DCE 23

5th DOCTORAL CONGRESS IN ENGINEERING

Book of Abstracts

DCE23 - Symposium on Engineering and Public Policy

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FEUP FACULDADE DE ENGENHARIA
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5th DOCTORAL CONGRESS IN ENGINEERING

Book of Abstracts

of the

Symposium on Engineering and Public Policy

Editors:

Bruno Santos, João Claro, José Coelho Rodrigues, Mário Amorim Lopes

Porto

June 2023

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This volume contains the peer reviewed and accepted abstracts, presented at the Symposium on Engineering and Public Policy, of the 5th Doctoral Congress in Engineering – DCE23, held at FEUP-U.Porto, Porto, Portugal, between June 15th and 16th, 2023.

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Welcome

Welcome to the symposium on Engineering and Public Policies. This is an interdisciplinary symposium, organized by the Doctoral Program in Engineering and Public Policy (PDEPP) of the Faculty of Engineering of the University of Porto (FEUP), focused on technological and policy issues that arise when designing, developing, regulating, implementing and managing networked infrastructures.

It aims at bringing together engineers, policymakers, researchers, and practitioners to discuss the latest advances in engineering and public policy, promoting engineering in the policy decision-making processes and giving it a more central role in the design of public policies.

The programme includes eight oral presentations, organized in three sessions, covering a wide range of topics within engineering and public policy, presented by PhD students. The topics addressed include engineering and public policy challenges and concerns related with renewable energies, systems optimization, carbon neutrality, cybersecurity management, forest management, research and development and innovation collaboration, organizational capabilities, and technology use for education. The programme also includes a round table bringing together experts in engineering and public policy to discuss the role of public policies and of engineering in our society.

This symposium creates a great opportunity for PhD students to present and for engineers, policymakers, researchers, and practitioners to discuss it with the authors, creating a bridge between academy and practice that is of utmost importance for research work to be meaningful and impactful.

We hope you enjoy these sessions and that the discussion dynamics intended are created and benefit all of us.

Porto, June 2023

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Enablers and challenges for the adoption of digital energy solutions in the EU

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Sector Coupling with Hydrogen: A new energy vector towards carbon neutrality

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Abstract

The world is facing the major climate changes effects in the recent history, which has been escalating since the industrial revolution, bringing societies to ensure the climate effect to a halt in the upcoming years. Increasingly higher energy demands have been bringing relevant costs to the environmental sustainability.
Contemporary public policies towards carbon neutrality of the human footprint converge towards electrification of the economy, exploiting an energy matrix resulting from a mix of renewable sources (solar, wind, water and biofuels). Therefore, guaranteeing the carbon neutrality of emissions, ensuring safety of supply and guaranteeing the financial sustainability of the energy system are key combined factors towards success. With a renewable based electricity system, public policies are fostering and strengthening the use of electricity in the different sectors of activity and economy, namely manufacturing, transportation and residential and service sectors. In parallel, the decarbonization goals require also the exploitation of biofuels and the use of renewable hydrogen, assuring the decarbonization of the gas sector, a key enabler of carbon neutrality, avoiding stranded assets, developing a transitional regulation framework.
Portugal, as long with other nations of the European Union, has developed a national roadmap for hydrogen deployment as a key element of the Portuguese energy transition towards carbon neutrality, generating synergies between the electric and gas systems. Such synergies must be further developed, where hydrogen appears as a renewable energy carrier capable of guaranteeing not only the transformation of the gas system but also the integration with the power system, ensuring the conversion of excess of renewable electrical energy into storable energy, namely via the storage of hydrogen. Such approach potentially solves security of supply issues of an electric power system based on renewable power sources, allowing the renewable energy harvesting throughout the year.
Sector coupling of energy vectors emerges as a solution to optimize scenarios of system operation, foster competition between energy players, and ultimately to address the climate change problems by repurposing the actual energy infrastructures, both assets and systems, connecting demand and supply, with efficient policies.
Hydrogen can be produced via electrolysis of water by either capturing surplus from the renewable electricity, producing “green” hydrogen, or by developing dedicated renewable generation projects.

The generation portfolio foreseen for Portugal in 2030 will lead to a surplus of more than 2 TWh/year of renewable energy. At the same time there are concerns regarding security of supply in this horizon, which require the availability of some firm capacity to keep reliability indices within the acceptable ranges.
Current research work demonstrates a decision-making approach to define a public policy based on the adoption of hydrogen to store the foreseen surplus of renewable electricity, in conjunction with the installation of firm generation capacity from hydrogen power plants. This requires also the optimization of the electrolysers's capacity and the hydrogen storage capacity, capable to store the required hydrogen needed to ensure generation adequacy levels within the usual patterns of security of supply.
Such overall approach could promote the creation of both physical and financial storage capabilities of renewable energy in the global energy system, transferring surpluses of electrical energy from the summer season to winter with higher-demand, leveraging seasonality and solving the security of supply concerns.
Regulatory frameworks were developed in order to assess new market operation conditions that foster the carbon neutrality of the energy system, assuring safety of supply and reducing the energy dependency, assuming the Portuguese scenario of the current energy policy targets up to 2040, where the solar photovoltaic and wind projects will be significantly higher, minimizing renewable energy curtailment.

Author Keywords. Hydrogen, networks, sector coupling, decarbonization.

Type: Oral communication

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Analysis of Technological Solutions for the Decarbonization of Industrial Processes by Natural Gas

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Abstract

The reduction of natural gas consumption has become a pressing issue in light of the current energy crisis and the need for decarbonization. This has led various technological sectors to create solutions to promote reduction and meet future challenges. As the plan to introduce green hydrogen into the natural gas network progresses, there is a pressing need to map the technical characteristics of the equipment and identify potential risks that come with operating them with mixtures of hydrogen and natural gas. This work aims to compile and analyze the conversion potential of these equipment, in order to support the industrial sector in the decarbonization process. Thus, the goal is to identify the most relevant opportunities and challenges for the Portuguese industrial sector, by process, equipment or sector.

Author Keywords. natural gas, energy production, boiler, furnace, gas turbine, carbon capture and storage, cogeneration, hydrogen, renewable energies, systems optimization, economic feasibility, environmental protocols

Type: Oral communication

1. Introduction

Natural gas can be used in two ways across industry: first, for heat and power generation, which is its primary use accounting for 64.7% of natural gas consumed in Portugal in 2020 and second, as feedstock which accounts for approximately 24.8% of natural gas applications for other industry products. Natural gas has a high heating content, leading to lower CO2 emissions relative to other fossil fuels. The emissions factor of natural gas (51 kg CO2e/GJ) is just over half that of coal (96 kg CO2e/GJ), though these figures depend on the method of gas production. Natural gas-powered industrial technologies typically have lower capital, operating, and electricity consumption than coal-powered industrial technologies and these characteristics make natural gas preferable for industrial use over other fossil fuels. However, the future of natural gas remains uncertain, particularly for industries aiming to be carbon neutral or net-zero by mid-century. Industrial carbon emissions, at 12.5 MtCO2 in 2019, make up approximately 18.7% of total carbon dioxide (CO2) emissions in Portugal. Additionally, a recent lifecycle study suggests that fugitive methane emissions from hydraulic fracturing of shale gas can drive the GHG footprint of natural gas closer to that of coal. To meet the Sustainable Development Goals, industries need to annually reduce emissions by 1.4% to 10.6 MtCO2 by 2030. This requires decarbonization of industries using innovative technologies, along with expanded use of renewable energy and energy efficiency.

2. Industrial Natural Gas Burning Equipment

The industrial equipment for burning natural gas, widely used in the industry, are designed to efficiently and safely convert the chemical energy of the fuel into thermal energy used in industrial processes. Boilers, fired heaters, gas turbines or gas engines are some of the options to convert these types of energy, however not all the energy can be converted, always existing losses. Hence, a substantial amount of energy can be saved by adopting energy saving measures and by improving the overall equipment efficiency.

2.1. The Boiler example

In the combustion chamber of a boiler, the produced heat is transferred through hot flue gas to water. As the hot flue gas transfers heat to water, a major portion of heat is lost through the outgoing flue gas, about 10–30%. Other heat losses from a boiler are radiation, blow-down, fly ash and bottom ash losses. For maximum efficiency, it is necessary to identify the major source of energy wastage and recover the energy which is wasted.

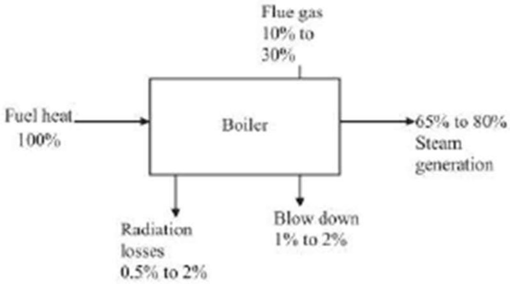

Figure 1 - Typical heat balance of a boiler

Other parameters such as excess air, fuel flow rate, steam demand, should also be optimized. To ensure complete combustion, a boiler is to be provided with more combustion air than what is theoretically suggested. Otherwise, there will be a rapid buildup of carbon monoxide in the flue gas. On the other hand, too much excess air increases the quantity of unnecessary air that is heated and exhausted at the stack temperature.

3. Industrial Uses of Natural Gas

The use of natural gas is mostly spread between the electricity and power generation, and the industry, accounting with 64.7% and 24.8% respectively. For the industry, the major consumers of natural gas in Portugal are the ceramics, glass, food, paper and pulp, and textile industries.

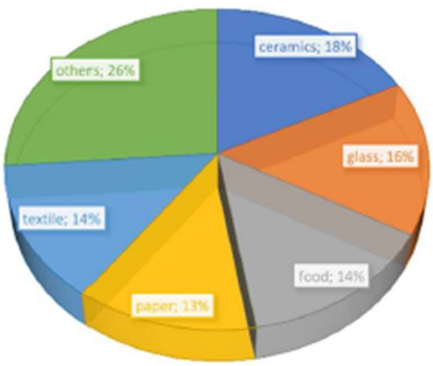

Figure 2 – Biggest natural gas consumers in the Portuguese industry

4. Technologies and practices for decarbonization

Decarbonizing the industry that uses natural gas is a critical towards the net-zero transition, there are several technologies and practices available today that can help reduce or eliminate carbon emissions. 1. Carbon Capture, Utilization, and Storage (CCUS) Technology, captures carbon dioxide emissions from industrial processes, compresses them, and stores them underground, preventing them from entering the atmosphere. 2. Renewable Natural Gas (RNG), is produced by capturing methane emissions from organic waste sources like landfills, wastewater treatment plants, and agricultural waste. 3. Energy Efficiency and Conservation, in industrial processes and equipment can significantly reduce energy consumption and associated carbon emissions. Upgrading equipment, optimizing processes, and reducing waste can all contribute to energy savings and carbon emission reductions, for example with cogeneration. 4. Electrification of the industrial equipment or retrofitting for another innovative and renewable fuel, as biomass, biogas, biomethane or hydrogen, that produce less emissions when burned. 5. Renewable Energy, like solar, wind, and geothermal can help reduce or eliminate carbon emissions associated with natural gas use, by producing clean electricity or heat to feed the industry. 5. Green Hydrogen, produced by using renewable energy through a process called electrolysis. Green hydrogen can be used as a fuel or feedstock in industrial processes, by mixing with natural gas to produce an efficient fuel blend.

5. Conclusions

Decarbonizing the industry requires a multidimensional strategy that includes improving the efficiency of the equipment, switching to lower-carbon fuels, implementing advanced combustion technologies, and performing routine maintenance and upgrades. By taking these actions, the industrial sector can become more sustainable and greenhouse gas emissions from industrial processes can be decreased.

References

IEA (2022), Natural Gas Security Policy, IEA, Paris https://www.iea.org/reports/natural-gas-security-policy, License: CC BY 4.0

, https://www.eea.europa.eu/en.

Barma, M. C., R. Saidur, S. M. A. Rahman, A. Allouhi, B. A. Akash, and Sadiq M. Sait. "A Review on Boilers Energy Use, Energy Savings, and Emissions Reductions." *Renewable and Sustainable Energy Reviews* 79 (2017): 970-83. https://doi.org/10.1016/j.rser.2017.05.187.

Griffiths, Steve, Benjamin K. Sovacool, Jinsoo Kim, Morgan Bazilian, and Joao M. Uratani. "Industrial Decarbonization Via Hydrogen: A Critical and Systematic Review of Developments, Socio-Technical Systems and Policy Options." *Energy Research & Social Science* 80 (2021). https://doi.org/10.1016/j.erss.2021.102208.

Martinez-Villarreal, Sergio, Maroua Kammoun, and Aurore Richel. "The Critical Role of Hydrogen in the Development of New Biofuels." *Current Opinion in Green and Sustainable Chemistry* 39 (2023). https://doi.org/10.1016/j.cogsc.2022.100716.

Mathur, Shivani, Greer Gosnell, Benjamin K. Sovacool, Dylan D. Furszyfer Del Rio, Steve Griffiths, Morgan Bazilian, and Jinsoo Kim. "Industrial Decarbonization Via Natural Gas: A Critical and Systematic Review of Developments, Socio-Technical Systems and Policy Options." *Energy Research & Social Science* 90 (2022). https://doi.org/10.1016/j.erss.2022.102638.

Peng, Peng, Feng Lu, Shifen Cheng, and Yu Yang. "Mapping the Global Liquefied Natural Gas Trade Network: A Perspective of Maritime Transportation." *Journal of Cleaner Production* 283 (2021). https://doi.org/10.1016/j.jclepro.2020.124640.

"<Sistemas Térmicos- Sebenta- Setembro De 2020 (1).Pdf>."

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Enablers and challenges for the adoption of digital energy solutions in the EU

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Abstract

The digitalization of energy brings us a pool of different challenges that still need further research, especially what is missing for the energy transition. The perceptions and factors influencing the adoption of digital energy solutions by households need additional exploration, such as the challenges and drivers of the adoption of those solutions by other ecosystem stakeholders. Through a combination of qualitative and quantitative research, we will identify the critical factors influencing the adoption of different types of energy digital services and products within the EU energy ecosystems. We expect that the result of this research will translate into a framework/model for the adoption and (potential) diffusion of digital technologies while recommending public policies to facilitate this energy transition process. As this project started in February, the presentation will focus on the state of the art, the work plan and preliminary results of a survey conducted among households.

Author Keywords. adoption, diffusion, digitalization, energy, energy ecosystem, energy transition, framework, perceptions, public policies

Type: Oral Communication
Open Access Peer Reviewed

1. Introduction

The energy sector ecosystem is a highly complex landscape undergoing significant transformation due to digitalization. Digitalization is critical to smart energy transitions, opening countless opportunities for future energy practices and systems (Sareen 2021). The current shift in the energy transition “involves complex developments in technology, business models, society and policy-making” and “includes changes in multiple levels of society” (Kirsi et al. 2016).

This research will focus on the enablers, barriers, and consumer behavior challenges for adopting digital energy-related products and services. Evidence in the current literature supports further exploration of this topic: “Consumers’ attitudes and behavioral intention to adopt technology are critical elements that should be examined in behavioral research to improve the current pool of knowledge” (Mishra et al. 2022). The research topic was aligned with some of the expected contributions of CITE for the EU-funded Enable eVeryone's Engagement in the eneRgY transitiON (Every1) project, which aims to facilitate the digitalization of energy transition through training and network development.

Understanding the factors that enable or hinder the adoption of energy-related technologies is crucial for effectively implementing the project's initiatives across diverse stakeholders. In addition, as part of the PhD research proposal, there is a plan to conduct further research on the diffusion of digital energy solutions within the EU energy ecosystem. This additional research aims to strengthen the expected outcomes of the research proposal and make them more robust and effective.

2. Materials and Methods

The research will explore consumers' attitudes toward technology adoption and examine their behavioral intentions concerning energy-related technologies. Within the first instance of the research, educational, cultural, and demographic factors will be analyzed through a descriptive analysis of data from approximately 4,000 households. This survey, spread across four EU member states: Germany, Poland, Portugal, and Sweden, contains information about individual attitudes and behaviors, households' digital electricity knowledge needs, learning choices, and networking patterns. The answers provided will help explain the acceptance/aversion to the progression of digitalization in the energy sector and be instrumental in explaining consumer attitudes and behavioral intentions. However, it is essential to acknowledge that a descriptive analysis may not be sufficient to fully comprehend how these insights can effectively explain perceptions and factors that drive the adoption of digital energy-related products and services. While the initial descriptive analysis can provide a preliminary understanding of the data, different research methods and analyses, such as regression analysis, may be necessary.

Concerning an organizational perspective, a descriptive analysis will also be conducted to identify educational, cultural, and demographic factors related to organization-related stakeholders. Data was captured through a survey shared across EU organizations. A preliminary analysis of the data has already indicated that drawing reasonable conclusions solely based on the survey responses regarding the knowledge needs of organizations concerning energy digitalization may not be sufficient. Therefore, a case research approach will be employed to enhance the research proposal through multiple interviews with key individuals likely to be connected with the organizations that participated in and responded to the survey. Combining survey responses and interviews will enable a more comprehensive understanding of the factors driving digitalization within organizations.

3. Discussion

The complex energy ecosystem includes suppliers, transmission system operators (TSOs), distribution system operators (DSOs), regulators, solution providers, consultants, government bodies, knowledge institutions, and energy consumers and prosumers. In addition to the diverse range of actors involved in the energy ecosystem, the products and services that contribute to the energy transition can be categorized into three main sectors: buildings, mobility, infrastructure and industrial processes. The European Green Deal (2019) supports that the diversity of energy-related technologies is critical to promoting sustainability within the energy sector. Specifically, within the buildings sector, examples of energy-related technologies include smart meters. For instance, the varied uptake of smart meters led to the selection of the EU member states select to spread out the survey. The mobility sector includes technologies such as scheduled charging services for electric vehicles. Demand Side Response is essential for a more efficient energy system in the infrastructure and industrial processes sector.

An overview of the ecosystem's complexities, starting by studying which factors influence the adoption of energy-related technologies among multiple stakeholders, is crucial to achieving the expected outcomes. These will cover the development of a framework or model that explains the adoption (and potential diffusion) of digital technologies associated with the energy transition process to systematize knowledge to be transmitted to potential users of technologies and companies that develop and deliver those technologies. Additionally, recommendations for public policies that might facilitate the energy transition process adapted to the different local contexts studied are expected to emerge as part of this research proposal.

4. Conclusions

Whereas some determinants of green energy adoption comprehend technical matters, adopter level, corporate promotion, and environmental challenges (Qin et al. 2022), this research will first cover educational, cultural, and demographic factors that might act as drivers or barriers to adopting energy-related technologies, from an individual and organizational perspective. Throughout a combination of quantitative and qualitative methods, consumers' attitudes toward technology adoption and behavioral intentions will be explored as part of this research proposal to contribute to the development of a new and robust framework comprising the factors that drive the adoption of these technologies, as well as, contribute to the growth of public policies that might facilitate the energy transition within the EU.

References

Comission, European. 2019. The European Green Deal.

Kirsi, Kotilainen, Jari Makinen, Jarvetausta Pertti, Antti Rautiainen, and Joni Markkula. 2016. "The role of residential prosumers initiating the energy innovation ecosystem to future flexible energy system." *2016 13th International Conference on the European Energy Market (EEM)*: 1-5.

Mishra, Rahul Dev, B. Koteswara Rao Naik, D. Raut Rakesh, and Mukesh Kumar. 2022. "Internet of Things (IoT) adoption challenges in renewable energy: A case study from a developing economy." *Journal of Cleaner Production*.

Qin, Yong, Zeshui Xu, Xinxin Wang, and Marinko Škare. 2022. "Green energy adoption and its determinants: A bibliometric analysis." *Renewable and Sustainable Energy Reviews*.

Sareen, Siddharth. 2021. "Digitalisation and social inclusion in multi-scalar smart energy transitions." *Energy research and social science* 81: 102251.

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Designing a novel database for disclosed cybersecurity incidents

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Abstract
Market regulators are becoming more concerned with cybersecurity incidents as companies increasingly rely on cyber environments. Nevertheless, companies experiencing such incidents have significant discretion in which variables they disclose after the events. Incident disclosure offers multiple benefits, such as reducing information asymmetry among market agents and improving cybersecurity levels through shared experience (stakeholders in general), improving valuation (investors), signaling preparedness against those threats (customers), and reducing audit fees or monitoring costs (companies and business partners). This research recommends a set of disclosure variables, determined using information reported by public companies in the US between 2011 and 2023. The selected variables allow designing a novel database with the potential to benefit market regulators and other agents.

Author Keywords. Cybersecurity incidents, database, SEC EDGAR, disclosure process

Type: Oral communication

1. Introduction

Companies' increased reliance on cyber environments propels new operational risks, particularly those directly related to cybersecurity (Strupczewski 2021). When cybersecurity risks materialize into incidents, perpetrators have found a way through cyber environments, threatening businesses (Arief, Adzmi, and Gross 2015). Furthermore, cybersecurity incidents also endanger stakeholder objectives, making their disclosure critical. Numerous regulations (e.g., GDPR, HIPAA, PCI-DSS) and compliance requirements (Securities and Exchange Commission 2011; 2018) indicate the need to disclose information after experiencing a cybersecurity incident. Despite stopping short of establishing a mandatory information set, the Securities and Exchange Commission, SEC (2022) has recently taken steps in this direction. Disclosing cybersecurity incidents has multiple benefits, especially when standardized. For the market agents in general, there is a reduction in information asymmetry among them (Walton et al. 2021) and an increase in cybersecurity levels derived from shared experience (Calderon and Gao 2022). For the disclosing companies, it lowers *ex-post* legal and reputational costs (Walton et al. 2021). For customers, it signals management's awareness and preparedness toward future incidents (Gao, Calderon, and Tang 2020). For investors, it improves the companies' valuation (Wang, Kannan, and Ulmer 2013) and increases the likelihood of complying with existing regulations (Wang, Yen, and Yoon 2022). For business partners, it reduces monitoring costs (Gao, Calderon, and Tang 2020). Furthermore, there is a refinement in the disclosing process the more attention regulators give to it (Walton et al. 2021).

Our research proposes such a set of mandatory variables, determined using information disclosed by public companies in the US from 2011 to 2023. This proposal may offer several contributions. First, defining an obligatory information set induces standardization, encouraging the development of incident databases. These are valuable for managers because they bring together examples to assist their decisions regarding mitigation strategies and budgets (Sheehan et al. 2021). Second, it enables agencies such as the SEC to identify a compact range of variables most disclosed by public companies to be considered in processes such as its recent consultation (Securities and Exchange Commission 2022). Third, it reduces information asymmetry (Hovav, Han, and Kim 2017) among market agents by relying on information companies already feel comfortable sharing. Fourth, it outlines the expected information to be shared with stakeholders after the cybersecurity incident. Stakeholders claim they receive suboptimal amounts of disclosed information nowadays, casting doubts over its usefulness (Cazier, McMullin, and Treu 2021).

The remainder of this abstract is organized as follows: Section 2 outlines the steps to design our database; Section 3 describes our results and defines the proposed variables; Section 4 offers concluding remarks, limitations, and proposals for improving the database.

2. Methods

This study used the SEC's EDGAR (*Electronic Data Gathering, Analysis, and Retrieval*) system to gather data on cybersecurity incidents from company filings and amendments for operational risk or incidents submitted between October 13, 2011, and May 1, 2023. We searched the EDGAR database using five keywords from Gordon et al. (2011) (*cybersecurity incident*, *cyber-attack*, *data security incident*, *data breach incident*, *information technology incident*) to identify relevant filings and then focused on document extracts where companies had reported actual incidents, not just risks. Initially, 2,814 companies were found. After excluding items related to risks and those from companies not disclosing concrete incidents, the study concentrated on 331 incidents reported by 256 companies, yielding 5,160 information extracts. The data were analyzed using direct content analysis, supported by recent research on classifying cybersecurity incidents (Gomes Filho, Rego, and Claro 2022). We used an open coding method, allowing for the incorporation of new variables from the documents (Mosterd et al. 2021), mitigating any pre-selection bias. This process, summarized in Figure 1**:** Methodology steps, was designed to provide a more accurate understanding of cybersecurity incident disclosure practices over a decade.

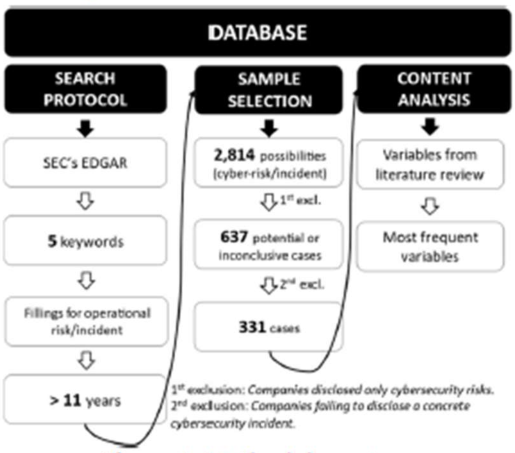

Figure 1: Methodology steps

3. Discussion

The proposed database almost doubles the information collected and analyzed in the previous largest cybersecurity incident studies (Gao, Calderon, and Tang 2020; Calderon and Gao 2022; Wang, Kannan, and Ulmer 2013; Wang, Yen, and Yoon 2022). It is not built solely upon information on 10-K/20-F fillings, which is a novelty compared to the literature. Additionally, its distribution across sectors is similar to the sector structure of incident disclosures observed by the SEC (2022). Table 1**:** Database variables. summarizes the most disclosed variables, their previous discussion in the literature (Gomes Filho, Rego, and Claro 2022), and their disclosure frequency in the information extracts.

Name	Description	Discussed earlier?	Frequency (%)
Vector	The technique employed by the perpetrator in the incident	Yes	1,813 (35.14)
PoE	The point of entry for the incident	Yes	2,764 (53.57)
A/V	The exploited asset or vulnerability	Yes	1,257 (24.36)
(Re)actions	The mitigation strategies adopted by companies	Yes	2,123 (41.14)
Costs	The net cost of the incident	Yes	505 (9.79)
F/S	The affected flows and stocks within the company	Yes*	2,581 (50.02)
SCImpact	The impact on the supply chain	Yes*	1,126 (24.57)
Financial	Expenses or other financial results related to the incident	No	2,787 (54.01)
Lit_1	The acknowledgment of potential litigation	No	1,790 (34.69)
Lit_2	The recognition of actual litigation	No	1,242 (24.07)
Insurance	The availability of insurance	No	1,307 (25.33)

Table 1: Database variables. *n* = 5,160. Notes: *Previous research tends to combine these variables in the variable "Impact." The cumulative frequency is larger than *n* because each information extract can have up to eleven disclosed variables.

The distribution of the number of variables disclosed in the information extracts had the following characteristics: 1) the mean number of disclosed variables is 3.78 ± 2.21; 2) the median is three variables; 3) it is positively skewed (0.53) and leptokurtic (2.42); 4) there are 16 outliers, consisting of extracts individually disclosing 10 (11 cases) and 11 (5 cases) variables.

4. Conclusions

Cybersecurity incidents endanger companies and their stakeholders, calling the attention of market regulators, like the SEC, to their disclosure. The disclosure process creates desirable positive externalities from the viewpoint of regulators. Market regulators, like the SEC, can shape, implement, and enforce public policy with well-established regulations, thus correcting market inefficiencies, such as companies' reluctance towards disclosure.

This research proposes mandatory variables for the disclosure process, using information already disclosed by public companies in the US between 2011 and 2023. Our database could be beneficial for market regulators and other agents.

The main limitation in creating the database is the absence of specific locations for the variables in company filings, which makes the search and updating time-consuming. For the subsequent versions of our database, we intend to 1) add extra variables, 2) allow the analysis by document and company, 3) add cases before the 2011 publication, and 4) combine public information with that available in specialized media.

References

Arief, Budi, Mohd Azeem Bin Adzmi, and Thomas Gross. 2015. "Understanding Cybercrime from Its Stakeholders' Perspectives: Part 1--Attackers." *IEEE Security & Privacy* 13 (1): 71–76. https://doi.org/10.1109/MSP.2015.19.

Calderon, Thomas G., and Lei Gao. 2022. "Comparing the Cybersecurity Risk Disclosures of U.S. and Foreign Firms." *Journal of Emerging Technologies in Accounting* 19 (2): 61–79. https://doi.org/10.2308/JETA-2020-008.

Cazier, Richard A., Jeff L. McMullin, and John S. Treu. 2021. "Are Lengthy and Boilerplate Risk Factor Disclosures Inadequate? An Examination of Judicial and Regulatory Assessments of Risk Factor Language." *The Accounting Review* 96 (4): 131–55. https://doi.org/10.2308/TAR-2018-0657.

Gao, Lei, Thomas G. Calderon, and Fengchun Tang. 2020. "Public Companies' Cybersecurity Risk Disclosures." *International Journal of Accounting Information Systems* 38 (September): 100468. https://doi.org/10.1016/j.accinf.2020.100468.

Gomes Filho, Núbio, Nazaré Rego, and João Claro. 2022. "A Cybersecurity Incident Classification Integrating the Perspectives of Perpetrators and Target Companies." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4101510.

Hovav, Anat, JinYoung Han, and Joonghyuk Kim. 2017. "Market Reaction to Security Breach Announcements." *ACM SIGMIS Database: The DATABASE for Advances in Information Systems* 48 (1): 11–52. https://doi.org/10.1145/3051473.3051476.

Mosterd, Lars, Vladimir C.M. Sobota, Geerten van de Kaa, Aaron Yi Ding, and Mark de Reuver. 2021. "Context Dependent Trade-Offs around Platform-to-Platform Openness: The Case of the Internet of Things." *Technovation* 108 (December): 102331. https://doi.org/10.1016/j.technovation.2021.102331.

Securities and Exchange Commission. 2011. "Topic 2: Cybersecurity." United States: CF Disclosure Guidance. https://www.sec.gov/divisions/corpfin/guidance/cfguidance-topic2.htm.

———. 2018. "Commission Statement and Guidance on Public Company Cybersecurity Disclosures." *Release Nos. 33-11038; 34-94382; IC-34529*. United States: Release Nos. 33-11038; 34-94382; IC-34529. https://www.sec.gov/rules/interp/2018/33-10459.pdf.

———. 2022. "Cybersecurity Risk Management, Strategy, Governance, and Incident Disclosure." *Release Nos. 33-11038; 34-94382; IC-34529;* . United States: Securities and Exchange Commission. https://www.sec.gov/rules/proposed/2022/33-11038.pdf.

Sheehan, Barry, Finbarr Murphy, Arash N. Kia, and Ronan Kiely. 2021. "A Quantitative Bow-Tie Cyber Risk Classification and Assessment Framework." *Journal of Risk Research* 0 (0): 1–20. https://doi.org/10.1080/13669877.2021.1900337.

Strupczewski, Grzegorz. 2021. "Defining Cyber Risk." *Safety Science* 135 (December 2020): 105143. https://doi.org/10.1016/j.ssci.2020.105143.

Walton, Stephanie, Patrick R. Wheeler, Yiyang (Ian) Zhang, and Xinlei (Ray) Zhao. 2021. "An Integrative Review and Analysis of Cybersecurity Research: Current State and Future Directions." *Journal of Information Systems* 35 (1): 155–86. https://doi.org/10.2308/ISYS-19-033.

Wang, Tawei, Karthik N. Kannan, and Jackie Rees Ulmer. 2013. "The Association between the Disclosure and the Realization of Information Security Risk Factors." *Information Systems Research* 24 (2): 201–18. https://doi.org/10.1287/isre.1120.0437.

Wang, Tawei, Ju Chun Yen, and Kyunghee Yoon. 2022. "Responses to SEC Comment Letters on Cybersecurity Disclosures: An Exploratory Study." *International Journal of Accounting Information Systems*. Elsevier Inc. https://doi.org/10.1016/j.accinf.2022.100567.

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Analyzing the EU forestry context using Minimum Spanning Tree based cluster analysis

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Abstract
New forestry machines have been considered as one of the solutions to address significant challenges, such as economic viability and address labor shortage in the forestry industry. However, in the EU, the momentum driving the demand for innovative solutions is varied and mostly depends on the specific forestry context that each country is facing. This is because each country has different conditions such as geographic characteristics, economic capabilities and policy direction. Especially, to seek and exploit new market opportunities that can influence the potential demand, the differences among the countries should be considered when analyzing the EU market. Cluster analysis can be a useful tool to analyze the global market environment in an integrated and comprehensive manner while considering the specific situation of each country using a large amount of data. The EU countries were grouped using Minimum Spanning Tree based cluster analysis and the outcome of the analysis resulted in six clusters, where countries exhibit clear similarities. Through cluster analysis, it was possible to understand the forestry market, detect new market opportunities and identify the group of countries with similar business potential. This information will be useful for developing new business strategies considering the complex issues for each country related to its forestry context.

Author Keywords. Cluster analysis, Forestry context, forestry market opportunities; EU forest strategy

Type: Oral communication

1. Introduction

The forestry industry faces significant challenges, such as economic viability, safety, labor shortages, and environmental performance. As one of the solutions to overcome some of these challenges and achieve more sustainable forest management, new forestry machines are being developed to automate plantation, fertilization, and vegetation control functions. However, the commercial success of these machines depends on the appropriate and robust business model. Recent studies show that business models heavily influence the development and diffusion of new products and services (Chesbrough and Rosenbloom 2002; Chesbrough 2010). To enter the global market, it is also important to design and develop business strategies considering the variability of each country's market. An extensive review of external environment is crucial to building a solid business strategy and for its successful implementation (Teece 2010; Trkman 2010). This will help draw implications in various scenarios, including potential market opportunities, and design the most appropriate business model for each country or set of countries. Since the main elements of the forestry context affecting the demand are complex, deeper analysis using other analytical tools could be required. Moreover, each country has different conditions such as geographic characteristics, economic capabilities, and policy direction related to the forestry industry.

Cluster analysis can be a useful tool to analyze these factors reflecting the complex market environment in an integrated and comprehensive manner considering the specific situation of each country. Clustering is a process of finding certain similarities in a large amount of complex data so they can be grouped (Gore Jr 2000; Arabie, Hubert, and De Soete 1996). In other words, clustering can find patterns in a given data that people may not readily recognize. In addition, clustering can lead to a far more accurate segmentation because it considers multiple concepts and similarities at the same time.

The main objective of this study was to analyze and evaluate the regional differences in the EU for the forestry sector to understand the wide range of variability of economic, social, and environmental factors using a cluster analysis approach. This information will help seek global market opportunities for developing new business models for developing new forestry machines. Moreover, the identification of clusters can serve as a valuable tool for understanding the specific situation at the national level.

2. Materials and Methods

To conduct cluster analysis, public data from major international organizations namely FAO (FAO 2022), EUROSTAT (EUROSTAT 2022), UNECE (UNECE 2022), and WTO Stats (WTO 2023), were selected. Previous studies have also used the socio-economic or environmental indicators to gauge sustainable impact of the bioeconomy or forest management (Miteva, Loucks, and Pattanayak 2015; Karvonen et al. 2017; D'Adamo, Falcone, and Morone 2020). For this study, thirty-four indicators were initially selected to analyze the forestry market environment of the twenty-seven EU countries. The selected indicators had to respect the following criteria: (i) be fact-based, and (ii) be based on the available data for the twenty-seven EU countries. Some indicators were recalculated to relative values in order to avoid multicollinearity and ease cross-country comparison (e.g., gross value added in GDP, CO2 emissions (tonne) per forest land (ha)).

Among the different algorithms considered for cluster analysis, Minimum Spanning Tree (MST) based clustering algorithm, which is an unsupervised learning branch from artificial intelligence, was used. The MST-based cluster analysis is known to be capable of detecting clusters with irregular boundaries. The partitioning methods of existing clustering algorithms, such as hierarchical cluster analysis, can easily identify clusters with spherical shapes. However, they are still unable to find clusters of irregular shapes and tend to split an elongated cluster into different groups (Pei and Zaiane 2006). To solve the problem, the clustering algorithm using MST has recently attracted a lot of attention (Grygorash, Zhou, and Jorgensen 2006; Tewarie et al. 2015; Wu et al. 2013). For this study, Prim's algorithm (Prim 1957) was applied to shape a complete graph into MST.

3. Results and discussion

The EU countries were grouped into six clusters as shown in Table 1. Cluster I had abundant forest areas and predominant private forestry. Also, Cluster I contributed more to the national economy than other countries with similar employment in forestry and logging. Cluster II was that it mainly comprised countries with balanced public and private ownership. In addition, Cluster II emit more greenhouse gas compared to other countries with similar CO2 storage capacity. Cluster III mainly includes countries with predominant public forestry. Cluster III contribution to employment was over twice the mean of the EU countries. Cluster IV was relatively low resources in forestry and had low-capacity carbon capture for greenhouse gas emissions. Cluster V was predominant public forestry and certificated forests. Cluster VI was predominantly private forests and larger agricultural areas.

Table 1. Cluster analysis results with different indicators

Cluster	EU countries	Main features
I	Austria, Finland, Slovenia, Sweden	Abundant forest and predominant private forests
II	Belgium, Germany, Ireland, Luxembourg, Netherlands	Balanced public and private ownership
III	Bulgaria, Croatia, Estonia, Hungary, Latvia, Lithuania, Romania	Predominant public forests and high contribution to employment
IV	Cyprus, Greece, Italy, Malta	Poor forest resources and economic contributions
V	Czechia, Poland, Slovakia	Predominant public forests and certificated forests
VI	Denmark, France, Portugal, Spain	Predominant private forests and low certificated forests

It appeared that each cluster was grouped around geographically adjacent countries. For example, "Austria-Slovenia," "Belgium-Netherlands-Germany-Luxembourg," "Czechia-Poland-Slovakia," "Estonia-Latvia-Lithuania," "Bulgaria-Romania-Hungary-Croatia," "Finland-Sweden," and "France-Spain-Portugal" belonged to the same. Grouping of adjacent countries could represent that neighboring countries are more likely to have similar forests due to the sharing of environmental factors such as climates, soil types, and amounts of carbon dioxide in the air. On the other hand, other factors, such as historical land use, forest management, and energy mix, could affect forest composition and structure. For example, forest conservation activities in a country could lead to similar changes in forests of non-contiguous countries. Countries grouped in a specific cluster will share several characteristics but are very dissimilar to countries not belonging to that cluster (Khan and Niazi 2017). Based on the results of grouped clusters, an in-depth analysis was conducted to obtain information necessary for new business strategies development. To analyze the features of the grouped countries in each cluster, they were plotted using the domains that more accurately characterize the countries' forestry context: forest areas and landowner type, economic contributions of forestry, labor productivity in forestry, and environmental conditions. Each cluster was analyzed based on the main indicators that affect forest policies to obtain strategy implications.

Although, it is not clear to identify the cluster or set of clusters with the higher business potential to develop a new market focused on the commercialization of machines for the forestry sector, the clusters have clearly different characteristics that make them unique and require specific business strategies and business models. Some clusters require strategies focused on the promotion of machines with multi-purpose functions (Cluster II and IV), others require strategies focused on promoting reduced costs and increase in productivity (Clusters III and V), and others require strategies that mix both the promotion of multi-purpose functions and of reduced costs and increase in productivity (Clusters VI) More specifically, Cluster I require strategies that can promote energy-efficient function of the machines, combined with customized strategies to meet the diverse needs of private owners. For Cluster II, promoting energy-efficient and functions for farming to respond to the existing specific circumstances of the countries will be important. Cluster III requires strategies to secure price competitiveness considering the labor cost or productivity. The proposed strategy of Cluster IV would be to promote multi-purpose functions and technical advances that allow machines to operate on higher slopes, still guaranteeing cost-effectiveness and high productivity. Cluster V should focus on promoting low price that is capable of stimulating new demand, while Cluster VI needs low-cost strategies, highlighting the increase in productivity in various working environments.

4. Conclusions

This study clustered twenty-seven EU countries considering a range of factors that affect the forestry market opportunities using MST-based clustering. Through cluster analysis, it was possible to analyze multi-dimensional indicators (thirty-two factors) in a more integrative and comprehensive way. To the best of authors' knowledge, this is the first attempt to utilize this method to analyze the EU countries in their forestry context. This information will be useful for developing new business strategies tailored to each cluster.

Appendix 1. List of variables used for cluster analysis. The original source codes of the indicators from the databases have been included (EC: element code, DC: data code, IC: item code).

Domain	Indicators	Unit	Source
Landowner type	Proportion of public ownership, % of forest area*	% as a decimal	UNECE
	Proportion of private ownership, % of forest area*	% as a decimal	UNECE
	Proportion of other ownership, % of forest area*	% as a decimal	UNECE
Forest condition	Proportion of forest area (EC: 5510, IC: 6646) in land area (EC: 5510, IC: 6601)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of planted forest (EC: 5510, IC: 6716) in forest area (EC: 5510, IC: 6646)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of primary forest (EC: 5510, IC: 6714) in forest area (EC: 5510, IC: 6646)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of naturally regenerating forest (EC: 5510, IC: 6717) in forest area (EC: 5510, IC: 6646)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of agricultural land (EC: 5510, IC: 6610) in land area (EC: 5510, IC: 6601)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of crop land (EC: 5510, IC: 6620) in agricultural area (EC: 5510, IC: 6610)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of land under meadows and pastures (EC: 5510, IC: 6655) in agricultural area (EC: 5510, IC: 6610)	% as a decimal (1000 ha / 1000 ha)	FAO

	Proportion of other land (EC: 5510, IC: 6670) in land area (EC: 5510, IC: 6601)	% as a decimal (1000 ha / 1000 ha)	FAO
Log removal (or production)	Proportion of pulpwood, round and split, coniferous (EC: 5516, IC: 1602), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of pulpwood, round and split, non-coniferous (EC: 5516, IC: 1603), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of sawlogs and veneer logs, coniferous (EC: 5516, IC: 1601), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of sawlogs and veneer logs, non-coniferous (EC: 5516, IC: 1604), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of other industrial roundwood, coniferous (EC: 5516, IC: 1623), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of other industrial roundwood, non-coniferous (EC: 5516, IC: 1626), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of wood fuel, coniferous (EC: 5516, IC: 1627), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
	Proportion of wood fuel, non-coniferous (EC: 5516, IC: 1628), in total roundwood production (EC: 5516, IC: 1861)	% as a decimal (m^3 / m^3)	FAO
Economic contribution	Proportion of gross value added of forestry (DC: for_eco_cp, IC: B1G) in GDP (DC: nama_10_gdp)	% as a decimal (million ¤ / million ¤)	EUROSTAT
	Proportion of compensation of employees of forestry (DC: for_eco_cp, IC: D1) in total compensation of employees (DC: nama_10_gdp, IC: D1)	% as a decimal (million ¤ / million ¤)	EUROSTAT
	Proportion of forest product exports (EC: 5922, IC: 1877) in total merchandise exports (DC: SI3_AGG - TO)	% as a decimal (1000 US$ / 1000 US$)	FAO, WTO
	Proportion of forestry and logging (DC: for_emp_lfs, IC: A02) in total employment (DC: nama_10_a10_e, IC: EMP_DC)	% as a decimal (1000 persons / 1000 persons)	EUROSTAT
Productivity	Gross value added (DC: for_eco_cp, IC: B1G) per annual roundwood production (total log removal)	¤ per m^3	FAO
	Gross value added (DC: for_eco_cp, IC: B1G) per employee (DC: for_emp_lfs, IC: A02)	1000¤ per person	FAO
	Annual roundwood production (total log removal) per employee (DC: for_emp_lfs, IC: A02)	m^3 per person	FAO
Forest management	Proportion of forest area under an independently verified forest management certification scheme (EC:6176, IC: 24038), in forest area (EC: 5510, IC: 6646)	% as a decimal (1000 ha / 1000 ha)	FAO
	Proportion of forest area within legally established protected areas (EC: 6121, IC: 24040)	% as a decimal	FAO
	Forest area annual net change rate (EC: 6121, IC: 24037)	%	FAO
New forest functions	Above-ground biomass stock in forest (EC:6177, IC: 24036)	Tonnes per hectare	FAO
	Emissions (CO_2) (EC: 7273, IC: 6751) by forest land (EC: 5510, IC: 6646)	Tonnes per hectare (kilotonnes / 1000 ha)	FAO

Final energy consumption per capita (DC: sdg_07_11)	Tonnes of oil equivalent (TOE) per capita	EUROSTAT
Annual greenhouse gas emissions per capita (DC: sdg_13_10, IC: TOTXMEMONIA)	Tonnes per capita	EUROSTAT
Proportion of renewable energy in gross final energy consumption by sector (DC: sdg7_40, IC: REN)	% as a decimal	EUROSTAT

*** There were no data codes for the indicators.**

References

Arabie, Phips, Larry Hubert, and Geert De Soete. 1996. *Clustering and classification.* World Scientific.

Chesbrough, Henry. 2010. "Business Model Innovation: Opportunities and Barriers." *Long Range Planning* 43 (2-3): 354-363. https://doi.org/10.1016/j.lrp.2009.07.010.

Chesbrough, Henry, and Richard S. Rosenbloom. 2002. "The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies." *Industrial and Corporate Change* 11 (3): 529-555. https://doi.org/10.1093/icc/11.3.529.

D'Adamo, Idiano, Pasquale Marcello Falcone, and Piergiuseppe Morone. 2020. "A New Socio-economic Indicator to Measure the Performance of Bioeconomy Sectors in Europe." *Ecological Economics* 176: 106724. https://doi.org/https://doi.org/10.1016/j.ecolecon.2020.106724. https://www.sciencedirect.com/science/article/pii/S0921800919312273.

EUROSTAT. 2022. Online statisical database - European Commission.

FAO. 2022. Online statisical database - Food and Agriculture Organization of the United Nations.

Gore Jr, Paul A. 2000. "Cluster analysis." In *Handbook of applied multivariate statistics and mathematical modeling.*, 297-321. San Diego, CA, US: Academic Press.

Grygorash, Oleksandr, Yan Zhou, and Zach Jorgensen. 2006. "Minimum Spanning Tree Based Clustering Algorithms." *2006 18th IEEE International Conference on Tools with Artificial Intelligence (ICTAI'06)*: 73-81. https://doi.org/10.1109/ictai.2006.83.

Karvonen, Jaakko, Pradipta Halder, Jyrki Kangas, and Pekka Leskinen. 2017. "Indicators and tools for assessing sustainability impacts of the forest bioeconomy." *Forest Ecosystems* 4 (1): 2. https://doi.org/10.1186/s40663-017-0089-8. https://doi.org/10.1186/s40663-017-0089-8.

Khan, Bisma S., and Muaz A. Niazi. 2017. "Network Community Detection: A Review and Visual Survey." *arXiv*.

Miteva, Daniela A., Colby J. Loucks, and Subhrendu K. Pattanayak. 2015. "Social and Environmental Impacts of Forest Management Certification in Indonesia." *PLOS ONE* 10 (7): e0129675. https://doi.org/10.1371/journal.pone.0129675. https://doi.org/10.1371/journal.pone.0129675.

Pei, Yaling, and Osmar R Zaiane. 2006. "A Synthetic Data Generator for Clustering and Outlier Analysis."

Prim, R. C. 1957. "Shortest connection networks and some generalizations." *The Bell System Technical Journal* 36 (6): 1389-1401. https://doi.org/10.1002/j.1538-7305.1957.tb01515.x.

Teece, David J. 2010. "Business Models, Business Strategy and Innovation." *Long Range Planning* 43 (2): 172-194. https://doi.org/https://doi.org/10.1016/j.lrp.2009.07.003. https://www.sciencedirect.com/science/article/pii/S002463010900051X.

Tewarie, P., E. van Dellen, A. Hillebrand, and C. J. Stam. 2015. "The minimum spanning tree: An unbiased method for brain network analysis." *NeuroImage* 104: 177-188. https://doi.org/10.1016/j.neuroimage.2014.10.015 PMID - 25451472.

Trkman, Peter. 2010. "The critical success factors of business process management." *International Journal of Information Management* 30 (2): 125-134. https://doi.org/10.1016/j.ijinfomgt.2009.07.003.

UNECE. 2022. Statistical Database - United Nations Economic Commission for Europe.

WTO. 2023. World Trade Organization stats portal.

Wu, Jianshe, Xiaoxiao Li, Licheng Jiao, Xiaohua Wang, and Bo Sun. 2013. "Minimum spanning trees for community detection." *Physica A: Statistical Mechanics and its Applications* 392 (9): 2265-2277. https://doi.org/10.1016/j.physa.2013.01.015.

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Diversification and its Impacts on Research & Development and Innovation Performance

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Abstract

This research aims to improve our understanding of how diversification influences the execution of Research & Development and Innovation (RDI) projects and its distinctive contributions to organization's performance. We use an embedded case design of collaborative innovation projects in a related-diversified company and a survey to complement data collection. We selected nine ongoing innovation projects for the embedded case study, and interviews are being conducted to identify specificities of collaboration, benefits, and challenges in these cross-unit RDI projects. The survey collected the perceptions of a sample of 527 professionals to understand better the company's innovation culture. After completing data collection, our analysis will focus on identifying specific mechanisms for explaining how RDI paths unfold in related-diversified environments and identifying different patterns for those RDI paths.

Author Keywords. Diversification, Research & Development and Innovation, collaboration.

Type: Oral Communication

1. Introduction

According to Ahuja & Novelli (2017), and Zhou (2011), a company with multiple business units (BUs) has an excellent opportunity to generate new ideas and innovate by exploring cross-unit synergy benefits, sharing resources, and managing projects and processes collaboratively. This kind of structure is known as diversification, where resources and knowledge sharing could increase a company's market power and provide business leverage by using cross-unit communication to identify new opportunities for innovation, maximize benefits, and mitigate risks (St. John & Harrison, 1999).

Diversification can be related or unrelated and alone does not positively impact RDI processes or company performance; more significant efforts are required to create an organizational structure and incentives to promote collaboration between existing BUs.

The focus here is related to diversification when a company consists of several operational units with given characteristics related to each other (Ahuja & Novelli, 2017; Bettis & Hall, 1982). Firms that adopt related diversification may have a high performance simply due to purposely or accidentally selecting related high-profit sectors or acquiring other high-profit firms in specifically related sectors to diversify.

Our goal with this research is to understand how the specificities of related diversification can shape the path of collaborative work during the RDI process. More specifically, this research seeks to answer the question: How does related diversification shape the cross-unit collaborative resource recombination path through which the RDI process unfolds?

2. Materials and Methods

This study consists of embedded case research designed with collaborative RDI projects as its focus. The research setting for the study is a large Portuguese company with eight BUs, distinctive cultures, including innovation, and different practices in each BU.

We have adopted an embedded case design for our research to explore mechanisms and develop a theory on the relationship between related diversification, collaboration, and RDI development.

An embedded design allows us to examine the similarities and differences among collaborative RDI projects and between collaborative and non-collaborative projects, to understand better their effects on the RDI activities and outputs of companies with more than one BU. Also, the chosen design can provide additional information, variation, and relevant differentiation to investigate cross-unit collaborative RDI projects compared to single-unit projects. It can create more robust empirical evidence and analytical arguments for this category of settings. An embedded case study in a context like ours is appropriate because it combines multiple data sources to capture the interplay of activities and their logic in their organisational context.

As part of the embedded case study design, we have adopted the typical ways of gathering data, i.e., observation, surveys, documental analysis, and individual interviews. Participant observation has been conducted in the field throughout the research project. Furthermore, a survey has already been completed with a sample of 527 professionals from the company to understand the organisational culture concerning innovation.

At the core of our research, we are running an in-depth study of a subset of the company's RDI projects. Semi-structured interviews are being conducted to collect additional data based on the experience of professionals who work with collaborative projects inside the company, to understand the relationship between related diversification, collaboration, and RDI development, mainly how the context can affect the process and outcomes of RDI projects. The context and project data will be analysed using statistical and content analysis to achieve our research goals and address our research questions.

3. Discussion

According to Tsai (2000) and Villasalero (2017), forming cross-unit linkages driven by social capital and strategic relationships can significantly impact innovation within a related-diversified company. When BUs are connected by stronger linkages, communication, and collaboration are facilitated, allowing ideas and information to be shared more easily. This type of bond can lead to greater capacity for innovation through combining knowledge, skills, and resources from different parts of the company. In addition, social capital can provide employees with access to information and resources outside the firm, including business partners, customers, and suppliers. These can be valuable sources of ideas and knowledge, further enhancing the firm's innovation ability. Therefore, investing in social capital and strategic relationships can be an effective strategy to drive innovation within a firm, allowing business units to work together and access valuable external resources to develop new ideas and products.

This mechanism was validated and often mentioned in the interviews already conducted. Most employees who work on collaborative projects stated that the main benefit of a related-diversified company is the relationship with other specialists in complementary areas who share the same challenges besides operational differences. They can combine their knowledge and competencies to provide more robust solutions to the market, not just product or service modules, but combinations with higher value to the customer. Besides that, complementarity and knowledge sharing can also help the BUs solve daily problems or work together on RDI projects.

On the other hand, the autonomy of the BUs may lead to specific friction patterns in coordinating tasks and deadlines, which the survey results confirmed. Although the survey results show that the innovation culture has differences among the BUs, there are complementary in many ways.

4. Conclusions

The following steps in our work will involve completing the semi-structured interviews and developing the analysis of the embedded case studies. This study of collaborative projects in a company with eight business units holds great promise to identify patterns and improve our understanding of how related diversification shapes the path of cross-unit collaborative resource recombination through which the RDI process unfolds in such settings.

This study is of potential significance to research and practice. For researchers, it may extend and further open empirical investigation on innovation in related-diversified environments and on “bounded” collaborations in innovation, which assume an intermediate position between more extreme entirely in-house or open modes. For practitioners, it may contribute to better informing the management of innovation processes in related-diversified contexts to achieve more positive outcomes.

References

Ahuja, Gautam, and Elena Novelli. 2017. ‘Redirecting Research Efforts on the Diversification–Performance Linkage: The Search for Synergy’. *Academy of Management Annals* 11 (1): 342–90. https://doi.org/10.5465/annals.2014.0079.

Ahuja, G., & Novelli, E. (2017). Redirecting Research Efforts on The Diversification–Performance Linkage: The Search For Synergy. *Academy of Management Annals*, 11(1), 342-390.

Bettis, R. A., & Hall, W. K. (1982). Diversification Strategy, Accounting Determined Risk, and Accounting Determined Return. *Academy of Management journal*, 25(2), 254-264.

St. John, C. H., & Harrison, J. S. (1999). Manufacturing-Based Relatedness, Synergy, and Coordination. *Strategic Management Journal*, 20(2), 129-145.

Tsai, W. (2000). Social capital, strategic relatedness and the formation of intraorganizational linkages. *Strategic Management Journal*, 21(9), 925-939.

Villasalero, M. (2017). A resource-based analysis of realized knowledge relatedness in diversified firms. *Journal of Business Research*, 71, 114-124.

Zhou, Y. M. (2011). Synergy, Coordination Costs, and Diversification Choices. *Strategic Management Journal*, 32(6), 624-639.

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Multi-level Sustainability Transition and RDI – Navigating systemic pathways from individual and organisational capabilities to macro challenges

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Abstract

A transformation toward sustainability has increasingly been argued for as a vision of the future for society. Different Research, Development, and Innovation (RDI) strategies, skills, and capabilities, rethinking how science and society relate to each other, and how Sustainability Transition (ST) knowledge is produced and applied, are essential to achieve that vision. We propose a multi-level framework of ST in RDI, refining a socio-technical change lens with portfolios of individual skills and organisational capabilities for sustainability-oriented organisational change. This systemic and multi-level framework aims at enabling the analysis of how various institutional and individual learning mechanisms enable and accelerate communication and mediation across boundaries on different levels. It also offers insight into how specific dimensions present at micro and meso levels in RDI systems may accelerate transitions and generate more sustainable paths at the macro level. Additionally, this systemic and multidimensional framing lens supports exploring and anticipating how capabilities, skills, visions, and leadership may shape socio-technical path generation for sustainability.

Author Keywords. Sustainability transitions (ST), research, development, and innovation (RDI), socio-technical change, multi-level, levers, systems thinking, individual and organisational change capabilities.

Type: Oral Communication

1. Introduction

A transformation toward sustainability has increasingly been argued for as a vision of the future for society. The United Nations Agenda for Sustainable Development has had a significant role in prioritising Research, Development, and Innovation (RDI) that contributes actively to Sustainability Transitions (ST). This momentum invites researchers and innovators to better understand human-nature interactions, exploring human, environmental, social, and economic pillars of sustainability, and transforming that knowledge into more sustainable development paths (Kates *et al.,* 2001).
Different RDI strategies and capabilities, reframing how science and society relate to each other and how ST knowledge is produced and applied, are essential in this process (Baker-Shelley *et al.*, 2017). A different paradigm implies modifications in current RDI systems, where actors must adopt attitudes and act in ways that transform interests and behaviours to bring sustainability systemically to their core (Schot, J., & Steinmueller, 2018). This framing of RDI as contributing to moving socio-technical systems to more sustainable development paths opens multiple critical discussions, among which we focus on the role of organisational capabilities and individual skills in better aligning environmental, social, and economic sustainability challenges with RDI.

2. Materials and Methods

This work focuses on advancing our understanding of the critical levers that emerge in RDI to enable its contribution to multi-level ST. We address the following Research Question (RQ): What levers emerge, and how do they interact, to enable progress in transitions towards sustainability in RDI organisations? As an initial step, we discuss here the findings of an analytical literature review and propose a preliminary framework for the multi-level connection between individual actors and the capabilities of their organisations in the RDI system, in the scope of socio-technical change and ST. This framework was developed by bringing together the most prominent frames and levers identified in the recent ST literature concerned with individual and organisational dimensions. These different components were articulated within a multi-level perspective (MLP) (Geels & Schot, 2007) to address our RQ. MLP is a prominent transition framework which posits that transitions happen through interaction processes within three analytical levels – 'niche', 'regime' and 'landscape'. Transitions researchers have developed MLP as an analytical frame for the empirical study of transitions. This framework highlights three levels with increasing coordination and structuration of activities, going from individual technologies and grassroots movements to larger-scale social configurations and institutions (Nykvist & Whitmarsh, 2008; El Bilali, 2019). The interactions across these levels can be observed in the analytical model presented in Figure 1.

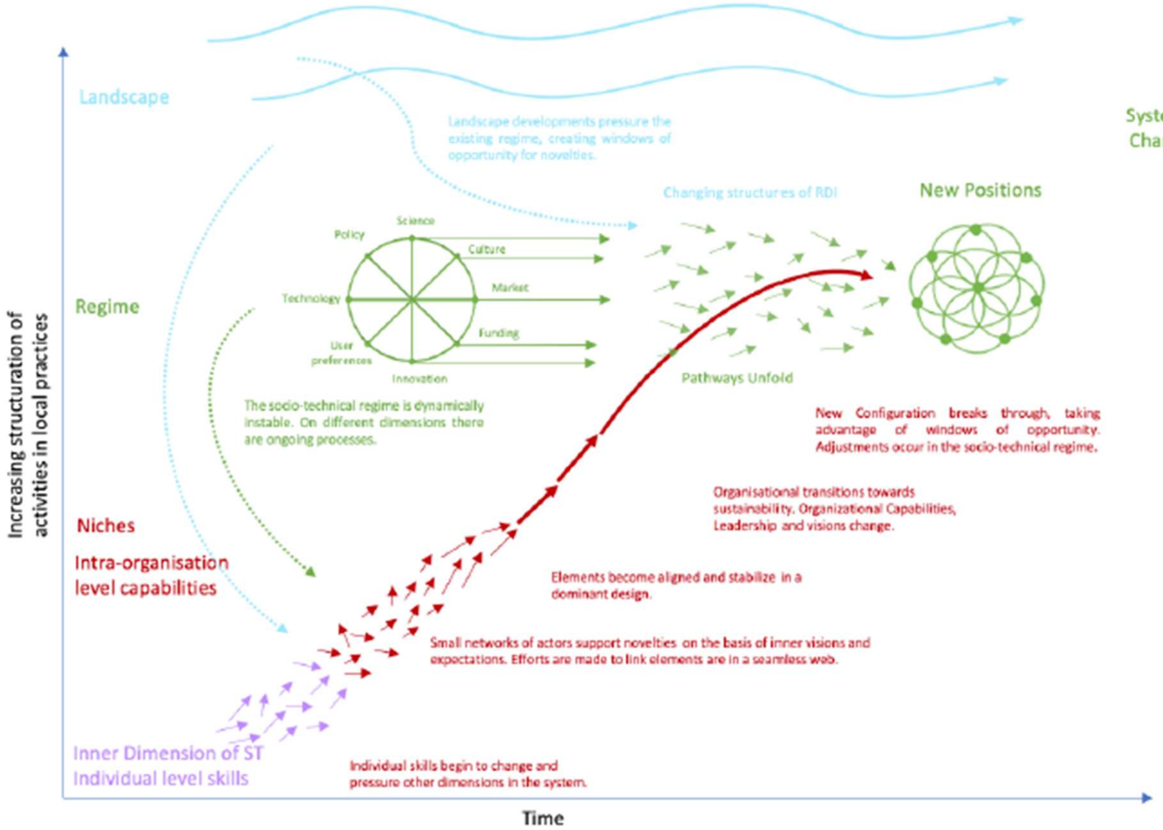

Figure 1. Elaboration of a multi-level perspective on transitions, considering individual and organisational levels, and illustrating the nonlinearity of transitions and different types of pathways. Adapted by the authors from the model of Geels & Schot (2007).

In our multi-level framework (Figure 2), we consider three levels. The macro level consists of the landscape of great societal challenges and includes the interaction of the RDI system with the 'outside-world' at local, regional, and global scales. Organisational capabilities (e.g., sensing, seizing, acting, leadership and relating for transforming RDI) are positioned at the meso level. Individual skills at the micro level (e.g., self-awareness, systems thinking, agency, visioning) are also identified as potential levers for the unfolding of ST at organisational and macro levels. This systematised and structured framework focuses on understanding individual transformation and organisational change, including deep and influential leverage elements for RDI. Since we are adopting MLP, it is vital that we develop an awareness of the distinct levels. Understanding the external landscape, the organisational structure, and the individual dimension is the first step to exploring how they influence each other in a socio-technical transition context.

3. Discussion

The identification of the perspectives and the levers that contribute to ST enhances our understanding of the abovementioned different frame that is required for RDI. In particular, these advances are part of a theoretical discussion about socio-technical change processes for sustainability and the potential of RDI-led path generation (Geels & Schot, 2007). Examining in detail the potential levers that were preliminarily identified – at the individual level, self-awareness, systems thinking, agency, relating and visioning; and at the organisation level, sensing, seizing, visioning, leadership, and agency for transforming RDI – we develop a systemic conceptual framework that comprises three entangled levels in a multi-layered view of transition for sustainability. Considering the view that has been emerging in the literature (Geels & Schot, 2007; Baker-Shelley *et al.*, 2017), we characterise and discuss a set of distinct theoretical perspectives that jointly establish a fuller picture of what transformation towards sustainability entails for RDI organisations at these multiple levels, as summarised in Figure 2.

This work has the potential to contribute to ST research by enhancing our understanding of the nexus between individual and organisational transformation, socio-technical change, and sustainability, outlining tangible and concrete elements of that nexus concerning leverage points, and casting real contexts in a framework that illustrates how to work with these levers to enact ST at individual and organisational levels in RDI systems.

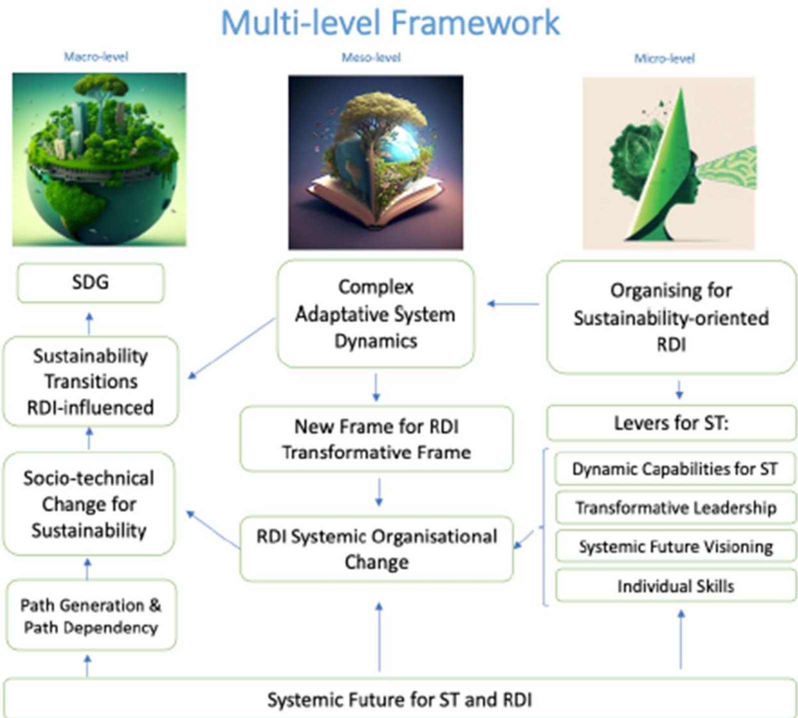

Figure 2. Multi-level conceptual framework on Sustainability Transitions and RDI. Elaborated by the authors. Images created with Midjourney Artificial Intelligence.

The multiple intertwined concepts in the framework (Figure 2) establish a fuller picture of our object of analysis – a Systemic Future for ST and RDI. At the macro level, the ultimate goal is to contribute to the UN's SDGs (Sustainable Development Goals), with one possible path being expanding RDI that influences and accelerates ST. The associated change in RDI can be regarded as a Socio-technical Change Process for Sustainability, i.e., a change process that involves technological, social, institutional, and economic transformations (Geels & Schot, 2007; Patterson *et al.*, 2017). Under this socio-technical lens, RDI has the potential to create new paths (Path Generation), a view that emphasises the role of strategic change and deliberate action for the development of new

technologies (Garud & Karnøe, 2001), complementarily with the Path Dependency view, which regards technological development as a historically embedded, emergent process.
The meso-level concepts bridge the transformations in the RDI community and the transition paths at a macro scale. The dynamics of this transition process suggest the usefulness of a Complex Adaptative System (CAS) perspective to understand and integrate the complexities in establishing a New Frame for RDI leading to the Systemic Organisational Change underlying these paths.
Within the micro-level context of Organisational Change towards this transformative frame in RDI (Baker-Shelley *et al.*, 2017), we highlight the main potential levers emerging in recent ST literature. The framework focuses on the organisational and individual changes associated with this new frame connected to a Sustainability-oriented RDI. As a complex and dynamic process, we acknowledge that these dimensions are interconnected in multiple ways and may present several feedback loops. Multiple aspects are present, with a significant role, at the intersection of ST and RDI, such as values, behaviours, structures, intermediaries, or spatial dynamics, among others. In our work, we start by highlighting the most cited gaps and levers associated with our phenomenon of interest. The literature on ST has considerably explored the external interconnections of these different levels to better understand and enable change at the macro level. Nevertheless, the literature presents significant gaps related to capabilities, leadership, vision, and individual skills that emerge at micro and meso levels and are linked with the generation of new paths for ST.

4. Conclusions

The proposed framework bridges the individual dimension of actors in RDI systems, organisational change mechanisms, and ST paths. Relevant future work may include empirical studies of unfolding ST paths in RDI, using the framework to improve our understanding of the role and impact of the multiple levers at the different levels.
An improved understanding of levers that contribute to accelerate transitions and generate paths towards sustainability goals in specific dimensions of RDI systems has potential policy implications. More specifically, exploring organisational levers such as leadership, dynamic and transforming capabilities, and individual levers such as self-awareness, visioning, agency and relating, contributes to a better understanding of how RDI is mobilised at the boundaries of knowledge, skills and action in ways that simultaneously enhance the credibility and legitimacy of the knowledge produced. More broadly, better knowledge of how institutional mechanisms and individual learning facilitate translation, communication, and mediation across boundaries on multiple levels, can bring new useful perspectives and approaches to help to move society and RDI toward sustainability.

References

Baker-Shelley, A., van Zeijl-Rozema, A., & Martens, P. (2017). A conceptual synthesis of organisational transformation: How to diagnose, and navigate, pathways for Sustainability at universities? *Journal of Cleaner Production*, 145, 262–276. Retrieved March 15, 2023, from https://doi.org/10.1016/j.jclepro.2017.01.026

Geels, F., & Schot, J. (2007). Typology of socio-technical transition pathways. *Research Policy*, 36, 399–417.

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., McCarthy, J. J., Schellnhuber, H. J., Bolin, B., Dickson, N. M., Faucheux, S., Gallopin, G. C., Grubler, A., Huntley, B., Jager, J., Jodha, N. S., Kasperson, R. E., Mabogunje, A., Matson, P., Mooney, H., Moore III, B., O'Riordan, T., Svedin, U. (2001). Sustainability Science. *Science,* 292, 641–642.

Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, 47(9), 1554–1567. https://doi.org/10.1016/j.respol.2018.08.011

Nykvist, B., & Whitmarsh, L. (2008). A multi-level analysis of sustainable mobility transitions: niche development in the UK and Sweden. *Technological Forecasting and Social Change*, 75, 1373–1387.

El Bilali, H. (2019). The multi-level perspective in research on sustainability transitions in agriculture and food systems: A systematic review. *Agriculture* (Switzerland), 9(4). https://doi.org/10.3390/agriculture9040074

Patterson, J., Schulz, K., Vervoort, J., Van Der Hel, S., Widerberg, O., Adler, C., *et al.* (2017). Exploring the governance and politics of transformations towards Sustainability. *Environmental Innovation and Societal Transitions*, 24, 1–16.

Garud, R., & Karnøe, P. (2003). Bricolage versus breakthrough: Distributed and embedded agency in technology entrepreneurship. *Research Policy*, 32, 277–300.

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The Implementation of Sandbox Videogames in Education -the case of Minecraft in Portuguese compulsory education

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Abstract
Education is fundamental to the development and growth of any country and the resources are frequently limited. The main focus of this work will be on the adaptations the videogame Minecraft and classrooms may go through in order to align both sides. Additionally, it will be studied how the implementation in a school (or system of schools) of videogames as a teaching tool may influence the cycles of adaptation and the convergence on following implementation processes. To achieve this goal, 6 case studies will be performed in six schools that are part of patrimonial education project. These studies will be mostly supported in semi-structured interviews and complementary data (such as newspapers articles, reports, opinion articles, among others), but also by information collected in focus groups.

Author Keywords: Implementation; Videogames, Education, Minecraft

Type: Oral communication
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1. Introduction

Education is fundamental to the development and growth of any country and resources are frequently limited.

Since the end of 2019 and beginning of 2020 that the world has been watchful due to the COVID-19 pandemic. This world-shattering event has had broad consequences all over the world, in a countless number of fields. The long periods of lockdown led to the decrease of freedom and mental and physical health, as well as to the adaptation of working and studying conditions, in order to allow working and studying from home, increasing largely the use of Information and Communication Technologies (ICTs). This study becomes relevant because, after the experience with the pandemic, the awareness of the possibility of being prepared for an historical event like this emerged.

According to Bento and Lencastre (2021), approximately 31% of Portuguese teachers claim they do not use new technology in classrooms because it does not work, and they perceive it more of a barrier than a benefit; 15% claim not to use technology as it is too hard or unnecessary; and 86% believe that they did not receive enough training to implement new technologies. Finally, 12% consider they lack the competence to use new technology in their classes.

Despite evidence suggesting videogames may be useful as a teaching or learning tool, its implementation in Portugal is limited, and very few cases of use can be found (MI.MOMO.Faro 2021; Campos 2016). Moreover, due to the difficulties Portuguese teachers face with current technologies (Bento and Lencastre 2021), the implementation of videogames in classrooms may present barriers.

Implementation can be defined as a process that begins when a technology is adopted and ends when it is routinized or abandoned (Greenhalgh and Abimbola 2019). To obtain all the advantages the technology can offer, this process must succeed (Greenhalgh and Abimbola 2019; Choi and Moon 2013; Leonard-Barton 1988; Simas and Rodrigues 2017).

The success of the implementation is also a requirement for generalization, since both processes are intrinsically connected. Generalization may be defined as the scaling use of a technology and involves alternative paths and dynamics for the different users (Schot and Steinmueller 2018; Sengers, Turnheim, and Berkhout 2021).

This work will focus on the implementation of videogames of the sandbox type in Portuguese classrooms from compulsory education, specifically the videogame Minecraf in schools enrolled in the MI.MOMO.Faro project.

2. Materials and Methods

The process of implementation of the videogame Minecraft in an educational context will be studied for this work. Minecraft is a sandbox type of videogame, where players may explore a blocky, procedurally generated 3D world with infinite terrain, extract materials, craft tools and items, build structures or earthworks (Minecraft 2021a).

The objective will be to learn about the process of implementation according to the TPACK (Technology, Pedagogy and Content Knowledge) framework, a framework that considers how existing technology, pedagogy and content knowledge and their different combinations TPACK is a development of the Pedagogical Content Knowledge framework (PCK, also better explained bellow) from Lee Shulman published in 1986 (Shulman 1986), in which the intersection of Content Knowledge and Pedagogical Knowledge was considered by the author "teaching at its best". (Koehler and Mishra 2006)added to Shulman's framework Technological Knowledge (TK), the knowledge about the tools (both digital and analog, as well as new and old) used for teaching.

Furthermore, it is expected that the whole context surrounding the implementation may influence the implementation process in each school and how the first implementations influenced the following ones. This phenomenon will also be studied, in order to understand how multiple implementation processes (consecutive or simultaneous) may lead to the routinization of Minecraft as a teaching tool in different schools, as well as how alternative paths and dynamics from different schools may influence the scaling of the same videogame.

Several contacts to perform case studies are currently being developed. These studies will be mostly supported in semi-structured interviews and complementary data (such as newspapers articles, reports, opinion articles, among others), but also by information collected in focus groups. For each case a Case Study protocol will be developed according to its characteristics, as well as an interview guide. Efforts will be made to guarantee that the interviews are performed in short and simultaneous periods of time.

In total, 6 case studies are expected to be performed, each one of them consisting in one of the 6 schools that are enrolled in MI.MO.FARO, a project of patrimonial education that aims the reproduction of emblematic buildings of Modern Architecture from Faro by students of the third cycle of studies (7th, 8th and 9th grades) in the platform Minecraft Education (MI.MOMO.Faro 2021; Minecraft 2021b). In this project are included 6 schools, more than 80 students and 24 teachers. Furthermore, Microsoft, Europeana Education, Regional

Administration of Culture from Algarve, and the Training Center from Ria Formosa are also partners of this project, and parts of the system to study.

3. Discussion

The goal of this project is to understand the implementation process and challenges of using videogames as a teaching tool in the mandatory school years. Contributions for literature and recommendation of better practices for the implementation of videogames in classrooms of compulsory education are the aim of this project. Education is fundamental to development and growth and resources are frequently limited. Implementation failure means that the technology is not being used to its full potential, and the risk of abandonment and waste of resources can be too high. A well-designed implementation process of technology, such as videogames, that contributes to the better development of learning is expected to bring benefits to society. Additionally, it will be studied how the implementation in a school (or system of schools) of videogames as a teaching tool may influence the cycles of adaptation and the convergence on following implementation processes and how external shocks (as it was, for example, the sudden emergence of a pandemic like COVID-19 was) may pressure to different degrees of adaptation on each side, and lead to cycles of adaptation different of those that would be normally expected.

Education is a particularly interesting field to study, since it is a system with several actors, the school board and policy makers (responsible for adoption and financial decisions), the parents (legally responsible for the students), and two different types of users (teachers and students). This is mainly interesting due to the presence of a wide range of people with impact in the decision of adoption, implementation and use. Furthermore, with the specifications of videogames, the study of the diffusion of this technology in Portuguese schools and the impact that each implementation has in the following ones, is still unexplored.

4. Conclusions

This work will focus on the adoption, implementation, and diffusion of videogames in Portuguese compulsory education classrooms. The implementation process has two main agents: users (teachers and students) and technology (videogames) that interact in a predetermined environment (classroom).

The focus of this wok will be on:

-finding the drivers and barriers for the adoption of videogames by schools as a teaching tool;

-understanding the implementation process: a) how teachers adapt the classroom and themselves to using videogames as a teaching tool; b) which misalignments may occur when introducing videogames in the classroom; c) which adaptations are needed regarding the user environment or/and the technology; d) the magnitude of those cycles of adaptation, and e) whether there is a situation of mutual adaption with tendency towards learning or instead reinvention ;

-understanding how multiple implementation processes (consecutive or simultaneous) may lead to the routinization of videogames as a teaching tool in different schools, as well as how alternative paths and dynamics from different schools may influence the scaling of the use of videogames.

References

Bento, Marco, and José Alberto Lencastre. 2021. "Estado Da Tecnologia Na Educação 2020/2021." *Promethean.*

Campos, Teresa. 2016. "Minecraft Na Sala de Aula. Vamos Jogar?" Visão. 2016. https://visao.sapo.pt/atualidade/sociedade/2016-01-29-minecraft-na-sala-de-aula-vamos-jogar/.

Choi, Jin Nam, and William J. Moon. 2013. "Multiple Forms of Innovation Implementation. The Role of Innovation, Individuals, and the Implementation Context." *Organizational Dynamics* 42 (4): 290–97. https://doi.org/10.1016/j.orgdyn.2013.07.007.

Greenhalgh, Trisha, and Seye Abimbola. 2019. "The NASSS Framework A Synthesis of Multiple Theories of Technology Implementation." *Studies in Health Technology and Informatics* 263: 193–204. https://doi.org/10.3233/SHTI190123.

Koehler, M.J., and P. Mishra. 2006. "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge." *Teachers College Record* 108 (6): 1017–54. http://one2oneheights.pbworks.com/f/MISHRA_PUNYA.pdf.

Leonard-Barton, D. 1988. "Implementation Characteristics of Organizational Innovations - Limits and Opportunities for Management Strategies." *Communication Research.* 15 (5): 603–31.

MI.MOMO.Faro. 2021. "MI.MOMO.Faro." 2021. https://www.faro2027.eu/mimomofaro.html.

Minecraft. 2021a. "Minecraft." Minecraft. 2021. https://www.minecraft.net/.

Minecraft. 2021b. "Minecraft Education Edition." Minecraft. 2021. https://education.minecraft.net/pt-pt/homepage.

Schot, Johan, and W. Edward Steinmueller. 2018. "Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change." *Research Policy* 47 (9): 1554–67. https://doi.org/10.1016/j.respol.2018.08.011.

Sengers, Frans, Bruno Turnheim, and Frans Berkhout. 2021. "Beyond Experiments: Embedding Outcomes in Climate Governance." *Environment and Planning C: Politics and Space* 39 (6): 1148–71. https://doi.org/10.1177/2399654420953861.

Shulman, Lee S. 1986. "Those Who Understand Knowledge." *Educational Researcher* 15 (2): 4–14.

Simas, OFJ, and JPC Rodrigues. 2017. "The Implementation of Videogames in Healthcare: The Case of Nintendo Wii® in Rehabilitation." In *2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC).* Madeira Island: IEEE. https://doi.org/10.1109/ICE.2017.8279908.

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