularly innovative, as it enables the structural optimisation of the enrolment system and the integrated evaluation of sustainability dimensions. The results support the strategic planning of digital transitions in the public sector, particularly in institutions where the goal of digital transformation encompasses not only speed but also long-term sustainability.

CURRENT SITUATION AND CHALLENGES OF DIGITALISATION IN PUBLIC SERVICES

The digitalisation of public services is progressing at different rates around the world, influenced by countries' economic development, technological infrastructure, regulatory

systems, and institutional readiness [6]. Although the overall goal of digital transformation is to increase administrative efficiency, reduce bureaucracy, and improve access to public services [7], the success of its implementation and its impact on sustainability are highly context-dependent. The diversity of international practices highlights that the success of digitalisation processes is not solely a technological issue, but is also linked to deeply embedded institutional, political, and social factors. Countries at the forefront of digital government, such as Estonia [8], Denmark [9], and the United Kingdom (UK) [10], have implemented well-structured, centrally managed e-government strategies. Through the e-Estonia program, Estonian citizens have a digital ID that enables them to file their taxes online, vote electronically, and perform other administrative tasks [11]. Denmark focuses on automating public services and using ethical Artificial Intelligence (AI) [12], while in the United Kingdom, the Government Digital Service (GDS) provides a single platform for accessing public services [13]. In developing countries, however, poor infrastructure, lack of digital literacy, and low institutional capacity are common obstacles [14]. India, for example, has introduced the Aadhaar biometric identification system (ID) [15], a globally unique solution that provides digital identity to more than one billion people; however, the system has also raised concerns regarding data protection and legality. In Africa, where internet access is often limited [16], Rwanda, for example, has made significant progress in the field of digital public administration [17]. In Nigeria, the lack of broadband internet is also an obstacle to the expansion of services [18]. It is essential to recognise that technological challenges are not exclusive to developing countries. In Germany, the decentralised structure of public institutions hinders the uniform implementation of reforms [19]. At the same time, in the United States, many government agencies still use outdated software that is difficult to integrate [20].

Another complex dimension of the digital transition is the regulatory and data protection environment. The General Data Protection Regulation (GDPR) introduced by the European Union (EU) [21] has had a global impact on data usage standards, while China's strict data flow controls [22] and data transfer disputes between the EU and the United States (US) – such as the Schrems II ruling [23] – further increase uncertainty in international cooperation. All these examples show that the development of digital public administration is far from uniform and is not solely a technical issue. Institutional resistance, the legal environment, social trust, and energy efficiency considerations all influence the sustainability impacts of digitalisation.

Although the current literature discusses the implementation challenges in increasing detail, it rarely addresses how digitalisation affects the economic, environmental, and social sustainability of public services, especially at the process level, in the specific procedures of institutional operations. This research aims to fill this gap by examining the university enrolment process from the perspective of how digitalisation can improve or even worsen the achievement of sustainability goals, depending on the mode of implementation and institutional conditions.

Relevant Models for the Optimisation of Administrative Workflows

Optimising administrative workflows is widely recognised as one of the most important tools for improving the efficiency, transparency, and service quality of public institutions [24]. Digitalisation and the use of modern process management methods contribute to simplifying procedures, reducing administrative costs, speeding up decision-making processes, and improving the citizen experience [25]. One of the most widely used methods is Business Process Management (BPM), which provides a structured framework for modelling, analysing, and continuously improving organisational processes [26]. When applied in the public sector, BPM enables the automation of workflows, the elimination of redundancies, and the precise tracking of performance indicators [27]. It also supports process optimisation in line with organisational strategy, which is particularly important in complex administrative systems

such as university enrolment. Based on the principles of lean management, lean public administration aims to reduce waste, strengthen customer focus, and prioritise value-adding processes. The method minimises unnecessary documentation, speeds up administrative procedures, and optimises resource use [28]. Following a lean approach, several countries have successfully reduced the time required for administrative procedures and streamlined customer relations. In recent years, the P-graph methodology, developed initially for the logical modelling of industrial processes [29], has been receiving increasing attention and can now be successfully applied to the optimisation of complex public administration systems [5]. The P-graph system, based on graph theory, enables the visual mapping of process structures, filtering out inoperable or redundant steps, and the identification of alternative solutions [30]. Municipal practices confirm that the use of P-graphs can significantly reduce human resource requirements and paper-based administration, while improving cost efficiency and transparency [31].

Digital transformation frameworks offer a comprehensive set of tools for implementing changes that impact the entire institutional system. They enable not only the redesign of processes but also the coordinated integration of data-driven decision-making, smart services, and sustainability goals. Government Technology (GovTech) models, such as the Estonian e-Estonia system, offer examples of how to develop a national digital ecosystem effectively [32] that supports governance transparency, in addition to providing citizen services [33]. In addition, the Open Group Architecture Framework (TOGAF) provides a means of aligning the Information Technology (IT) systems of institutions with sustainability and organisational goals at a strategic level, particularly in countries such as Canada [34]. Several frameworks support the integration of innovative technologies such as artificial intelligence and blockchain, as well as the rethinking of human resource strategies. Successful digitalisation is not only a technical challenge, but also requires organisational change management, which in turn necessitates the use of appropriate tools and methods. Although the approaches mentioned above have contributed significantly to improving the efficiency of the public sector, their integration into a multidimensional sustainability assessment framework is rarely mentioned in the literature. This is particularly true for process-level analyses of higher education administration, where the joint consideration of economic, environmental, and social factors is still not widespread. This study aims to fill this gap by combining P-graph modelling and a sustainability indicator system, using the example of a specific higher education procedure: the enrolment process.

Sustainability Assessment Methods in the Context of Digitalisation

Analysing the sustainability impacts of digitalisation is essential to ensure that technological developments not only make public administration processes more efficient, but also more environmentally and socially responsible. However, integrating sustainability considerations poses significant challenges, particularly in public services, where assessment methods are often fragmented and not sufficiently integrated. Domingues et al. (2015) highlight in a case study how sustainability labels can serve as an evaluation tool in the functioning of local governments [35]. Several evaluation frameworks are available to address this, which aim to explore the long-term economic, environmental, and social impacts of digitalisation interventions. One of the best-known approaches is the Life Cycle Thinking (LCT) methodology, which examines the environmental, social, and economic impacts of a given product, service, or system throughout its entire life cycle [36]. In the case of digital transition, this includes, for example, the energy consumption of IT equipment, the sustainability of data centres, and the impacts of the production and disposal of digital infrastructure [37]. The LCT method is particularly suitable for demonstrating the extent to which digital processes can reduce the ecological footprint compared to paper-based administration, while also highlighting that digitalisation can also entail new types of environmental impacts. Multi-Criteria Decision Analysis (MCDA) is a decision support tool

that enables the consideration and simultaneous weighting of different sustainability aspects [38]. The method can be used, for example, to evaluate digital platforms, service models or IT systems in a complex manner – not only in terms of energy efficiency, but also in terms of accessibility, data security and economic return [39]. Comparative analyses of this kind are used in many countries when planning the digitalisation of public services, but they are often not linked to specific administrative processes. The literature also provides examples of sustainability performance measurement at the municipal level, such as the indicator system developed by Adams *et al.* [40] or a study of Romanian counties, which showed that only 11 of the 42 counties met the criteria for efficient use of public funds [41]. However, such studies primarily evaluate at the institutional level and pay little attention to process-level impacts.

This research aims to offer something new at this point: sustainability assessment is not carried out at a general institutional level, but is applied to a specific administrative process – university enrolment. The study develops a conceptual sustainability indicator system that combines the methodological logic of LCT and MCDA, enabling the estimation of the economic, environmental, and social impacts of digital work processes. In doing so, it contributes to filling a methodological gap that has been neglected in the discourse on digitalisation in the public sector.

The Role of Sustainability in Digital Transformation, with a Special Focus on the Administration of Higher Education Institutions

Digital transformation is playing an increasingly important role in the implementation of the UN Sustainable Development Goals (SDGs), particularly in the public sector and educational institutions [42]. The use of digital technologies not only increases administrative efficiency but also contributes to sustainability, for example, by reducing paper consumption, improving energy efficiency, and optimising resource use. The digitalisation of higher education institutions – particularly in line with SDG 4 (quality education) [43], SDG 9 (industry, innovation, and infrastructure), and SDG 13 (climate action) – can contribute significantly to a more sustainable future [44]. International examples show that digitalisation measures in higher education institutions can lead to sustainability outcomes at multiple levels [45]. Cloud-based data storage, for instance, in university management systems and document repositories, significantly reduces the need for physical document storage, thereby reducing the environmental impact of infrastructure [46]. Monash University in Australia utilises sustainable data centres powered by solar energy, which significantly reduces the emissions associated with its IT systems [47]. Distance learning platforms such as Moodle and Canvas can substantially reduce travel needs and associated environmental impacts while expanding access to education [48]. According to studies by the Royal Institute of Technology (KTH) in Sweden, hybrid education, which has become widespread during the Coronavirus disease (COVID-19) pandemic, can reduce the environmental impact of transportation by up to 30% [49]. In addition, artificial intelligence-based, personalised e-learning systems can contribute to the replacement of printed materials, optimising educational processes and minimising the use of paper-based tools, thereby contributing to reducing the environmental impact of education [50]. The sustainability is not just a technological or environmental issue. Human resource management is also a factor of strategic importance in the digitalisation of higher education. Globalisation and internationalisation are placing increasing emphasis on research excellence, innovation, and productivity, yet many institutions have not yet recognised that human resource management plays a key role in building a knowledge-based economy [51].

Digitalisation Strategies and Regulatory Environment for Higher Education Institutions

The digitalisation of higher education institutions is receiving increasing attention worldwide, as the goal is to ensure more efficient administration, better educational quality, and more accessible services [52]. Online student administration eliminates paper-based

processes, streamlines workflows, and enhances flexibility. Methodist University College, for example, has developed an online registration system that allows remote administration, eliminating the need for personal attendance [53]. With the spread of distance learning, platforms such as Moodle, Blackboard, and Canvas, which provide effective online course management, have grown in importance. EdX, founded by Massachusetts Institute of Technology (MIT) and Harvard, offers open access to global educational materials [54]. Artificial intelligence is also playing an increasingly important role: Georgia State University uses chatbots to answer student questions, reducing administrative burdens [55]. However, the digital transition brings not only technological challenges, but also regulatory ones. The EU's General Data Protection Regulation (GDPR) requires the protection of student and teacher data, while German universities use special data security solutions for online exams. In the United States, the Americans with Disabilities Act (US ADA) requires accessible e-learning systems, while the UK's Digital Education Strategy supports the development of online services [56]. The EU Plan S initiative aims to ensure open access to scientific publications [57]. At the same time, the United Nations Educational, Scientific and Cultural Organization's Open Educational Resources (UNESCO's OER) recommendation promotes freely accessible digital learning materials [58]. In the United States, the Family Educational Rights and Privacy Act (FERPA) law protects the security of student data [59], while in Australia, the Privacy Act serves similar purposes [60]. Online exam systems such as ProctorU and Examity have raised privacy concerns, and several universities have become embroiled in legal disputes over them [61]. All these examples highlight that the digitalisation of higher education is not a uniformly positive or problem-free phenomenon, but a complex, multidimensional process that requires careful planning from an institutional, regulatory, and sustainability perspective. Technological innovations and digitalisation tools alone do not guarantee sustainable development – this can only be achieved through a systemic approach that takes into account the entire ecosystem of university operations. The aim of this research is to examine the university enrolment process from a sustainability and process management perspective, identifying administrative inefficiencies and assessing how digital transformation can increase economic, environmental, and social sustainability in the public sector. The research develops a conceptual sustainability assessment framework and provides high-level estimates of efficiency gains, thereby supporting institutional governance and policy decisions related to sustainable digital transition. In order to achieve the research objective and explore the sustainability aspects of public sector digitalisation, the following questions were formulated:

- How can process management principles support the development of sustainable digital public administration in university enrolment systems?
- What institutional, policy, and governance strategies are needed to ensure that digitalisation truly aligns with sustainability goals?
- What economic, environmental, and efficiency benefits can be gained from switching from a hybrid system to digital enrolment?

Although there is increasing discourse on the digitalisation of the public sector, most research still focuses primarily on technical efficiency gains and pays less attention to sustainability considerations. The present study aims to address this gap by presenting a conceptual framework that assesses the economic, environmental, and social impacts of digital work processes. Unlike previous research, this study does not merely examine the introduction of IT solutions. Still, it treats process optimisation and sustainability indicators in an integrated manner, while providing high-level estimates of paper reduction, efficiency gains, and institutional governance opportunities. The results can also be used at the policy level, contributing to a digital transformation in which sustainability is a real strategic priority in the planning and operation of public services.

MATERIALS AND METHODS

The study focuses on the process of university enrolment, a significant administrative process involving the submission of documents, verification, and communication between university staff and students. A majority of universities still rely on hybrid or paper-based enrolment processes, which lead to inefficiencies such as redundant paperwork, excessive processing time, and high resource utilisation.

This study is based on a real-life case from a large Hungarian university with approximately 14,000 students and a central administrative system. The enrolment process was selected as it is critical, highly standardised, and representative of wider administrative functions. The model was developed in close cooperation with university staff and reflects the actual process structure and constraints. The study uses a qualitative and conceptual research approach, integrating process analysis, combined CO₂ emission analysis, sustainability assessment, and policy recommendations to determine the impact of digital transformation on administrative efficiency and sustainability. The authors collected data for the process model through internal documentation, administrative logs, and structured interviews with university staff involved in enrolment. Task durations, error rates, staff availability, and paper usage patterns were estimated based on data from the 2022 and 2023 fall/spring semesters. While exact metrics vary year to year, the figures used represent average institutional experience over the past five years. Quantitative inputs for paper use, CO₂ emissions, and labour costs were based on both institutional records and secondary literature.

The research process consists of three primary elements. First, process mapping will be conducted by examining the university enrolment process. Inefficiencies and bottlenecks will be detected by utilising both the Business Process Modelling technique and the P-graph methodology [62]. The P-graph methodology was selected over alternatives such as discrete-event simulation due to its strength in modelling combinatorial process structures and resource allocation. P-graph allows for the systematic synthesis of feasible process structures while preserving visual transparency and adaptability, which is essential in communicating administrative workflows to non-technical stakeholders. Its integration with optimisation routines and scenario generation makes it particularly suited for sustainability evaluation.

Second, a conceptual model of sustainability is applied to develop a three-dimensional framework for evaluating digital transformation in terms of its economic, environmental, and social aspects. Third, conceptual approximations of sustainability and efficiency are established utilising the data obtained to perform rough calculations at high levels to gauge paper savings, process efficiency gain, CO₂ emission reduction levels, and sustainability measures of the process under examination.

The university's enrolment process has two main phases: initial data processing and document validation, as well as managing paper-based records. Student information is accessed from the central database upon admission. However, administrators must validate, edit, and request any outstanding information within two weeks (three weeks prior to the signing of the contract ceremony). The second phase involves integrating other paper documents into the system, which requires repetitive corrections due to students committing mistakes more frequently, with around 60% of them submitting incomplete documentation. This bureaucratic process, characterised by tight deadlines and administrative inefficiencies, usually results in overtime. The university admits 4000–6000 students annually out of 14,000, with a regular rate of new admissions. However, the real problem lies with staff adapting to varying workload volumes, further exacerbated by high turnover (20% over two years) and the need for seasoned employees, as productive administration requires a minimum of 1–2 years of training.

Figure 1 shows the Business Process Modelling representation of the process. Students must present data and documents at the onset of the admissions process, which administrators

collect and examine through various stages. When inconsistencies or incomplete information are found, further clarification requests are issued to the students. These procedural steps are essential for enrolling students in the university system and initiating the administration of courses. A formal contract will be signed later, which will require additional requests for information and documents to proceed with the administrative process. It may be necessary to provide further information until the process is complete, which typically concludes with the granting of official student status to university students.

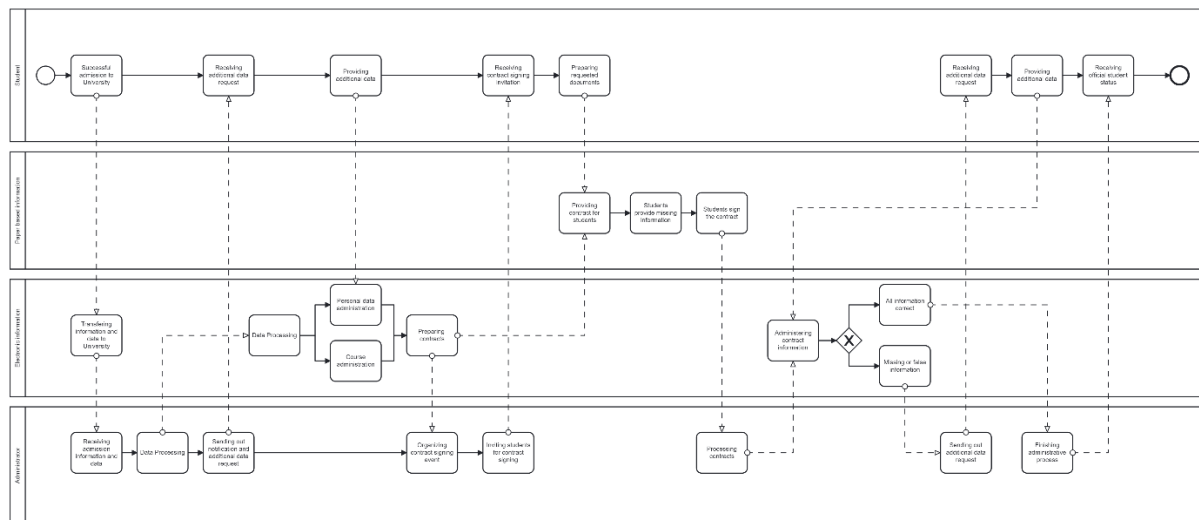


Figure 1. Business Process Model visualisation of the university enrolment process

To evaluate the sustainability benefits of digitalising administrative processes, as shown in [Table 1](#), a three-dimensional sustainability framework is developed and applied. The applied conceptual sustainability indicator framework is designed based on established sustainability assessment methodologies, such as Multi-Criteria Decision Analysis (MCDA) and Life Cycle Thinking (LCT), as described in the literature review. To assess the robustness of the model, a sensitivity analysis was conducted by varying two key input parameters: the number of administrators (15, 17, 22) and the number of enrolling students (3500, 4500, 5000). Sustainability indicators, including total CO₂ emissions, paper usage, process completion time, and labour costs, were recalculated for each scenario. This procedure enabled the evaluation of how administrative capacity and demand impact sustainability performance.

Table 1. Applied sustainability framework dimensions

Dimension	Key factors	Impact of digitalisation
Economic	Cost efficiency, workforce productivity, and operational scalability	Reduced administrative costs, optimised labour allocation
Environmental	Paper waste, energy consumption, and CO ₂ emissions	Lower resource consumption, reduced carbon footprint
Social	Service accessibility, administrative transparency, and digital equity	Improved user experience, accessibility for remote users

The framework evaluates digital transformation across economic, environmental, and social dimensions using a weighted scoring system. It assesses how digital transformation impacts sustainability by comparing the current hybrid workflow with digital workflows, utilising institutional data and estimating potential reductions in administrative burden

through process streamlining, while also highlighting the potential improvements from digital enrolment.

To evaluate sustainability in a structured and comparative manner, a composite scoring framework was developed based on the three classical pillars: environmental, economic, and social. Each pillar was assigned a relative weight (0.4 for environmental, 0.3 for economic, and 0.3 for social dimensions) based on MCDA-related literature on sustainability assessment in administrative and service systems. This weighting reflects the institutional priority placed on environmental performance while recognising the operational and human factors critical to process feasibility. Each scenario was evaluated on a scale from 1 to 5 per dimension (5 – most sustainable), based on predefined performance thresholds derived from the range of observed results across scenarios. For example, environmental scores were calculated based on relative CO₂ emissions and paper usage, economic scores on labour costs and resource usage, and social scores on process duration and workload of administrators. This scoring structure enables easy comparison of the digital and hybrid cases under different workforce and enrolment assumptions. It facilitates transparent decision-making by highlighting multidimensional trade-offs that encompass efficiency, environmental considerations, and human resource implications.

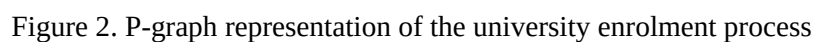
The implementation of models and simulations relied on the use of P-graph Studio software and Microsoft Excel for data processing and calculating sustainability scores.

RESULTS

This section presents the comparative analysis of digital and hybrid enrolment workflows based on consistent sustainability criteria: CO₂ emissions (from electricity, gas, heating, water, and paper), process efficiency, and workload distribution. All results are based on process data collected from a Hungarian university (2017–2023), modelled through BPMN and P-graph representations and evaluated using institutional process logs and staff interviews. All data and calculations are based on the authors' own modelling using real institutional data (2017–2023). All emissions values are calculated based on standard conversion factors and scenario-specific assumptions regarding resource usage. The findings highlight workflow inefficiencies, estimated paper savings, administrative efficiency, and scores of sustainability to facilitate a systematic comparison of the advantages of digitalisation.

The process mapping exercise revealed several inefficiencies in the current hybrid enrolment system. Firstly, there is duplicated paper-based documentation because the submission and verification of hard copies of documents lead to lengthy delays, increased administrative costs, and excessive paper use. Secondly, there is the issue of manual Data Processing Delay and Entry, as student data is keyed in and handled manually by administrators, resulting in a high cost per application. Thirdly, there is the issue of Intensity of resource, as paper, printing, and administrative processing cause wasted environmental effort and also additional institutional costs. These inefficiencies indicate that transitioning to a digital enrolment process would significantly reduce administrative burden, processing times, and resource utilisation.

Figure 2 is a P-graph of the university admissions process with resources, operations, and workflows. Administrators accept student-submitted documents, issue corrections if needed, and handle paper-based records distinctly after contract signing. Each step has varying time allocations, with paper-based processing requiring more time than digital processing. Repeated student errors include multiple data requests, which are delay-causing, while management of overall time limits is necessary for both phases.



The calculation formulas applied were derived from Eisinger and Buics (2024) [63]. The following formula is used to calculate the administrative resources required:

Where: N_a denotes the number of administrators (17 administrators in baseline scenario), H – working hours per day (8 h per day), D – working days per week (5 days per week), W – number of weeks for the process stages (3 weeks in the first stage when $n = 1$, and 2 weeks in the second stage when $n = 2$), and N_s – number of enrolled students (4500 students in baseline scenario).

The following formula is used to calculate the labour hours required:

Where: L_n denotes the labour hours needed per documentation [h], and σ – fraction of working time spent on the enrolment process by administrator (0.55 according to collected data).

During the university admissions process, the number of students admitted annually has a significant impact on paper usage, administrative workload, and process efficiency. The

baseline case is 4500 students per year. Two additional scenarios were also presented to study the impact of varying student volumes: a reduced student enrolment scenario of 3500 students per year (−1000 from baseline), and an increased student enrolment scenario of 5000 students per year (+500 from baseline). These variations facilitate the intensive analysis of paper savings, administrative efficiency, and sustainability across different levels of enrolments and labour force situations through several formulas used to estimate the effects of digital transformation on paper savings, processing efficiency, administrative complexity, and sustainability measurement.

The cost and savings of recycled paper were calculated by the formula provided below, where the cost per page printed is €0.02 and 9 pages are required on average per student.

$$S_P = [(P_H - P_D)/P_H] \times 100 \quad (3)$$

Where: S_P denotes paper savings [%], P_H – paper usage in the hybrid process, and P_D – paper usage in the digital process

Table 2 highlights the impact of digitalisation on paper usage and cost reduction. The end-to-end electronic enrolment eliminates the use of paper, offering significant cost advantages. The hybrid model, however, still relies on paper and is therefore more resource-intensive. The varying number of students also affects paper usage: fewer students result in paper savings, while more students lead to higher usage and added costs. The increased number of workers under a digital structure maximises efficiency by completely eradicating paper expenses.

Table 2. Paper savings and cost reduction across student and workforce scenarios

Scenario	Students enrolled	Paper usage [pages/year]	Paper savings [%]	Cost savings [€]
Baseline (17 Admins, Hybrid)	4500	40,500	0%	0
Baseline (17 Admins, Digital)	4500	0	100%	854
Reduced workforce (15 Admins)	4500	40,500	0%	0
Expanded workforce (22 Admins, Digital)	4500	0	100%	854
Reduced enrolment (Hybrid, 17 Admins)	3500	31,500	22.2%	663
Increased enrolment (Hybrid, 17 Admins)	5000	45,000	−11.1%	−332

The processing time savings and workload efficiency were calculated by using the following formulas:

$$PT_S = \left(\frac{AT_H - AT_D}{AT_H} \right) \times 100 \quad (4)$$

Where: PT_S denotes process time savings [%], AT_H – time per application in the hybrid process, and AT_D – time per application in the digital process

In the estimation of time gained through the process, the time spent in processing different registration means is assumed to be 2.5 h per application in case of the hybrid process where documents are manually processed, verified, entered into databases, and processed with administrative delay and 1.8 h per application in case of the digital process where documents are processed automatically, reduced manual verification, and increased effectiveness in the workflow.

$$A_W = \frac{PT_T}{A_N} \quad (5)$$

Where: A_W denotes workload per administrator, PT_T – total processing time, and A_N – number of administrators.

Table 3 illustrates the effect of staff and pupil numbers on administrative workload. The smaller staff in a blended model results in a significant increase in workload per administrator, negatively impacting efficiency and the quality of service. Doubling the staff and transitioning to an all-digital-based system significantly reduces the workload per administrator, making the process more manageable. Reducing the number of students in a hybrid model lowers administrative pressure, while increasing the number of students requires additional processing time and can stress available workforce capacity.

Table 3. Administrative efficiency gains across student and workforce scenarios

Scenario	Students enrolled	Processing time per application [h]	Workload per administrator [h/year]
Baseline (17 Admins, Hybrid)	4500	2.5	662
Baseline (17 Admins, Digital)	4500	1.8	477
Reduced workforce (15 Admins)	4500	3.0	900
Expanded workforce (22 Admins, Digital)	4500	1.8	368
Reduced enrolment (Hybrid, 17 Admins)	3500	2.5	514
Increased enrolment (Hybrid, 17 Admins)	5000	2.5	735

The combined analysis of electricity, gas, heating, water, and paper consumption provides a comprehensive assessment of the total CO₂ emissions across different administrative scenarios. The results highlight the significant impact of workforce size, digitalisation, and enrolment variations on sustainability metrics.

The total CO₂ emissions are calculated using the following formula:

$$CO_2 = \sum_{i=1}^n (Q_i \times E_i) \quad (6)$$

Where: Q_i denotes energy consumption factor (electricity in kWh, gas in m³, heating in GJ, water in m³, paper in pages), E_i – CO₂ emission factor (kg CO₂ per unit of energy or per unit volume or per page of paper).

The emission factors used in the calculations are based on data from the World Bank and the Hungarian Central Statistical Office (KSH 2023): electricity 0.233 kg CO₂ per kWh, gas 2.05 kg CO₂ per m³, heating 0.057 kg CO₂ per GJ, water 0.045 kg CO₂ per m³, paper usage 0.006 kg CO₂ per page. **Table 4** presents the breakdown of CO₂ emissions from different energy consumption demands and paper usage across the analysed enrolment process scenarios.

Table 4. CO₂ emissions breakdown across scenarios

Scenario	Electricity CO ₂ [kg]	Gas CO ₂ [kg]	Heating CO ₂ [kg]	Water CO ₂ [kg]	Paper CO ₂ [kg]	Total CO ₂ [kg]
Baseline (17 Admins, Hybrid)	3335	80,160	2180	11	240	85,926
Baseline (17 Admins, Digital)	2660	80,155	2180	11	0	85,006
Reduced workforce (15 Admins)	3134	70,725	1924	10	243	76,036
Expanded workforce (22 Admins, Digital)	3359	103,730	2822	15	0	109,926
Reduced enrolment (Hybrid, 17 Admins)	3247	80,155	2180	11	189	85,782
Increased enrolment (Hybrid, 17 Admins)	3378	80,155	2180	11	270	85,994

As is evident, digitalisation reduces CO₂ emissions and does not affect gas and heating consumption. Baseline Hybrid scenario (17 Admins) ranks second highest in terms of total CO₂ emissions (85,926 kg CO₂), primarily due to comparatively high paper-induced emissions and office energy consumption. Completing the transition to a fully digital process (Baseline Digital, 17 Admins) eliminates paper-related emissions and reduces electricity CO₂ emissions by 20.2%, lowering the overall footprint to 85,006 kg CO₂. Emissions related to gas and heating are not impacted, as heating demand is a function of office space rather than administrative processes. The Reduced Workforce scenario (15 Admins) yields the lowest overall emissions (76,036 kg CO₂), primarily due to an 11.7% reduction in gas and heating requirements resulting from fewer occupied desks. Per-administrator electricity consumption increases; however, since each employee spends more time on manual processes, this counteracts partial energy efficiencies. Work per administrator rises significantly, which can negatively impact efficiency and long-term sustainability due to heightened stress and resignations.

The Expanded Workforce (22 Admins, Digital) model has the highest total emissions (109,926 kg CO₂). While digitalisation reduces paper emissions, the expanded office space results in a 29.5% increase in gas and heating requirements, which significantly contributes to the overall CO₂ output. Electricity consumption has increased by 26.3%, with more workstations operating under a fully digital modus, contributing to the energy burden. This situation suggests that the growth of workforce capacity in a digital environment requires optimisations in infrastructure, such as power-efficient workspaces and the integration of renewable energy. Reducing student enrolment to 3500 (Hybrid, 17 Admins) reduces paper consumption, cutting 141.94 kg CO₂ emissions, but total emissions remain fairly stable (85,782 kg CO₂). Increasing student enrolment to 5,000 (Hybrid, 17 Admins) raises CO₂ emissions related to paper by 27.65 kg, but total emissions only change fractionally (85,994 kg CO₂). This suggests that administrative sustainability efforts should focus on streamlining the workforce and improving energy efficiency rather than making enrolment changes.

The sustainability score was also calculated by using the following formula:

$$S_s = \sum_{i=1}^n (W_i \times S_i) \quad (7)$$

Where: S_s denotes overall sustainability score (1 to 5 scale), W_i – weight assigned to each sustainability criterion (0.4 weight for environmental aspect, 0.3 weight for economic aspect, 0.3 weight for social aspect), S_i – score assigned for each criterion (scale from 1 to 5, where environmental sustainability score is based on total CO₂ emissions, economic sustainability score is based on operational efficiency, social sustainability score is based on administrative workload and workforce well-being)

The sustainability score evaluates environmental, economic, and social sustainability across different administrative scenarios. This composite indicator is designed to reflect the trade-offs between CO₂ emissions, operational efficiency, and workforce well-being. The results of [Table 5](#) reveal that the Baseline Digital (17 Admins, Digital) scenario is the most balanced scenario, scoring high on sustainability (3.38), while also eliminating paper-related inefficiencies and maintaining workforce balance, as well as achieving economic and social optimisation.

Table 5. Sustainability assessment across student and workforce scenarios

Scenario	CO ₂ emissions [kg]	Environmental score	Economic score	Social score	Overall sustainability score
Baseline (17 Admins, Hybrid)	85926	2.8	3.2	3.5	3.12
Baseline (17 Admins, Digital)	85006	3.2	3.5	3.8	3.38
Reduced Workforce (15 Admins)	76036	3.8	2.5	2.2	3.02
Expanded workforce (22 Admins, Digital)	109926	1.5	3.8	4.0	2.87
Reduced enrolment (Hybrid, 17 Admins)	85782	2.9	3.3	3.6	3.18
Increased enrolment (Hybrid, 17 Admins)	85994	2.7	3.0	3.4	3.05

Reducing the workforce reduces emissions, but at the expense of efficiency and workforce well-being. It has the lowest emissions overall, but it reduces efficiency and workload, thereby decreasing social and economic sustainability scores. Increasing the workforce without energy efficiency measures can also be unsustainable. The Expanded Workforce (22 Admins, Digital) option improves workforce well-being, but it also substantially increases emissions. Sustainability in that instance requires energy-efficient office buildings and the integration of renewable energy, rather than the current environment.

The sensitivity analysis provided important trade-offs among enrolment size, administrative capacity, and sustainability performance. Higher enrolment (5000 students) increased overall CO₂ emissions and administrative workload, but also improved labour efficiency per student in digital settings. The reduction in workforce (15 administrators) resulted in higher overtime needs and processing tension, which lowered the social sustainability score by a fraction, especially under hybrid settings. The most sustainable

scenario remained the all-digital process with optimised personnel (22 administrators) at baseline enrolment, with well-balanced environmental, economic, and social outcomes. Specifically, when student enrolments grew without an increase in staffing, the sustainability score declined, processing time increased, and indirect energy consumption rose. These findings validate the importance of dynamic resource planning in association with digital transformation to maintain gains in sustainability in real-world administrative settings.

One can ultimately conclude that partial benefits of digitalisation-driven sustainability are attainable even in the absence of an energy transition. Baseline Hybrid is less sustainable due to paper waste and energy-intensive electricity consumption, whereas all-digital workflows conserve paper-related emissions but require parallel efforts to limit CO₂ emissions from gas and heating. Currently, the baseline digital (17 Admins, Digital) scenario offers the most suitable balance between environmental, economic, and social sustainability. Nevertheless, achieving long-term sustainability requires emission reduction from heating and gas, incorporating renewable energy, and streamlining workforce management strategies as well.

DISCUSSION

The research demonstrates that switching to entirely digital processes can significantly reduce CO₂ emissions resulting from paper usage and electricity consumption. The Baseline Hybrid scenario (17 Admins, Hybrid) emits 85,926 kg CO₂ annually, whereas its digital counterpart (17 Admins, Digital) reduces this to 85,006 kg CO₂, eliminating paper emissions and reducing electricity use. Although these benefits are present, digitalisation by itself does not mitigate heating and gas consumption, which remain the most significant contributors to total emissions. This situation means that, although digital transformation is part of the path to sustainability, additional energy efficiency interventions are needed to achieve the greatest impact.

Workforce reduction leads to reduced total CO₂ emissions, as evident in the Reduced Workforce scenario (15 Admins), resulting in 76,036 kg CO₂, which is largely attributed to decreased gas and heating usage. The reduction, however, comes at economic and social expense, as the increased workload per administrator causes inefficiencies and increased stress levels. Conversely, expanding the workforce in a digital context (22 Admins, Digital) results in substantially high energy usage, which raises total emissions to 109,926 kg CO₂. While this model provides the best working conditions and decreases administrative burden, it demonstrates that expanding scale without energy efficiency can detract from sustainability goals. A sensitivity analysis of student enrolment numbers shows that variations in student volume have only a minimal effect on total emissions.

The results indicate that digitalisation needs to be supported by broader sustainability initiatives, such as energy-efficient heating systems to lower gas and heating emissions, office space planning to reduce unnecessary heating requirements, and workforce planning initiatives to avoid excessive workload without compromising on sustainability. Without these initiatives, even completely digital workflows will continue to be limited in their potential to lower emissions at a systemic level. The report finds a fundamental trade-off between environmental sustainability and staff efficiency. Workforce reductions lower emissions, but at the cost of operational efficiency. Conversely, adding employees raises efficiency, but also increases emissions. The best-balanced optimal scenario is Baseline Digital (17 Admins, Digital), as it reduces paper and electricity emissions while maintaining workforce stability. Institutions can take the following policy steps accordingly. First, they should give top priority to electronic record-keeping and automation of processing to reduce paper consumption and electricity usage. Second, they should implement renewable energy sources for electricity and heating to reduce dependence on gas. Third, they should optimise office space and flexible work arrangements to minimise running and heating costs, and

provide job stability by optimising workload and efficiency, without excessive burden on administrators.

This research contributes to the scientific community by incorporating sustainability assessment into digital public administration processes, which are often overlooked. Unlike existing work that focuses on technical optimisation or policy interventions, this dual approach employs a methodical approach to compare digital and hybrid administrative processes. By applying a multidimensional sustainability indicator system in a real-world case study, the study provides a transparent methodology for evaluating the net sustainability benefits of digital transformation in higher education administration.

In terms of limitations, this study focused on the enrolment process. Other administrative procedures, such as the management of financial aid and the maintenance of academic records, may have had mixed sustainability impacts. Future research should expand to include these various functions. Estimates are based on calculated energy use, workload, and administrative efficiency measures, which may vary between institutions. Empirical confirmation with actual administrative energy and workload information would provide improved accuracy of outcomes. External regulatory systems, institutional budgets, and stakeholder opposition to digital change – factors not considered in this research – can all potentially affect the feasibility of sustainability projects.

CONCLUSION

This study has evaluated the sustainability impact of digitalisation of university back-office procedures in terms of energy consumption, labour productivity, and CO₂ emissions. The evidence indicates that fully digital procedures can significantly reduce paper-based emissions and electricity use, but that their environmental benefits are limited unless complemented by energy-efficient technology and optimised staff planning.

The Baseline Digital case (17 Admins, Digital) offers the most balanced strategy, with lower emissions, more efficient operational performance, and improved labour conditions compared to hybrid designs. Gas and heat emissions remain dominant in all cases, implying that digitalisation of administration is insufficient to achieve full sustainability. Additional measures, such as renewable energy integration, optimised office heating, and space enhancements, must be implemented to further reduce the environmental footprint.

This study demonstrates that transitioning from a hybrid to a fully digital enrolment process can result in a 100% reduction in paper usage and a 23% reduction in electricity-related CO₂ emissions. Furthermore, the proposed sustainability indicator framework enables institutions to evaluate such reforms systematically across environmental, economic, and social dimensions.

This study aimed to provide a comprehensive overview of the sustainability effects of digitalisation, both its advantages and disadvantages in administrative environments. By integrating energy consumption calculations, CO₂ impact evaluations, and labour efficiency calculations, the research highlights the complexity of optimising sustainability without compromising operational effectiveness. The study indicates that planning the workforce is central to balancing sustainability goals, as reducing personnel lowers emissions but at the cost of efficiency, whereas adding personnel improves operations but increases energy consumption.

The findings suggest that even modest digitalisation, when driven by strategic workforce planning, can provide measurable sustainability benefits. It highlights the value of systematic decision-making frameworks in guiding public sector digital transformation policy. This study relied on institutional averages and estimated coefficients for energy consumption. Real-world variations may influence the exact savings calculated, and the administrative environment of the case study may differ from those of institutions with lower IT readiness or regulatory flexibility. Additionally, the scope of the analysis was limited to one university process, while

many other administrative areas, such as human resources or finance, may have different process characteristics. Subsequent studies should extend the model to these domains and include long-term monitoring of energy and material use to validate the estimated savings. The addition of real-time data acquisition and stakeholder feedback to the optimisation mechanism would further enhance accuracy and impact.

Broadly speaking, the results highlight the importance of institutions going beyond digitalisation and embracing a multi-pronged strategy for sustainability. Process automation, infrastructure upgrades, and policy reforms are needed to achieve maximum environmental gains while maintaining economic and social sustainability. There is a need for future studies to investigate the broader administrative applications of digitalisation, such as in financial and student affairs, incorporating real-world energy consumption data to inform more accurate sustainability evaluations.

Future research may build on this framework by incorporating dynamic simulation models, such as agent-based modelling, to account for variability in user behaviour and institutional response. Furthermore, extending this approach to assess other administrative processes can support broader sustainable transformation in the public sector. To achieve long-term environmental returns, institutions must adopt a multifaceted approach that integrates digitalisation with strategic workforce management and green infrastructure investment.

NOMENCLATURE

Symbols

A_N	number of administrators	[person]
AT_D	time per application in the digital process	[h]
AT_H	time per application in the hybrid process	[h]
A_W	workload per administrator	[h/year]
D	working days per week	[day]
		[kg CO ₂ /unit of energy] or
E_i	CO ₂ emission factor	[kg CO ₂ /page of paper]
H	working hours per day	[h]
L_n	labour hours needed per documentation	[h]
N_a	number of administrators	[person]
N_S	number of enrolled students	[person]
P_D	paper used in the digital process	[piece]
P_H	paper used in the hybrid process	[piece]
PT_S	process time savings	[h]
PT_T	total processing time	[h]
Q_i	energy consumption factor (electricity)	[kWh]
Q_i	energy consumption factor (gas/water)	[m ³]
Q_i	energy consumption factor (heating)	[GJ]
Q_i	energy consumption factor (paper)	[page]
S_i	score assigned for each criterion	
S_P	paper savings	[€]
S_S	overall sustainability score	
W	number of weeks for the process stages	
W_i	weight assigned to each sustainability criterion	

Greek letters

σ fraction of working time spent on the enrolment process by administrator

Abbreviations

BPM	Business Process Management
LCT	Life Cycle Thinking
MCDA	Multi-Criteria Decision Analysis
SDGs	Sustainable Development Goals

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