UNIVERSIDADE DE SÃO PAULO

ESCOLA POLITÉCNICA

DEPARTAMENTO DE ENGENHARIA DE PRODUÇÃO

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Assessing the Importance and Level of Adoption of Green Ergonomics Practices in Brazilian Organizations

São Paulo

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Versão Original

Trabalho de Formatura apresentado à Escola Politécnica da Universidade de São Paulo para obtenção do Diploma de Engenharia de Produção.

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São Paulo

2025

Catalogação na publicação

Biblioteca

Escola Politécnica

Santos, Isabella Ide de Carvalho
Assessing the Importance and Level of Adoption of Green Ergonomics Practices in Brazilian Organizations / I. I. C. Santos -- São Paulo, 2025.
64 p.

Trabalho de Formatura - Escola Politécnica da Universidade de São Paulo. Departamento de Engenharia de Produção.

1.Ergonomia 2.Sustentabilidade 3.Ergonomia verde I.Universidade de São Paulo. Escola Politécnica. Departamento de Engenharia de Produção II.t.

SANTOS, Isabella Ide de Carvalho. **Assessing the Importance and Level of Adoption of Green Ergonomics Practices in Brazilian Organizations.** Trabalho de Formatura (Engenharia de Produção) – Escola Politécnica, Universidade de São Paulo, São Paulo, 2025.

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AGRADECIMENTOS

Ao meu orientador, Professor Doutor Tiago Fonseca Albuquerque Cavalcanti Sigahi, pela orientação atenta, paciência e confiança depositadas ao longo de todo o desenvolvimento deste trabalho. Sua contribuição foi essencial para que esta pesquisa se concretizasse.

À minha família, que sempre esteve ao meu lado, especialmente à minha mãe, Telma Yochico Ide Covre, por todo o amor e suporte necessários para que eu pudesse conquistar meus sonhos.

Aos professores do Departamento de Engenharia de Produção da Escola Politécnica da Universidade de São Paulo, por todo o conhecimento, orientação e desenvolvimento proporcionados ao longo dos últimos cinco anos.

RESUMO

O presente trabalho investiga a integração entre ergonomia e sustentabilidade por meio da análise das práticas de ergonomia verde (*green ergonomics*) em organizações brasileiras. Com base no reconhecimento de que o bem-estar humano e a preservação ambiental são dimensões interdependentes do desenvolvimento sustentável, o estudo teve como objetivo avaliar a importância percebida e o nível de adoção de quinze práticas de ergonomia verde, distribuídas entre cinco dimensões conceituais: *Green Work Design, Environmental Education, Occupational Health and Safety, Green Organizational Design* e *Green Workplace and Equipment.*

A pesquisa adotou uma abordagem quantitativa multicritério, utilizando o método *Fuzzy TOPSIS* para lidar com a incerteza e a imprecisão inerentes aos julgamentos humanos. Foram coletadas respostas de 41 especialistas — entre profissionais e acadêmicos das áreas de ergonomia, engenharia de produção e sustentabilidade — que avaliaram cada prática quanto à sua relevância e grau de implementação. Três cenários analíticos foram desenvolvidos: (i) Cenário 0, com ponderação dos respondentes conforme seu nível de expertise; (ii) Cenário 1, com pesos iguais para todos os participantes; e (iii) Cenário 2, segmentado em subamostras acadêmica e profissional-mista.

Os resultados indicam que as práticas mais valorizadas concentram-se nas dimensões de *Occupational Health and Safety (OHS)* e *Green Work Design*, especialmente aquelas voltadas ao desgin ergonômico de estações de trabalho e à eficiência no uso de recursos. Em contraste, práticas ligadas a *Green Organizational Design* e *Green Environmental Education* apresentaram menor priorização e menor nível de adoção, revelando um distanciamento entre o discurso estratégico e a aplicação efetiva da sustentabilidade no contexto organizacional. A comparação entre importância e adoção evidenciou um *gap* significativo: as organizações tendem a implementar ações operacionais e de curto prazo, enquanto práticas educacionais e de transformação cultural permanecem menos desenvolvidas.

Conclui-se que a ergonomia verde, embora em expansão, ainda se encontra em uma fase predominantemente técnico-operacional, na qual a sustentabilidade é buscada por meio de melhorias incrementais de eficiência e segurança. O avanço para um paradigma verdadeiramente sustentável requer maior integração entre os aspectos humanos, organizacionais e ambientais, consolidando a ergonomia como um instrumento de transição rumo a sistemas de trabalho mais resilientes e regenerativos.

Palavras-chave: Ergonomia; Sustentabilidade; Ergonomia verde; *Fuzzy TOPSIS*; Práticas Organizacionais; Sistemas de Trabalho Sustentáveis.

ABSTRACT

This study investigates the integration of ergonomics and sustainability through the evaluation of green ergonomics practices in Brazilian organizations. Grounded in the understanding that human well-being and environmental preservation are interdependent pillars of sustainable development, the research aimed to assess both the perceived importance and the level of adoption of fifteen green ergonomics practices, organized into five conceptual dimensions: Green Work Design, Green Environmental Education, Occupational Health and Safety, Green Organizational Design, and Green Workplace and Equipment.

A quantitative multicriteria approach was employed using the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), which enables the treatment of qualitative judgments expressed through linguistic scales under conditions of human uncertainty. Data were collected from 41 experts — including academics and professionals in ergonomics, production engineering, and sustainability — who evaluated each practice in terms of perceived relevance and degree of implementation. Three analytical scenarios were developed: (i) Scenario 0, incorporating expertise-based weights for each respondent; (ii) Scenario 1, assigning equal weights to all participants; and (iii) Scenario 2, which analysed separately the academic subgroup and the professional/mixed subgroup.

The results indicate that the most highly valued practices belong primarily to the Occupational Health and Safety (OHS) and Green Work Design dimensions, particularly those related to ergonomic workstation design and resource-efficient processes. In contrast, practices associated with Green Organizational Design and Green Environmental Education exhibited lower prioritization and lower levels of adoption, revealing a clear gap between strategic importance and practical implementation, which reflects organizations are prioritizing operational and short-term sustainability actions over practices that require cultural change, long-term investment, or organizational restructuring.

The findings suggest that green ergonomics, while gaining relevance, remains situated predominantly within a technical-operational paradigm, where environmental responsibility emerges through incremental improvements rather than systemic transformation. Advancing toward a more mature model of sustainable work systems will require greater integration of organizational, educational, and cultural dimensions, ensuring that ergonomics becomes a driver not only of human well-being but also of environmental regeneration.

Keywords: Green Ergonomics; Sustainability; Green Ergonomics; Fuzzy TOPSIS; Organizational Practices; Sustainable Work Systems.

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LISTA DE ABREVIATURAS E SIGLAS

ABERGO – Associação Brasileira de Ergonomia

CSR – Corporate Social Responsibility (Responsabilidade Social Corporativa)

OHS – Occupational Health and Safety (Saúde e Segurança Ocupacional)

FPIS – Fuzzy Positive Ideal Solution (Solução Ideal Positiva Fuzzy)

FNIS – Fuzzy Negative Ideal Solution (Solução Ideal Negativa Fuzzy)

HFE – Human Factors and Ergonomics (Fatores Humanos e Ergonomia)

HCI – Human–Computer Interaction (Interação Humano-Computador)

IEA – International Ergonomics Association (Associação Internacional de Ergonomia)

MCDM – Multi-Criteria Decision Making (Tomada de Decisão Multicritério)

P1–P15 – Green Ergonomics Practices (Práticas de Ergonomia Verde)

D1–D5 – Green Ergonomics Dimensions (Dimensões de Ergonomia Verde)

SDGs – Sustainable Development Goals (Objetivos de Desenvolvimento Sustentável)

TBL – Triple Bottom Line (Tripé da Sustentabilidade)

TOPSIS – Technique for Order Preference by Similarity to Ideal Solution (Técnica para Ordenação por Similaridade à Solução Ideal)

UNCHE – United Nations Conference on the Human Environment (Conferência das Nações Unidas sobre o Meio Ambiente Humano)

WCED – World Commission on Environment and Development (Comissão Mundial sobre Meio Ambiente e Desenvolvimento)

SUMÁRIO

1. INTRODUCTION

1.1. THE LINK BETWEEN SUSTAINABLE DEVELOPMENT AND ERGONOMICS

1.1.1. The origins and evolution of sustainable development research and agenda

The modern understanding of sustainable development emerged gradually during the second half of the twentieth century, when the accelerating industrial growth of the post-war period revealed the ecological limits of the planet. The first major milestone in this discussion was the United Nations Conference on the Human Environment (UNCHE), held in Stockholm in 1972, which marked the first global recognition that economic progress could no longer be pursued independently of environmental preservation (UNCHE, 1972). The conference, often considered the birth of international environmental policy, drew attention to the deteriorating quality of air, water, and natural resources as a direct result of unchecked industrialization and population growth. Its final declaration emphasized that environmental protection was not an obstacle to development, but rather a prerequisite for the survival and well-being of humanity. This event initiated a global political awareness that human activity and environmental systems were deeply intertwined, laying the foundation for the modern sustainability agenda.

Throughout the 1970s and early 1980s, discussions on environmental management evolved from localized pollution control toward broader systemic concerns regarding the depletion of finite resources and the inequitable distribution of environmental impacts. Influential reports such as *The Limits to Growth* (Meadows et al., 1972) and subsequent United Nations initiatives argued that economic expansion, if maintained in its conventional form, would inevitably lead to social and ecological crises. The idea of balancing development with ecological capacity began to take root, but the lack of a clear conceptual framework made it difficult to operationalize sustainability in policy and organizational contexts.

A decisive conceptual turning point came with the publication of the Brundtland Report, officially titled *Our Common Future*, in 1987. Chaired by Gro Harlem Brundtland, then Prime Minister of Norway, and produced by the World Commission on Environment and Development (WCED), the report introduced the most enduring definition of sustainable development: *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987, p. 43). This formulation was revolutionary because it unified environmental, economic, and social objectives under a single paradigm, reframing sustainability not merely as an ecological issue but as a multidimensional challenge of justice, equity, and intergenerational responsibility. The Brundtland Report also underscored the necessity of multilateral cooperation and systemic thinking, recognizing that environmental issues transcended national borders and required coordinated global governance.

The report conceptualized sustainable development through what later became known as the triple bottom line (TBL) approach, built on three interconnected pillars: economic, social, and environmental capital. This triad proposed that development must occur within the planet’s ecological boundaries while fostering equitable social conditions and viable economic growth. Economic sustainability, in this sense, involves innovation, efficient use of resources, and technological progress aligned with environmental stewardship. Social sustainability demands fairness in access to basic needs such as education, health, and decent living conditions, promoting inclusivity and social cohesion. Environmental sustainability focuses on preserving the integrity of natural ecosystems to ensure the continuity of the life-support systems upon which all human activities depend (WCED, 1987).

From a systemic perspective, this tri-pillar framework can be interpreted as an attempt to manage the interrelations among the human, social, economic, and ecological capitals that sustain global viability (Fischer & Zink, 2012). As Fischer and Zink (2012) argue, sustainability is fundamentally a property of open systems that depend on continuous exchanges of matter, energy, and information with their environment. This systems-oriented interpretation provides a conceptual bridge between global sustainability and organizational or work-system sustainability — the same level at which ergonomics operates. Therefore, the principles established by the Brundtland Report and the systems theory perspective underpinning it have direct implications for understanding sustainable work systems, where human well-being, social equity, and ecological preservation must coexist as interdependent goals.

In subsequent decades, the sustainable development concept evolved into a comprehensive global agenda. The United Nations Sustainable Development Goals (SDGs), established in 2015, operationalized the Brundtland vision into 17 measurable objectives encompassing poverty eradication, decent work, responsible production, and climate action. This modern framework reinforced sustainability as both a policy imperative and a design principle, influencing diverse fields from engineering and management to ergonomics and human factors. The evolution of sustainability, from Stockholm to the SDGs, thus reflects a paradigmatic shift: from a reactive concern with environmental degradation to a proactive approach seeking balance between human advancement and the planet's long-term viability.

1.1.2. The evolution of Ergonomics: From human–machine interaction to sustainability

The scientific study of ergonomics, also referred to as human factors, originated in the early twentieth century as societies transitioned toward industrial economies increasingly reliant on mechanization and mass production. Rooted in the interaction between humans and their working environments, the field emerged from the convergence of psychology, engineering, physiology, and design. Its primary aim was to understand human capabilities and limitations in order to optimize performance, efficiency, and safety within work systems (Helander, 2005). The historical trajectory of ergonomics closely mirrors broader technological and social transformations throughout the century, evolving from an applied science of physical labour to a comprehensive discipline addressing cognitive and organizational dimensions of human activity.

The earliest traces of ergonomics can be found in the 1920s, when industrial psychologists and engineers began studying worker fatigue, productivity, and the relationship between human physiology and machine design. These efforts were largely motivated by the need to enhance industrial efficiency and reduce accidents within factories, which had become increasingly complex environments as a result of mechanized production (Helander, 2005). The discipline gained significant prominence during the 1940s and 1950s, when the demands of World War II revealed the importance of optimizing human–machine interfaces in high-risk military systems such as aircraft, submarines, and radar technologies (Wiener & Nagel, 1988). During this period, ergonomics was consolidated as a distinct scientific field, characterized by systematic research on human error, task analysis, and system design, all aimed at improving performance reliability under conditions of technological complexity.

By the 1960s, the focus of ergonomics expanded beyond military contexts to encompass industrial production and manufacturing processes. The field increasingly sought to improve workplace design by adapting tools, machines, and workstations to human physical and cognitive characteristics. The introduction of ergonomics into industrial engineering helped to formalize its methods, integrating human considerations into system design, occupational health, and safety management (Chapanis, 1995). This period also witnessed the formation of professional associations and standard-setting bodies, such as the International Ergonomics Association (IEA), which helped to consolidate ergonomics as a global discipline. In parallel, researchers began emphasizing the role of ergonomics in reducing occupational injuries and illnesses, demonstrating that improved work design could contribute not only to worker well-being but also to organizational productivity and economic performance (Helander, 2005).

During the 1970s and 1980s, ergonomics continued to expand its scope in response to social and technological changes. The rise of consumer goods industries led to the emergence of product ergonomics, focusing on the usability, comfort, and safety of everyday objects (Braidwood, 1951). The growing influence of information technologies brought new challenges that demanded attention to human–computer interaction (HCI), software usability, and interface design (Christensen, 1962). These developments marked a fundamental shift from the study of physical performance to the study of cognitive and perceptual processes, giving rise to what would later be known as cognitive ergonomics. By the 1990s, the field had also embraced organizational ergonomics, which addressed the social and managerial dimensions of work systems, including communication, teamwork, and decision-making processes (Helander, 1997).

This historical evolution reveals a continuous broadening of ergonomics from the micro-level optimization of human–machine systems to a macro-level understanding of work as a socio-technical phenomenon. As global environmental concerns began to emerge in the late twentieth century, the scope of ergonomics extended once again. The discipline increasingly recognized that human work systems are embedded within broader ecological systems, and that designing for human well-being must also account for the environmental consequences of production, consumption, and technological development. This recognition marked the first conceptual intersection between ergonomics and sustainability, laying the groundwork for the subsequent emergence of approaches such as sustainable work systems (Fischer & Zink, 2012) and, later, green ergonomics (Thatcher, 2013). In this sense, the rise of ergonomics not only reflects the evolution of industrial society but also anticipates the contemporary need to integrate human performance, social responsibility, and ecological awareness within the same systemic framework.

1.1.3. The emergence of the concept of sustainable work systems

The concept of sustainable work emerged from the growing awareness that modern labour systems must not only ensure productivity and economic efficiency but also preserve the long-term well-being and adaptability of workers. In the latter half of the twentieth century, technological progress, automation, and globalization reshaped the nature of work, creating what many scholars describe as the post-industrial or knowledge-based economy. These developments transformed traditional notions of stability and employability, replacing repetitive and standardized work with more fluid, cognitively demanding, and interdependent tasks (Ashford et al., 2007; Heckscher & Appelgate, 1994). While these changes opened new opportunities for innovation and flexibility, they also produced heightened job insecurity, intensification of work, and new psychosocial pressures (Butts, 1997; Kira & Forslin, 2008). The resulting challenge was to design work systems that could sustain human functioning and development over time rather than deplete workers' physical and psychological resources.

Within this context, the notion of sustainable work was articulated by Kira, Van Eijnatten, and Balkin (2010), who defined it as the capacity of individuals to maintain and develop their work ability over the long term through the creation and renewal of personal resources. These resources—such as competence, self-efficacy, motivation, resilience, and social connectedness—are viewed as dynamic assets that enable employees to adapt to environmental changes, manage complexity, and continue contributing positively to their organizations and communities. Sustainable work therefore emphasizes a dual process: maintaining existing capabilities while fostering learning and personal growth that prepare individuals for future challenges. It reframes work not as a static set of tasks but as a developmental arena where employees and organizations co-evolve through interaction, reflection, and mutual adaptation (Kira et al., 2010).

A key mechanism for achieving sustainability in work design lies in the balance between the demands imposed by work and the resources available to meet those demands. Building on socio-technical systems theory, Fischer and Zink (2012) argued that sustainable work systems must integrate social, economic, and ecological considerations into their structures and processes. They propose that organizations operate as open systems that exchange energy, materials, and information with their environments, and that sustainability can only be achieved when these exchanges promote the regeneration of both human and natural capital. In this view, sustainable work depends not merely on minimizing harm to employees but on creating conditions that actively develop their competencies, health, and sense of meaning at work—conditions that, in turn, support organizational innovation and societal well-being.

The design of work plays a pivotal role in this process. Grant and Parker (2009) emphasized that contemporary work design must be seen as a participatory and adaptive activity that shapes the socio-technical environment in which people perform. Unlike traditional top-down job design, sustainable work design relies on collaborative work crafting—a process through which employees engage in modifying their own tasks, relationships, and perceptions to enhance both personal fulfilment and organizational outcomes (Wrzesniewski & Dutton, 2001; Kira et al., 2010). This participatory approach recognizes employees as active agents capable of aligning their work with their strengths and values, thus generating a virtuous cycle of engagement and development.

Sustainable work also carries broader implications for economic and societal sustainability. As Fischer and Zink (2012) highlight, organizations that fail to preserve the health and adaptability of their workforce risk undermining not only individual well-being but also long-term productivity and resilience. Consequently, sustainable work represents a bridge between the social dimension of sustainable development and the micro-level realities of human work systems. It encapsulates a shift from viewing employees as expendable inputs toward recognizing them as renewable and evolving resources within larger socio-ecological systems. This paradigm paves the way for the emergence of green ergonomics, where the focus expands from sustaining human work ability to sustaining the intertwined well-being of people and the planet.

1.1.4. The integration of Ergonomics and environmental sustainability

As the notion of sustainable work evolved and organizations began to recognize the interdependence between economic, social, and ecological systems, the boundaries of ergonomics also started to expand. The discipline, traditionally focused on optimizing human performance and well-being, increasingly faced the need to respond to the broader environmental implications of work. This transition marked a pivotal point in the development of the field, as ergonomists realized that human-centered design could no longer be separated from the sustainability of the natural systems that support it.

As sustainability discourse matured in the early twenty-first century, researchers and practitioners increasingly recognized that the human-centered focus of ergonomics could not be isolated from the ecological systems that sustain life and work. The same industrial and technological processes that shaped modern ergonomics also contributed to global environmental degradation, resource depletion, and climate change. Consequently, the field began to expand its scope beyond human performance and occupational well-being to consider the environmental consequences of work systems, products, and organizational processes. This conceptual shift culminated in the emergence of green ergonomics, a framework that integrates human factors principles with environmental sustainability goals (Thatcher, 2013).

The roots of this integration can be traced to the work of Steimle and Zink (2006), who proposed that the sustainability paradigm must explicitly encompass the human dimension within economic and social systems. They argued that sustainable work systems should respect the physical, physiological, and psychological limits of human functioning while also enabling opportunities for recovery and development. In their view, human capital—along with social and natural capital—forms one of the essential foundations of sustainable development. By emphasizing that people are both agents and beneficiaries of sustainability, their approach established the theoretical foundation for connecting ergonomics with ecological responsibility.

Building upon this premise, Thatcher (2013) defined green ergonomics as the study and design of work systems, products, and environments that optimize both human well-being and environmental performance. Rather than viewing these goals as competing, green ergonomics treats them as mutually reinforcing improving the fit between people and systems can lead to reduced material waste, energy consumption, and environmental impact. The field therefore extends traditional ergonomic principles—safety, efficiency, comfort, and usability—into a broader framework that also considers the ecological consequences of human activity. As Thatcher, Waterson, and Todd (2013) note, this integration reflects a shift from anthropocentric design, which focuses solely on human optimization, to eco-centric design, which situates humans as interdependent components of larger socio-ecological systems.

Hanson (2013) describes this transition as both a challenge and an opportunity for ergonomics. The challenge lies in rethinking established models of human–system interaction to include environmental flows of energy, materials, and waste; the opportunity lies in redefining ergonomics as a discipline capable of supporting sustainable innovation and responsible design. This approach demands that ergonomists collaborate with environmental scientists, industrial designers, and systems engineers to create interventions that balance operational performance with ecological integrity. The ultimate goal is not merely to make work less harmful to the environment, but to design work systems that actively contribute to ecological regeneration and long-term resilience.

Bolis, Morioka, and Sznelwar (2014) further expanded on this notion by examining the interrelationships between work and sustainability, arguing that both concepts share a concern for maintaining and renewing essential resources—whether human or environmental—over time. Their analysis situates work as a central element in achieving sustainable development, since it is through work that societies produce goods, services, and cultural value. In this sense, sustainable work and green ergonomics converge: both advocate for a systemic perspective in which human and natural systems are co-dependent and must evolve together.

The integration of ergonomics and environmental sustainability thus represents a natural progression in the historical evolution of the field. Early ergonomics sought to align tools and technologies with human capabilities; modern ergonomics seeks to align entire socio-technical systems with the ecological boundaries of the planet. This broader scope calls for new research and design paradigms that consider life-cycle impacts, circular economy principles, and sustainable production models. As organizations increasingly adopt environmental management systems and corporate sustainability strategies, ergonomists can play a pivotal role in linking worker well-being with ecological performance.

In summary, this convergence redefines the mission of ergonomics in the twenty-first century: to design systems that are not only safe, efficient, and comfortable for people, but also restorative and sustainable for the environment. By integrating human and ecological concerns, ergonomics moves beyond its traditional boundaries to contribute meaningfully to the global pursuit of sustainable development. This conceptual alignment sets the foundation for the empirical analysis presented in the following chapters, which explores how professionals and academics perceive and apply green ergonomics practices within organizational contexts.

1.2. CORPORATE SOCIAL RESPONSIBILITY AND ORGANIZATIONAL SUSTAINABILITY

1.2.1. From corporate philanthropy to organizational sustainability

The concept of Corporate Social Responsibility (CSR) has progressively evolved from a philanthropic notion to a strategic and systemic component of organizational management. Its origins can be traced to Howard Bowen's seminal work *Social Responsibilities of the Businessman* (1953), which introduced the idea that corporations bear obligations extending beyond profit maximization. Bowen (1953) argued that firms should consider the broader social consequences of their decisions, acknowledging that business operations inevitably affect communities, employees, and the environment. This perspective marked the beginning of an ethical dialogue that challenged the classical economic view of the firm as a purely self-interested entity and laid the foundation for integrating social concerns into business decision-making.

Throughout the 1960s and 1970s, CSR gained momentum as a response to growing societal awareness of inequality, consumer protection, and environmental degradation. The rise of social movements and environmental activism demanded greater corporate accountability, stimulating academic efforts to conceptualize CSR more systematically. Carroll (1979) formalized this discussion by identifying four dimensions of corporate responsibility—economic, legal, ethical, and philanthropic—that coexist and interact within a firm's activities. His model suggested that responsible companies must not only pursue profitability but also operate within the law, behave ethically, and contribute voluntarily to social welfare. During the 1980s and 1990s, this multidimensional understanding of CSR converged with strategic management theory. Scholars and practitioners began to recognize that responsible practices could enhance reputation, foster innovation, and reduce operational risk. Elkington (1997) later advanced the triple bottom line (TBL) approach, which reframed corporate success as a balance among economic prosperity, environmental stewardship, and social equity—an idea that strongly influenced modern sustainability discourse.

In the twenty-first century, CSR has become closely intertwined with the broader concept of organizational sustainability**,** which refers to a firm's capacity to generate long-term value by managing the interdependence of economic, social, and environmental dimensions. Rather than treating CSR as an external or voluntary activity, contemporary organizations embed sustainability into their strategic planning and governance structures (Morioka & de Carvalho, 2016). Organizational sustainability entails not only compliance and philanthropy but also the proactive alignment of business models with global sustainability goals. It emphasizes the creation of shared value for stakeholders and the continuous adaptation of processes to meet societal expectations and planetary boundaries (Porter & Kramer, 2011).

1.2.2. The intersection of CSR and Green Ergonomics

Recent studies highlight the transition from instrumental or symbolic CSR—focused primarily on image management—to more integrative frameworks that acknowledge the coexistence of economic and ethical tensions within sustainability strategies (Dzhengiz, 2022). In this view, organizations act as complex systems that must balance profitability with moral and ecological responsibilities. Effective CSR implementation therefore requires not only compliance mechanisms but also a cultural transformation that embeds sustainability principles into daily operations, employee engagement, and innovation processes (Silva et al., 2019). By incorporating sustainability indicators into performance evaluation and decision-making, organizations can move toward a more resilient and adaptive model capable of responding to global challenges such as climate change, resource scarcity, and social inequality.

The adoption of CSR as a pathway to organizational sustainability is further reinforced by the United Nations Sustainable Development Goals (SDGs)**,** established in 2015 as part of the 2030 Agenda for Sustainable Development (United Nations, 2015). The SDGs provide a comprehensive framework that encourages companies to align their strategies with universal objectives such as eradicating poverty, reducing inequality, promoting decent work, and mitigating climate change. SDG 8—Decent Work and Economic Growth—and SDG 12—Responsible Consumption and Production—call for sustainable work environments, efficient use of resources, and fair employment conditions. These goals directly intersect with the principles of green ergonomics, which emphasize designing work systems that are simultaneously human-centered and environmentally conscious (Sigahi et al., 2024). Integrating ergonomic principles into CSR and sustainability strategies allows organizations to enhance occupational health and safety while reducing their ecological footprint, creating workplaces that support both human and environmental well-being.

Empirical research demonstrates that firms adopting integrated sustainability management frameworks benefit from improved performance, stakeholder trust, and innovation capacity (Pranugrahaning et al., 2021). Such organizations treat CSR not merely as a reputational tool but as a structural driver of organizational learning and long-term competitiveness. In this context, the connection between CSR and ergonomics becomes particularly relevant: ergonomic interventions aimed at improving work design, employee well-being, and resource efficiency directly contribute to corporate sustainability objectives (Silva et al., 2019). By aligning ergonomic practices with CSR initiatives, companies can simultaneously advance social responsibility and operational excellence, bridging the gap between human-centered design and environmental management.

Despite these advances, the systematic application of green ergonomics within corporate sustainability frameworks remains limited. Many organizations have adopted CSR policies in principle but struggle to translate them into measurable practices that integrate environmental and human-factor considerations. There is therefore a pressing need for analytical approaches that can assess and prioritize green ergonomics practices based on their perceived importance and level of implementation. The present study responds to this need by employing a fuzzy multicriteria method to evaluate how professionals and academics perceive the importance and application of green ergonomics within organizations.

2. LIRERATURE REVIEW

2.1. THE EMERGENCE OF GREEN ERGONOMICS AS A RESEARCH FIELD

The emergence of green ergonomics represents a conceptual broadening of traditional ergonomics, driven by the growing need to integrate human-centered design with environmental sustainability. While ergonomics has historically focused on optimizing safety, health, and performance within work systems, scholars in the late twentieth century began emphasizing that these objectives must also consider the ecological systems that support human activity (Helander, 1997; Moray, 1995). This shift reflected an acknowledgment that the long-term well-being of workers and organizations depends on the preservation of natural resources and the mitigation of environmental impacts.

Building upon earlier notions of sustainable work systems (Steimle & Zink, 2006), researchers in the 2000s and 2010s began framing ergonomics as a discipline capable of contributing directly to sustainable development. The establishment of specialized committees and research groups, such as the International Ergonomics Association's Technical Committee on Human Factors and Sustainable Development, provided an institutional foundation for this integration. The formal definition of green ergonomics by Thatcher (2013) consolidated this movement, positioning it as an approach that seeks not only to enhance human well-being and system performance but also to preserve and restore environmental health.

Recent literature underscores that green ergonomics has matured into a critical interface between Human Factors and Ergonomics (HFE) and global sustainability agendas. It operationalizes sustainability principles – such as eco-efficiency, circular design, and regenerative thinking – within work and production systems (Bolis et al., 2023). Methodological developments, including fuzzy decision-making approaches for evaluating sustainable ergonomic design (Adem et al., 2022), illustrate how the field is moving beyond conceptual advocacy toward analytical application. Despite this progress, the systematic implementation of green ergonomics in organizations remains limited, and more empirical studies are needed to assess its adoption and impact on organizational sustainability (Rathore & Gupta, 2025).

In this sense, green ergonomics has evolved from an aspirational concept into a practical framework that links human well-being, organizational performance, and environmental stewardship—an evolution that provides the foundation for the subsequent analysis of its scope, dimensions, and applications.

2.2. THE SCOPE OF GREEN ERGONOMICS

Green ergonomics extends the traditional scope of ergonomics by explicitly integrating environmental sustainability into its central objectives. Whereas conventional ergonomics has primarily emphasized safety, usability, and performance within human–machine systems, green ergonomics recognizes that the design and operation of such systems also have environmental consequences. It thus aims not only to minimize harm but to actively contribute to the conservation, restoration, and regeneration of natural systems (Thatcher, 2013; Hanson, 2013). In this expanded scope, human and ecological well-being are viewed as interdependent, and effective design must simultaneously address both.

This approach builds upon the recognition that human systems and natural systems are coupled in complex ways. Industrial processes, product design, and work environments consume energy and materials, generate waste, and shape behavioural patterns that affect the planet's resilience. Green ergonomics therefore seeks to incorporate ecological principles—such as resource circularity, energy efficiency, and regenerative feedback—into the ergonomic design of workplaces, tools, and technologies (Bolis et al., 2023). Rather than treating environmental issues as external constraints, it positions them as integral design parameters within ergonomic evaluation and decision-making. This systemic perspective reframes human-centered design as an opportunity to achieve ecological responsibility through the optimization of work systems that are sustainable for both people and the environment.

Thatcher (2013) proposed three guiding principles that anchor the theoretical and practical reach of green ergonomics: eco-efficiency, eco-effectiveness, and eco-productivity. Eco-efficiency emphasizes achieving more with less—creating products and services that consume fewer resources and generate fewer emissions without compromising functionality or safety. For instance, ergonomic workspace redesigns that enhance natural lighting and ventilation can improve comfort and reduce energy consumption simultaneously. Eco-effectiveness extends this goal by ensuring that design interventions yield a net positive effect on ecological systems, supporting processes such as air purification, biodiversity, or energy regeneration. Examples include incorporating vegetation or green materials into workplace design, which can both improve indoor air quality and foster psychological well-being (Thatcher et al., 2013). Finally, eco-productivity evaluates whether systems can sustain equilibrium over time, maintaining production and performance levels within the regenerative capacity of the ecosystem. This concept aligns closely with circular economy principles, promoting material reuse and life-cycle design approaches that minimize waste and environmental degradation.

In practice, the scope of green ergonomics extends across diverse domains, including product design, organizational processes, infrastructure, and human behavior. It influences the creation of low-resource systems and products that minimize environmental impact throughout their life cycle; the development of green jobs and workplaces that ensure both occupational health and ecological efficiency; and the design of behavioural interfaces that encourage sustainable actions through feedback and information systems. By embedding ecological considerations into every stage of design and evaluation, green ergonomics transcends its traditional focus on human factors to become a discipline of systemic sustainability.

The practical relevance of green ergonomics emerges through its application across several key domains, as follows:

2.2.1. Design of low-resource systems and products

A central application of green ergonomics lies in the design of systems, products, and services that minimize environmental burdens throughout their life cycles. Ergonomic interventions in this area aim to integrate usability, safety, and environmental performance by prioritizing material circularity, energy efficiency, and waste prevention. Examples include substituting virgin materials with recycled or rapidly renewable inputs, reducing mass and part count through value engineering, and employing passive solutions—such as daylighting and natural ventilation—that lower operational load without compromising comfort (Thatcher, 2013; Adem et al., 2022). In practice, life cycle thinking aligns ergonomic parameters such as reach, force, posture, and cognitive demand with eco-design indicators including embodied energy, recyclability, and reparability. This synthesis operationalizes eco-efficiency, eco-effectiveness, and eco-productivity within product–service systems (Thatcher, 2013; Bolis et al., 2023).

2.2.2. Design of green jobs and workplaces

Green ergonomics also plays a crucial role in the transformation of work systems and environments within sustainability-driven industries such as renewable energy, circular manufacturing, recycling, and sustainable construction. As these sectors expand, they introduce new task demands and risk profiles—ranging from work at height in offshore wind farms to manual handling of reusable materials—that require ergonomically informed design of tools, workflows, and training (Hanson, 2013; Zink, 2013). Organizations that integrate participatory work design, exposure reduction at source, and spatial optimization to shorten material flow have demonstrated concurrent improvements in both safety and sustainability outcomes (Rathore & Gupta, 2025). Even in office or hybrid contexts, principles of green ergonomics apply with biophilic elements, acoustic and visual comfort strategies, and energy-aware space management, linking employee well-being to resource stewardship (Bolis et al., 2023).

2.2.3. Behavioral design for sustainability

Beyond physical and organizational design, green ergonomics contributes to shaping human behaviours toward sustainable action. Drawing on cognitive and organizational ergonomics, this domain explores how environmental information, feedback systems, and decision aids can support eco-conscious habits at work. Interfaces such as energy-use dashboards, eco-driving systems, and intelligent waste-sorting aids help reduce cognitive load and promote intuitive engagement with sustainability goals (Thatcher et al., 2013). Effective behavioural design relies on salience, timing, and feedback—communicating environmental consequences clearly and enabling workers to act accordingly. When coupled with supportive organizational culture, these tools reinforce sustainable decision-making and align everyday actions with key sustainability objectives, including SDGs 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), and 13 (Climate Action) (Bolis et al., 2023; Sigahi et al., 2024).

2.3. DIMENSIONS OF GREEN ERGONOMICS

Green ergonomics encompasses five interrelated dimensions (D) that connect human-centered design to environmental stewardship. These dimensions structure how sustainability principles are translated into workplace practices, shaping the design of tasks, organizations, and environments. Together, they form a systemic framework that embeds ecological awareness and social responsibility into ergonomic practice, ensuring that work systems enhance both human and planetary well-being (Rathore & Gupta, 2025; Bolis et al., 2023).

2.3.1. D1 – Green work design

Green work design integrates sustainability directly into the structure of work tasks, workflows, and physical or cognitive demands. The objective is to minimize resource depletion, energy consumption, and waste generation while maintaining efficiency and worker safety. In sectors such as renewable energy or sustainable construction, ergonomically optimized tools and lightweight materials reduce physical strain and enhance eco-efficiency simultaneously (Hanson, 2013; Rathore & Gupta, 2025). Similarly, in administrative or service-oriented contexts, workplace redesign that employs energy-efficient lighting, natural ventilation, or adaptive workstations contributes to both environmental conservation and worker comfort. By harmonizing ergonomic design with ecological performance, green work design establishes the foundation for sustainable productivity.

2.3.2. D2 –Green environmental education

Environmental education within organizations serves as the foundation for cultivating a culture of sustainability. Training and awareness programs equip employees with knowledge about environmental issues and empower them to contribute actively to eco-efficient practices. For example, companies may implement internal campaigns on waste reduction, energy conservation, or responsible material use, reinforcing environmental responsibility as part of daily work behaviour (Rathore & Gupta, 2025). This dimension also includes integrating sustainability principles into safety inductions, operational manuals, and leadership programs, ensuring that environmental awareness becomes embedded in organizational learning processes. When aligned with ergonomic principles, such education enhances workers' understanding of how their own tasks influence both occupational health and environmental outcomes (Sigahi et al., 2024).

2.3.3. D3 –Occupational Health and Safety (OHS)

The dimension of occupational health and safety remains central to ergonomics, but in green ergonomics it expands to include environmental health and systemic risk reduction. It focuses on designing work systems that protect workers from physical and psychological hazards while also minimizing environmental harm (Torres et al., 2009). For instance, in offshore wind energy or organic farming, ergonomic interventions such as task-specific protective equipment, redesigned tools, and improved task rotation can mitigate physical strain and exposure to environmental extremes. Environmentally responsible OHS practices also emphasize minimizing pollutants, reducing noise and chemical hazards, and adopting eco-friendly materials. In this way, green ergonomics aligns worker protection with ecological preservation, reinforcing the principle that a healthy environment is inseparable from a healthy workforce (Hanson, 2013).

2.3.4. D4 –Green organizational design

At the organizational level, green ergonomics promotes participatory and systemic approaches that integrate sustainability into management structures, decision-making, and performance evaluation. Green organizational design involves creating workflows, hierarchies, and incentive systems that prioritize resource efficiency and employee engagement in sustainability initiatives (Bolis et al., 2023; Rathore & Gupta, 2025). For instance, organizations can embed environmental criteria in performance appraisals, encourage collaborative problem-solving for reducing energy or material waste, and adopt transparent reporting mechanisms for sustainability goals. Participatory ergonomics—where employees co-create solutions for safer and more eco-efficient processes—illustrates this dimension in practice. Such integration ensures that sustainability becomes a shared responsibility across all levels of the organization, fostering alignment between business objectives, worker well-being, and environmental performance.

2.3.5. D5 –Green workplace and equipment

The final dimension concerns the physical and material components of the work environment. Green workplaces are designed to be both ergonomically sound and environmentally sustainable. This involves selecting equipment, furniture, and materials that reduce ecological impact while promoting comfort, safety, and productivity. Examples include using renewable materials such as bamboo or recycled composites in office furniture, implementing adjustable ergonomic workstations made from low-impact materials, and adopting smart technologies that regulate lighting and temperature based on occupancy (Sigahi et al., 2024). In construction or manufacturing settings, eco-friendly tools and energy-efficient equipment reduce waste and emissions while improving usability and reducing worker fatigue (Rathore & Gupta, 2025). The design of the physical workspace thus becomes an active contributor to organizational sustainability and employee well-being.

2.4. GREEN ERGONOMICS PRACTICES

Based on the five key dimensions previously discussed, a set of practices (P) was identified. Table 1 presents specific strategies for each dimension, offering organizations concrete pathways to implement green ergonomics within their operations.

Table 1 – Green ergonomics practices

Dimension	Practice	Reference
D1 – Green Work Design	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	(Thatcher, 2013; Adem et al., 2022).
	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	(Hanson, 2013; Bolis et al., 2023; Rathore & Gupta, 2025).
	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	(Thatcher, 2013; Rathore & Gupta, 2025).
D2 – Green Environmental Education	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	(Rathore & Gupta, 2025; Sigahi et al., 2023).
	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	(Sigahi et al., 2024; Bolis et al., 2023).
	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	(Sigahi et al., 2023; Rathore & Gupta, 2025).
D3 – Occupational Health and Safety (OHS)	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	(Torres et al., 2009; Rathore & Gupta, 2025).
	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	(Hanson, 2013; Sigahi et al., 2023; Thatcher, 2013).

Dimension	Practice	Reference
	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	(Sigahi et al., 2024; Rathore & Gupta, 2025).
D4 – Green Organizational Design	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	(Bolis et al., 2023; Sigahi et al., 2023).
	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	(Sigahi et al., 2024; Rathore & Gupta, 2025).
	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	(Sigahi et al., 2023; Sigahi et al., 2024; Bolis et al., 2023).
D6 – Green Workplace and Equipment	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	(Thatcher, 2013; Sigahi et al., 2024).
	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	(Sigahi et al., 2023; Rathore & Gupta, 2025).
	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	(Bolis et al., 2023; Sigahi et al., 2024).

Source: Author's own elaboration.

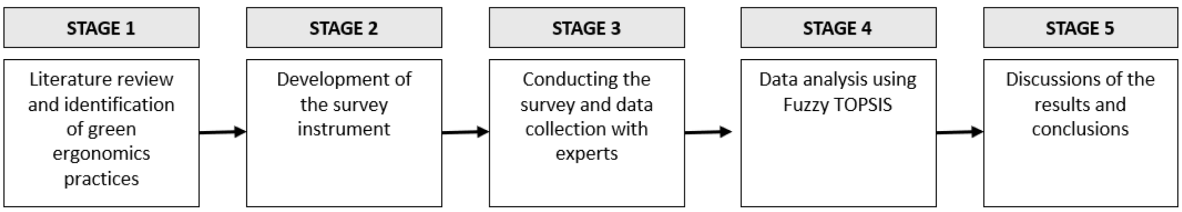
3. MATERIALS AND METHODS

3.1. RESEARCH DESIGN AND STEPS

This research adopted a quantitative multicriteria decision-making (MCDM) approach, aimed at evaluating the perceived importance and level of application of green ergonomics practices in contemporary organizations. The methodological framework was grounded in the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a well-established method that enables the systematic analysis of alternatives under conditions of uncertainty and vagueness inherent to human judgment (Hwang & Yoon, 1981; Chen, 2000). By combining the rigor of mathematical modelling with the flexibility of fuzzy set theory, this approach allows for a nuanced representation of expert opinions, which are often expressed linguistically rather than numerically.

The research process was divided into five main stages, which together ensured the theoretical coherence and analytical robustness of the study (Figure1).

Figure 1 – Research steps



Source: Author's own elaboration.

First, a comprehensive and structured literature review was conducted to map the theoretical foundations of green ergonomics and its intersection with sustainability and human factors research. This step involved analysing both classical and contemporary studies to identify the main conceptual dimensions of green ergonomics and their corresponding practical actions. From this synthesis, 15 representative practices were defined and organized into five key dimensions—Green Work Design, Environmental Education, Occupational Health and Safety, Green Organizational Design, and Green Workplace and Equipment—forming the analytical foundation of the study.

Based on the identified practices, a survey instrument was designed to collect expert assessments regarding both the importance and current level of adoption of each practice within organizational contexts. The questionnaire was structured around two evaluation criteria: (Q1) Importance, measuring the perceived relevance of each practice for advancing green ergonomics; and (Q2) Level of adoption, assessing the extent to which the practices are implemented in real-world settings. Both questions employed a five-point linguistic scale ranging from "very low" to "very high", subsequently converted into triangular fuzzy numbers for quantitative analysis.

The questionnaire was distributed to a panel of 41 respondents, encompassing experts from both academic and professional backgrounds related to ergonomics, production engineering, and sustainability. The selection process ensured diversity of experience and disciplinary representation, allowing the integration of theoretical insights and practical perspectives. The responses provided the empirical basis for the fuzzy decision matrix used in the subsequent analysis.

The collected responses were first transformed into fuzzy numbers following the linguistic scales established in the previous step. The Fuzzy TOPSIS method was then applied to evaluate and rank the 15 practices according to their proximity to the ideal solution. This procedure included the stages of fuzzification, normalization, weighting of respondents, determination of fuzzy ideal and anti-ideal solutions, and calculation of the squared Euclidean distances and closeness coefficients. The analysis was implemented in Microsoft Excel, following the computational structure proposed by Chen (2000) and later adapted in studies by Adem et al. (2022) and Rampasso et al. (2024).

The resulting rankings were analysed to determine the relative positioning of each practice in terms of perceived importance and level of adoption. This comparison made it possible to identify gaps between the practices considered essential and those that are effectively implemented in organizations. The insights obtained from this analysis contributed to the formulation of recommendations for improving the integration of sustainability principles into ergonomic design and organizational practices.

Overall, this methodological structure allowed for a rigorous, transparent, and replicable evaluation process, combining expert judgment with fuzzy multi-criteria modelling. The integration of literature-based practices, expert participation, and fuzzy logic ensured that both theoretical and practical dimensions of green ergonomics were captured in a balanced and systematic manner.

3.2. QUESTIONNAIRE DEVELOPMENT AND DATA COLLECTION

The questionnaire was designed around the 15 green ergonomics practices outlined in Table 1, which are distributed across five key dimensions: Green Work Design (D1), Environmental Education (D2), Occupational Health and Safety (D3), Green Organizational Design (D4), and Green Workplace and Equipment (D5). Participants were asked to assess each practice using two evaluation criteria: (Q1) Importance – the extent to which the practice is perceived as relevant to promoting green ergonomics within organizations; and (Q2) Level of adoption – the degree to which the practice is currently applied in organizational settings. Both questions employed a five-point linguistic scale, as presented in Table 2.

Table 2 - Linguistic scales used for the evaluation

Scale	Question 1 - Importance	Question 2 – Level of adoption
5	Very high importance	Adopted at an advanced level
4	High importance	Adopted consistently
3	Moderate importance	Adopted at a basic level
2	Low importance	Adopted partially
1	Very low importance	Not adopted

Source: Author's own elaboration

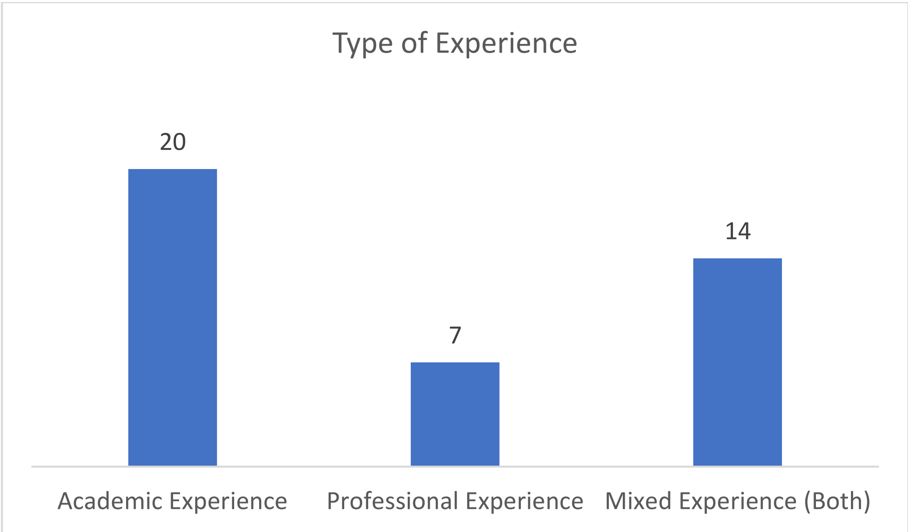
3.3. CHARACTERIZATION OF THE SAMPLE

The study comprised a total of 41 respondents, all of whom were professionals or academics working in disciplines related to ergonomics, production engineering, design, or other branches of engineering. The classification of respondents into academic, professional, or mixed profiles was conducted by the researcher through an analysis of each participant's professional background available on LinkedIn and the Brazilian academic platform Currículo Lattes**.** As shown in Figure 1, participants presented a balanced distribution: 20 individuals were categorized as having predominantly academic experience, 7 as mainly professional experience, and 14 with mixed experience encompassing both domains. This categorization ensured a comprehensive representation of both theoretical and applied perspectives on ergonomics and sustainability.

Regarding the specific field of expertise, the majority of respondents were affiliated with ergonomics (23) and production engineering (21), followed by other engineering disciplines (4) and design (3).

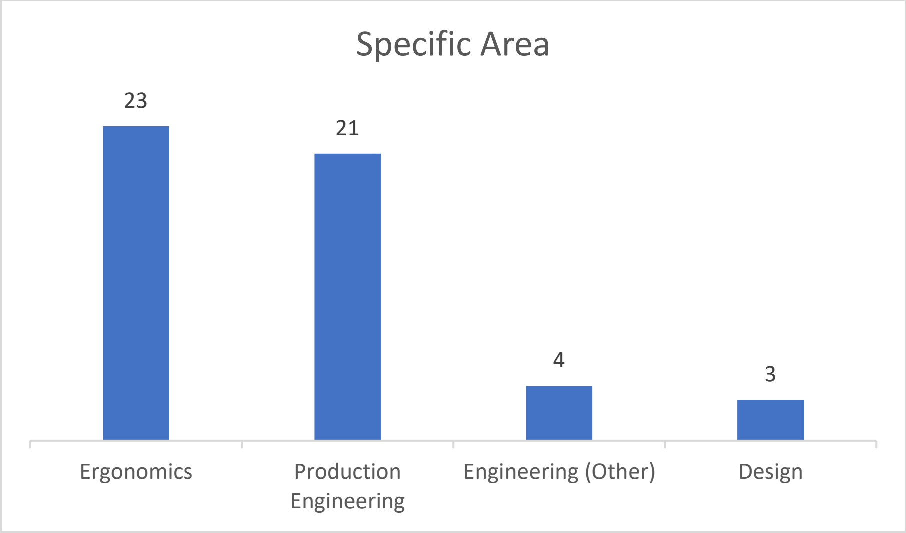
In terms of years of experience, most participants reported between 10 and 29 years of experience (29 respondents), while 7 had less than 10 years and 5 had more than 30 years of experience. Furthermore, 25 respondents held a Ph.D. degree in their respective areas of specialization, reinforcing the high academic and professional qualifications of the sample. This composition indicates a mature and experienced group of participants, combining early-career and senior professionals capable of providing diverse and informed perspectives on the relevance and implementation of green ergonomics practices in organizations.

Figure 2 – Respondent's type of experience



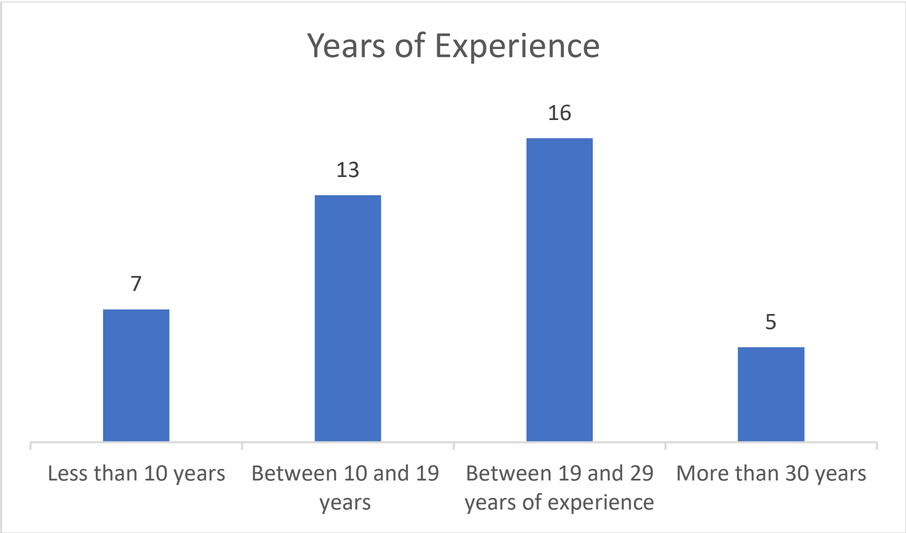
Source: Author's own elaboration

Figure 3 - Respondent' specific experience



Source: Author's own elaboration

Figure 4 – Respondent's years of experience



Source: Author's own elaboration

3.4. FUZZY TOPSIS PROCEDURE

The analysis was conducted using the Fuzzy TOPSIS method, originally proposed by Chen (2000) and widely used in sustainability and ergonomics research (Adem et al., 2022; Rampasso et al., 2024). This method allows decision-making under conditions of uncertainty by combining classical multi-criteria evaluation with fuzzy set theory, thereby incorporating the imprecision inherent in linguistic assessments (Zadeh, 1965).

In this study, the Fuzzy TOPSIS was applied to prioritize the 15 green ergonomics practices according to two criteria obtained from the questionnaire: Importance (Q1) and Level of adoption (Q2). Each practice was considered an alternative, while the respondents represented the criteria. The decision matrix was therefore transposed so that each column corresponded to one respondent and each row to one green ergonomics practice.

To account for the varying degrees of expertise among respondents, individual weights were assigned to each criterion (respondent). The weighting system ranged from 1 to 5, based on five binary parameters: (i) experience greater than 10 years, (ii) professional involvement in sustainability, (iii) professional involvement in ergonomics, (iv) possession of an ABERGO certification or equivalent, and (v) holding a doctoral degree. Each positive attribute contributed a value of 1, resulting in a total weight ranging from 1 (very low expertise) to 5 (very high expertise).

Table 3 - Respondent weighting criteria

Criterion	Binary value	Weight	Expertise level
Professional experience more than 10 years	1	5	Very high
Work in sustainability	1	4	High
Work in ergonomics	1	3	Medium
ABERGO certification or equivalent	1	2	Low
Doctoral degree	1	1	Very low

Source: Author's own elaboration

These weights were converted into fuzzy values according to the linguistic scale shown in Table 4, which defines the triangular fuzzy numbers associated with each level of expertise.

Table 4 - Linguistic scale for respondent weights

Expertise level	Triangular Fuzzy Number (l, m, u)
5 – Very High	(0.80, 1.00, 1.00)
4 – High	(0.60, 0.80, 1.00)
3 – Medium	(0.40, 0.60, 0.80)
2 – Low	(0.20, 0.40, 0.60)
1 – Very Low	(0.20, 0.20, 0.40)

Source: Author's own elaboration

Similarly, the responses collected for each practice under Importance (Q1) and Level of adoption (Q2) were converted into fuzzy values using the five-point linguistic scale shown below.

Table 5 - Linguistic scale for evaluation of importance and adoption

Linguistic Term	Triangular Fuzzy Number (l, m, u)
5 – Very High	(7.5, 10, 10)
4 – High	(5, 7.5, 10)
3 – Medium	(2.5, 5, 7.5)
2 – Low	(0, 2.5, 5)
1 – Very Low	(0,0,2.5)

Source: Author's own elaboration

The methodological steps implemented in Microsoft Excel are summarized as follows. The fuzzy decision matrix $\tilde{A} = [\tilde{x}_{ij}]$ was constructed, where each element $\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ represents the triangular fuzzy number corresponding to the evaluation of the *i-th* practice (alternative) by the *j-th* respondent (criterion). The linguistic scales used to convert responses into fuzzy values followed the standard five-point structure presented in Table 5 for both importance and adoption.

Next, the fuzzification step was performed by substituting all linguistic terms in the decision matrix with their corresponding triangular fuzzy numbers. The normalization of the matrix was then carried out to ensure comparability across criteria. For benefit-type criteria, normalization was achieved using the equation:

$$\tilde{r}_{ij} = (\frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*}),$$

where $u_j^* = \max_i (u_{ij})$represents the maximum upper bound for criterion *j*.

Subsequently, the normalized matrix was weighted by multiplying each respondent's normalized rating $\tilde{r}_{ij}$by their respective fuzzy weight $\widetilde{w}_j = (l_{wj}, m_{wj}, u_{wj})$:

$$\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \widetilde{w}_j.$$

After obtaining the weighted normalized fuzzy matrix $\tilde{V}$, the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) were determined as follows:

$$A^+ = \{\tilde{v}_j^+ \mid \tilde{v}_j^+ = \max_i (u_{ij})\}, A^- = \{\tilde{v}_j^- \mid \tilde{v}_j^- = \min_i (l_{ij})\}.$$

The computation of the distances between each alternative and the fuzzy ideal solutions followed the Euclidean structure defined by Chen (2000) and consistent with the traditional TOPSIS method (Anholon, 2024). In this study, the squared distances were adopted as an adaptation to simplify the calculations in Microsoft Excel while preserving the integrity of the ranking results.

The distances to the Fuzzy Positive Ideal Solution (FPIS) and to the Fuzzy Negative Ideal Solution (FNIS) were obtained as follows:

$$D_i^+ = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^+), \quad D_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-)$$

where $d_v(\tilde{v}_{ij}, \tilde{v}_{pj})$ denotes the Euclidean distance between two triangular fuzzy numbers.

The squared Euclidean distance used in this study is expressed as:

$$d_v(\tilde{v}_{ij}, \tilde{v}_{pj}) = \frac{1}{3}[(l_{ij} - l_{pj})^2 + (m_{ij} - m_{pj})^2 + (u_{ij} - u_{pj})^2]$$

Finally, the closeness coefficient (CC_i) was calculated to determine the relative proximity of each practice to the positive ideal solution:

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-}.$$

Higher CC_i values indicate practices closer to the ideal solution—that is, those simultaneously perceived as highly important and well implemented within organizations. Conversely, lower CC_ivalues correspond to practices perceived as less implemented or less relevant for advancing green ergonomics in organizational contexts.

All calculations were performed in Microsoft Excel, following the computational structure of Rampasso et al. (2024) and Adem et al. (2022), using built-in mathematical functions for fuzzy arithmetic and distance computation. The results provided a ranked list of the 15 green ergonomics practices, reflecting their relative priority for adoption and improvement.

After obtaining the fuzzy rankings for the 15 green ergonomics practices, two separate rankings were generated: one for the level of importance (Q1) and another for the level of adoption (Q2). These initial results, obtained using the weighted respondents as described earlier, constituted Scenario 0, which represents the baseline configuration of the analysis.

To test the robustness of the model and assess the influence of respondent weighting, two additional scenarios were analysed. In Scenario 1, all respondents were assigned equal weights (weight = 1), allowing comparison with the baseline results and identification of potential biases arising from expertise-based weighting. In Scenario 2, the analysis was replicated using two subsamples: one composed exclusively of academic respondents, and the other including professional and mixed-profile respondents. This segmentation enabled the examination of how professional background affects the perceived importance and adoption of green ergonomics practices.

Together, these scenarios provided a comprehensive perspective on the consistency of the results and the alignment between academic and professional viewpoints regarding the implementation of sustainable and ergonomically oriented practices in organizations.

4. RESULTS

This chapter presents the results of the Fuzzy TOPSIS analysis applied to assess the relative importance and level of adoption of 15 green ergonomics practices across organizational contexts. Two distinct sets of rankings were built: one reflecting how experts perceive the importance of each practice for advancing green ergonomics, and another representing the degree to which these practices are currently adopted in organizations in Brazil.

It is important to emphasize that these rankings are relative, i.e., each position expresses the standing of a practice in comparison to the others within the same evaluated set, rather than an absolute measure of its relevance or implementation level.

4.1. DEFINITION OF EXPERTISE LEVELS AND ANALYTICAL SCENARIOS

A total of eight rankings were produced through the application of the Fuzzy TOPSIS method across three analytical scenarios.

Table 6 - Overview of analytical scenarios

Scenario	Sample	Weights	Purpose
Scenario 0	41 respondents	Expertise-based weights (1–5)	Incorporate differences in professional and academic maturity
Scenario 1	41 respondents	Equal weights (1)	Assess sensitivity to weighting and ensure robustness of results
Scenario 2 - Professional	20 respondents from academic background	Expertise-based weights (1–5)	Capture academic perspectives on green ergonomics
Scenario 2 – Academic	21 respondents from professional and mixed background	Expertise-based weights (1–5)	Capture practical, field-based perspectives on green ergonomics

Source: Author’s own elaboration

In Scenario 0, the full sample of 41 respondents was considered, with each respondent assigned a specific weight according to the five-criterion scale described in Section 3. These weights ranged from 1 to 5 and were determined based on factors such as professional experience exceeding ten years, involvement in sustainability and ergonomics, possession of ABERGO certification or equivalent, and attainment of a doctoral degree (see Section 3.4). The weighting system aimed to capture differences in expertise and ensure that the evaluations reflected varying levels of professional and academic maturity.

Table 7 - Respondents characteristics and assigned weights

Respondent	Professional involvement in ergonomics	Professional involvement in sustainability	ABERGO certification or equivalent	Education Level (PhD)	Years of professional practice > 10	Expertise Level
R1	1	1	1	1	1	5
R2	1	1	0	1	0	3
R3	1	0	0	1	1	3
R4	1	0	1	1	0	3
R5	1	0	0	1	1	3
R6	1	1	0	1	1	4
R7	1	0	1	0	0	2
R8	1	1	0	1	1	4
R9	1	1	0	1	1	4
R10	0	1	0	1	1	3
R11	1	1	0	1	1	4
R12	1	0	0	1	1	3
R13	1	0	1	1	1	4
R14	1	1	0	1	1	4
R15	0	1	0	1	1	3
R16	1	0	0	1	1	3
R17	1	0	0	0	1	2
R18	1	0	0	1	0	2
R19	1	0	0	0	1	2
R20	1	0	1	0	1	3
R21	1	0	0	0	0	1
R22	1	1	1	1	1	5
R23	1	0	0	0	0	1
R24	1	0	0	0	1	2
R25	1	1	1	1	1	5
R26	1	1	0	1	1	4
R27	1	0	0	0	1	2
R28	1	0	1	0	1	3
R29	1	0	0	1	1	3
R30	1	0	0	1	1	3
R31	1	0	0	0	1	2
R32	1	0	0	1	1	3
R33	1	0	0	0	1	2
R34	1	1	0	1	1	4
R35	1	0	0	0	1	2
R36	1	0	1	0	1	3
R37	1	0	0	0	1	2
R38	1	0	1	0	1	3
R39	1	1	0	1	0	3
R40	1	0	0	1	0	2
R41	1	0	1	0	1	3
Total	39	14	11	25	33	

Source: Author’s own elaboration

Scenario 1 also included all 41 respondents, but with equal weights (weight = 1) assigned to each participant, allowing for the comparison of results and the assessment of how expertise-based weighting influenced the ranking outcomes. Scenario 2, in turn, divided the sample into two subgroups: 20 respondents with predominantly academic experience and 21 respondents with professional or mixed experience. Separate rankings were generated for each subgroup, enabling the comparison between academic and practical perspectives on the importance and adoption of green ergonomics practices.

This multi-scenario approach provided a comprehensive view of the data, making it possible to identify consistent patterns, divergences, and relationships across different weighting schemes and respondent profiles.

4.2. IMPORTANCE RANKINGS

The results for the baseline configuration (Scenario 0), which incorporated the weighted responses of all 41 participants, are presented in Table 8.

Table 8 - Importance ranking (scenario 0)

Ranking	Practice	CCi
1	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,84
2	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,82
3	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,82
4	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,81
5	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,81
6	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,80
7	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,79
8	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,77
9	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,76
10	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,75
11	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,75

Ranking	Practice	CCi
12	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,74
13	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,74
14	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,74
15	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,71

Source: Author's own elaboration

tThe highest-ranked practices in terms of importance were P8 – Design ergonomic workstations that reduce physical strain while promoting environmental sustainability (Occupational Health and Safety), P2 – Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources (Green Work Design), and P4 – Develop training programs on sustainable practices such as energy conservation and waste reduction (Environmental Education). These results suggest that experts perceive the integration of ergonomics and sustainability primarily through tangible and human-centered strategies that simultaneously promote worker well-being and environmental efficiency. The top-ranked practices share an operational and design-oriented focus, consistent with the eco-efficiency phase of ergonomic development described by Thatcher (2013), in which sustainability is pursued through optimizing material use, reducing environmental impact, and improving human performance. At the opposite end, the lowest positions P6 - Integrate environmental education into employee performance reviews (Green Environmental Education), P14 - Invest in ergonomic furniture and tools made from recycled materials (Green Workplace and Equipment), and P10 - Establish a sustainability task force or green team to oversee environmental initiatives (Green Organizational Design) reflect practices that require more systemic or organizational-level change.

When all respondents were given equal weights (Scenario 1), the ranking pattern remained remarkably consistent, reinforcing the robustness of the results (Table 9).

Table 9 - Importance ranking (scenario 1)

Ranking	Practice	CCi
1	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,85

Ranking	Practice	CCi
2	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,84
3	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,84
4	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,84
5	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,82
6	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,82
7	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,80
8	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,80
9	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,79
10	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,78
11	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,78
12	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,77
13	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,76
14	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,76
15	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,74

Source: Author's own elaboration

P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability), P2 (Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources) and P3 (Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption) occupied the top positions, showing that even when expertise-based weighting is removed, the focus on ergonomic design, resource optimization, and technical efficiency remains dominant. This convergence indicates that respondents, regardless of expertise level, associate the advancement of green ergonomics with practices that yield concrete, measurable outcomes in work design and resource management. Lower-ranked practices again included P6 (Integrate environmental education into employee performance reviews, rewarding sustainable behaviour), P14 (Invest in ergonomic furniture and tools made from recycled or sustainable materials), and P10 (Establish a sustainability task force or green team to oversee environmental initiatives), confirming that actions demanding structural reorganization continue to receive lower importance ratings. This reinforces the interpretation that the perceived relevance of green ergonomics practices is primarily linked to their operational feasibility rather than their capacity to transform organizational culture.

In Scenario 2, the results obtained from the academic subgroup (Table 10) show a more pronounced emphasis on Occupational Health and Safety (OHS) and policy-related initiatives.

Table 10 - Importance ranking (scenario 2 – academic subgroup)

Ranking	Practice	CCi
1	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,90
2	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,89
3	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,86
4	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,85
5	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,84
6	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,83
7	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,82
8	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,80
9	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,80
10	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,79
11	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,79
12	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,78
13	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,78
14	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,77
15	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,72

Source: Author’s own elaboration

The top-ranked practices were P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability), P7 (Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment) and P2

(Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources), two of which belongs to the OHS dimension. This outcome reveals that academic experts tend to view green ergonomics through the lens of worker protection, health promotion, and environmental impact reduction—dimensions that align closely with the theoretical foundations of sustainable work systems (Fischer & Zink, 2012; Kira et al., 2010). Practices such as P11 (Develop policies that integrate environmental responsibility into organizational performance metrics) and P3 (Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption) also ranked highly, suggesting that academics give slightly more weight to organizational and systemic structures than professionals. The lowest positions were P5 (Conduct workshops to raise awareness about the environmental impacts of workplace practices), P9 (Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment), and P10 (Establish a sustainability task force or green team to oversee environmental initiatives) suggest that academics may perceive awareness initiatives as secondary when compared to systemic and design-based interventions.

In contrast, the results from the professional and mixed-experience subgroup in Scenario 2 displayed a markedly different pattern (Table 11).

Table 11 - Importance ranking (scenario 2 – professional subgroup)

Ranking	Practice	CCi
1	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,81
2	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,80
3	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,78
4	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,77
5	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,77
6	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,73
7	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,73
8	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,72
9	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,72

Ranking	Practice	CCi
10	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,72
11	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,72
12	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,71
13	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,69
14	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,69
15	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,68

Source: Author's own elaboration

The top-ranked practices were P5 (Conduct workshops to raise awareness about the environmental impacts of workplace practices), P4 (Develop training programs on sustainable practices) and P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability). This ordering highlights the greater practical emphasis professionals place on behavioral and educational dimensions, viewing knowledge dissemination and awareness as the most important tools to foster sustainable change in the workplace. The prominence of training and workshop-based practices suggests that for professionals, developing sustainability competence among workers is a prerequisite for implementing more complex ergonomic interventions. The lower portion of the ranking included P13 (Design workplaces using sustainable building materials), P10 (Establish a sustainability task force or green team to oversee environmental initiatives) and P14 (Invest in ergonomic furniture and tools made from recycled or sustainable materials). Table 11 summarizes the importance ranking for the professional and mixed subgroup.

Overall, across all four rankings, the practices from Occupational Health and Safety (OHS) and Green Work Design consistently appear at the top, while those related to Green Organizational Design and Green Workplace and Equipment remain at the bottom. This pattern reveals a shared understanding across respondent groups that the core of green ergonomics still lies in operational and human-centered practices—those that directly link worker well-being with environmental performance—while broader institutional or strategic dimensions are less frequently prioritized.

4.3. LEVEL OF ADOPTION RANKINGS

Regarding the level of adoption of green ergonomics practices, the same analytical scenarios were considered in the analysis.

The results from the baseline configuration (Scenario 0), which considered the weighted responses of all 41 participants, are shown in Table 12.

Table 12 – Level of adoption ranking (scenario 0)

Ranking	Practice	CCi
1	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,56
2	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,56
3	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,55
4	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,54
5	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,53
6	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,53
7	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,53
8	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,50
9	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,50
10	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,50
11	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,47
12	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,45
13	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,44
14	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,41
15	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,36

Source: Author's own elaboration

The practices perceived as most widely adopted were P2 (Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources), P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability) and P9 (Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment). These results show that organizations tend to implement practices that produce immediate, measurable operational benefits and are easier to integrate into existing work processes. Actions related to material efficiency, ergonomic workstations and recycling represent low-risk, high-visibility efforts that simultaneously improve productivity and signal environmental commitment. At the lower end of the ranking, P6 (Integrate environmental education into performance reviews), P14 (Invest in ergonomic furniture and tools made from recycled or sustainable materials), and P13 (Design workplaces using sustainable building materials) appeared as the least implemented, indicating that initiatives demanding structural investment or long-term cultural change remain less developed.

Under the equal-weight configuration (Scenario 1), the pattern remained largely consistent with the baseline, confirming the stability of the findings (Table 13).

Table 13 – Level of adoption ranking (scenario 1)

Ranking	Practice	CCi
1	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,60
2	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,58
3	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,58
4	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,58
5	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,57
6	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,57
7	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,56
8	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,54
9	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,54
10	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,54
11	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,51
12	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,48
13	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,47

Ranking	Practice	CCi
14	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,44
15	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,39

Source: Author’s own elaboration

The top-ranked practices again included P2 (Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources), P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability), and P9 (Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment), followed by P10 (Establish a sustainability task force or green team to oversee environmental initiatives) and P7 (Replace hazardous materials with eco-friendly alternatives). This combination suggests that, even when weighting by expertise is removed, respondents perceive organizations as prioritizing operational and compliance-oriented actions that are easier to measure or externally communicate. The lowest-ranked practices were P6 (Integrate environmental education into employee performance reviews, rewarding sustainable behaviour), P14 (Invest in ergonomic furniture and tools made from recycled or sustainable materials), and P13 (Design workplaces using sustainable building materials and energy-efficient systems), revealing the limited institutionalization of sustainability into daily management systems. Overall, this scenario reinforces that the implementation of green ergonomics in practice still concentrates on visible technical improvements rather than systemic or educational transformations.

The results of the academic subgroup from Scenario 2 show a slightly different configuration, with a stronger emphasis on Occupational Health and Safety (OHS) practices (Table 14).

Table 14 – Level of adoption ranking (scenario 2 – academic subgroup)

Ranking	Practice	CCi
1	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,56

Ranking	Practice	CCi
2	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,55
3	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,53
4	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,53
5	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,53
6	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,53
7	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,52
8	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,51
9	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,49
10	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,48
11	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,47
12	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,44
13	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,44
14	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,36
15	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,35

Source: Author’s own elaboration

The three most adopted practices were P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability), P9 (Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment) and P7 (Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment). The dominance of these items highlights an academic perception that the most tangible progress in green ergonomics occurs through interventions that directly affect the physical and environmental safety of workers. These priorities align with the literature emphasizing the dual objective of ergonomic design—to safeguard human well-being while reducing ecological impact (Thatcher, 2013; Sigahi et al., 2024). At the bottom of the ranking, P13 (Design workplaces using sustainable building materials and energy-efficient systems), P14 (Invest in ergonomic furniture and tools made from recycled materials) and P6 (Integrate environmental education into performance reviews) again appear, suggesting that academic respondents view these actions as aspirational rather than consolidated in current practice.

In contrast, the professional and mixed-experience subgroup from Scenario 2 displayed a more operational and managerial focus (Table 15).

Table 15 – Level of adoption ranking (Scenario 2 – professional subgroup)

Ranking	Practice	CCi
1	P2 - Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources.	0,59
2	P8 - Design ergonomic workstations that reduce physical strain while promoting environmental sustainability.	0,56
3	P9 - Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment (PPE).	0,56
4	P4 - Develop training programs on sustainable practices such as energy conservation and waste reduction.	0,55
5	P7 - Replace hazardous materials with eco-friendly alternatives in work processes and safety equipment.	0,54
6	P12 - Promote green leadership by incorporating sustainability goals into the company's leadership training programs.	0,54
7	P11- Develop policies that integrate environmental responsibility into organizational performance metrics.	0,53
8	P10 - Establish a sustainability task force or green team to oversee environmental initiatives.	0,53
9	P5 - Conduct workshops to raise awareness about the environmental impacts of workplace practices.	0,51
10	P6 - Integrate environmental education into employee performance reviews, rewarding sustainable behaviour.	0,47
11	P15 - Implement waste-reduction strategies, such as reusable or compostable products, in office spaces.	0,47
12	P3 - Use energy-efficient machinery and ergonomically designed tools to reduce resource consumption.	0,46
13	P1 - Implement eco-design principles in task and workflow planning to minimize energy consumption.	0,45
14	P13 - Design workplaces using sustainable building materials and energy-efficient systems (e.g., LED lighting, renewable energy sources).	0,43
15	P14 - Invest in ergonomic furniture and tools made from recycled or sustainable materials.	0,35

Source: Author's own elaboration

The most adopted practices were P2 (Introduce resource-efficient work processes, such as reducing material waste and optimizing the use of renewable resources), P8 (Design ergonomic workstations that reduce physical strain while promoting environmental sustainability), and P9 (Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment)—a hierarchy nearly identical to Scenario 0—but the group also ranked P4 (Develop training programs on sustainable practices) and P12 (Promote green leadership by incorporating sustainability goals into leadership training) among the top six. This indicates a stronger appreciation of training and leadership as enabling mechanisms for sustainable implementation. Professionals appear to value not only efficiency-based design but also the behavioral foundations necessary to sustain it. Conversely, P13 (Design workplaces using sustainable building materials), P14 (Invest in ergonomic furniture and tools made from recycled or sustainable materials), and P1 (Implement eco-design principles in task and workflow planning to minimize energy consumption) occupied the lowest positions, reinforcing once again that actions requiring higher financial investment or long-term infrastructure redesign are still seen as less attainable in current organizational realities.

Overall, across all scenarios, Occupational Health and Safety (OHS) and Green Work Design continue to dominate the upper rankings, underscoring that the practical application of green ergonomics remains concentrated in areas where environmental responsibility overlaps directly with safety, productivity, and efficiency. Meanwhile, the consistently lower placement of Green Environmental Education, Green Organizational Design, and Green Workplace and Equipment practices demonstrates that the transition from awareness to institutionalized sustainability is still in progress within most organizations.

5. DISCUSSION

The comparative analysis between the importance and adoption rankings reveals a clear distinction between the practices perceived as relevant for advancing green ergonomics and those most frequently implemented in organizational contexts.

Table 16 - Summary of key patterns and changes across analytical scenarios

Scenario	Key Patterns in Importance Rankings	Key Patterns in Adoption Ra’nkings	Observations
Scenario 0	P8 (OHS), P2 (Green Work Design), and P4 (Green Environmental Education) ranked highest; P6 (Green Environmental Education), P14 (Green Workplace and Equipment), P10 (Green Organizational Design) ranked lowest	P2 (Green Work Design), P8 (OHS), and P9 (OHS) ranked highest; P13 (Green Workplace and Equipment), P6 (Green Environmental Education) and P14 (Green Workplace and Equipment) ranked lowest	P4 is highly valued but not widely implemented; Green Work Design and OHS ranked highest in both importance and level of adoption; Green Environmental Education, Green Workplace and Equipment dimensions, remain low ranked
Scenario 1	P8 (OHS), P2 (Green Work Design), and P3 (Green Work Design) ranked highest; P6 (Green Environmental Education), P14 (Green Workplace and Equipment), P10 (Green Organizational Design) ranked lowest	P2 (Green Work Design), P8 (OHS), and P9 (OHS) ranked highest; P13 (Green Workplace and Equipment), P6 (Green Environmental Education) and P14 (Green Workplace and Equipment) ranked lowest	Weighting does not substantially affect results; rankings remain stable.
Scenario 2 – Academic subgroup	P8 (OHS), P7 (OHS), and P2 (Work Design) ranked highest; P9 (OHS), P6 (Green Environmental Education) and P10 (Green Organizational Design) ranked lowest	P8 (OHS), P9 (OHS) and P7 (OHS) ranked highest; P13 (Green Workplace and Equipment), P14 (Green Workplace and Equipment) and P6 (Green Environmental Education) ranked lowest	P2 is highly valued but not widely implemented; Green Workplace and Equipment dimension remain low ranked
Scenario 2 - Professional subgroup	P5 (Green Environmental Education), P4 (Green Environmental Education), and P8 (OHS) ranked highest; P13 (Green Workplace and Equipment), P10 (Green Organizational Design), P14 (Green Workplace and Equipment) ranked lowest	P2 (Work Design), P8 (OHS), and P9 (OHS) ranked highest; P1 (Green Work Design), P13 (Green Workplace and Equipment), P14 (Green Workplace and Equipment) ranked lowest	P5 and P4 are highly valued but not widely implemented; Green Workplace and Equipment dimension remain low ranked

Source: Author’s own elaboration

In terms of importance, the top-ranked practices were P8 – Design ergonomic workstations that reduce physical strain while promoting environmental sustainability, P2 – Introduce resource-efficient work processes, and P4 – Develop training programs on sustainable practices. Conversely, the practices most widely adopted were P2 – Introduce resource-efficient work processes, P8 – Design ergonomic workstations that reduce physical strain while promoting environmental sustainability, and P9 – Implement workplace recycling programs and promote the use of eco-friendly personal protective equipment.

The overlap between P2 and P8 across both rankings suggests a partial alignment between perceived importance and practical implementation, as both involve measurable improvements in work design, material efficiency, and safety—areas where the relationship between sustainability and productivity is most evident. However, the substitution of P4 (training programs) by P9 (recycling programs) among the most adopted practices highlights an implementation gap between strategic human-centered actions and operational environmental initiatives. While respondents recognize the importance of education and behavioural change in sustaining green practices, organizations still tend to prioritize visible, practical actions with quantifiable outcomes, such as recycling and process optimization. This gap reflects the broader challenge described by Bolis et al. (2014) and Sigahi et al. (2024), where sustainability efforts often emphasize operational efficiency rather than deeper cultural transformation.

The persistence of low rankings for P6 (Integrate environmental education into performance reviews), P14 (Invest in ergonomic furniture and tools made from recycled materials), and P13 (Design workplaces using sustainable building materials) across both criteria further reinforces this tendency. These practices require long-term investment, structural redesign, or systemic cultural integration—elements that organizations frequently perceive as less feasible or urgent. According to Thatcher (2013), this pattern characterizes the eco-efficiency stage of ergonomic development, in which sustainability is pursued through incremental adjustments that improve efficiency and reduce waste, rather than through the systemic reconfiguration of work systems. As a result, many organizations appear to have adopted a form of surface-level sustainability, implementing practices that yield measurable environmental outcomes while postponing the integration of green principles into strategic and educational structures.

From a dimensional perspective, the findings reveal that the most valued and most implemented practices largely belong to the dimensions of Occupational Health and Safety (OHS) and Green Work Design, while Green Organizational Design, Green Environmental Education, and Green Workplace and Equipment consistently occupy the lower positions in both importance and adoption rankings. This distribution suggests that green ergonomics is still primarily interpreted through an operational and human-centered lens, focusing on the immediate interface between the worker and the physical environment. The prevalence of OHS-related practices—such as ergonomic workstation design and substitution of hazardous materials—confirms that the first steps toward sustainability are often taken where safety and environmental protection overlap. Similarly, the prominence of Work Design practices indicates that sustainability is advancing mainly through process optimization and efficiency improvements, which are easier to measure and justify economically.

In contrast, the lower prioritization of Green Organizational Design and Green Environmental Education practices reveals a gap in the institutional embedding of green ergonomics. These dimensions require leadership engagement, employee empowerment, and the development of new organizational norms—factors that, according to Kira et al. (2010) and Fischer & Zink (2012), are essential for the long-term sustainability of work systems. The findings therefore suggest that while green ergonomics is gaining traction as a technical and design-oriented field, it has yet to achieve full maturity as a socio-technical and cultural paradigm. Bridging this gap will depend on strengthening the educational and organizational dimensions that enable continuous learning, leadership alignment, and systemic integration of sustainability principles into ergonomic practice.

6. CONCLUSIONS

This study investigated the integration of environmental sustainability into ergonomic practice through the evaluation of fifteen green ergonomics practices across organizational contexts. Grounded in the understanding that human well-being and ecological preservation are interdependent dimensions of sustainable development, the research applied the Fuzzy TOPSIS method to assess both the perceived importance and the level of adoption of these practices. The analysis incorporated four scenarios—weighted full sample, equal-weight full sample, and academic versus professional subgroups—allowing for a comprehensive and comparative interpretation of how green ergonomics is currently valued and implemented in Brazilian organizations.

Across all scenarios, the findings consistently indicated that practices associated with Occupational Health and Safety (OHS) and Green Work Design occupy the highest positions in both importance and adoption rankings. Practices such as the design of ergonomic workstations that reduce physical strain while promoting environmental sustainability (P8) and the introduction of resource-efficient processes (P2) were repeatedly prioritized. These results suggest that organizations and experts view green ergonomics as most relevant when it operates at the intersection of human well-being, safety, and operational efficiency—domains in which environmental responsibility can be integrated without requiring disruptive structural change.

In contrast, practices belonging to the dimensions of Green Organizational Design, Environmental Education, and Green Workplace and Equipment consistently ranked lower in both perceived importance and actual adoption. Actions such as integrating environmental criteria into performance evaluations (P6), establishing sustainability task forces (P10), or investing in sustainable materials for workplace infrastructure (P14, P13) appeared less institutionalized. These findings reveal a clear implementation gap: while the strategic relevance of green ergonomics is acknowledged, organizations still prioritize operational and measurable actions over initiatives involving cultural transformation, longer-term investment, or organizational restructuring. This pattern aligns with the eco-efficiency stage of green ergonomics described in the literature, where sustainability is pursued primarily through incremental improvements rather than systemic redesign.

The comparison between academic and professional subgroups further deepened this interpretation. Academics tended to emphasize OHS and policy-oriented practices, reflecting a more systemic and theoretical perspective, whereas professionals prioritized educational and operational actions that are more feasible and actionable in everyday organizational environments. This divergence highlights the importance of integrating both theoretical and practical perspectives for the advancement of green ergonomics as a field.

Overall, the results suggest that green ergonomics in contemporary organizations remains in an early stage of maturity. While there is clear recognition of the potential benefits of integrating environmental sustainability into ergonomic practice, adoption is uneven and concentrated in areas already familiar to ergonomists—particularly work design, safety, and resource efficiency. Advancing to a more mature and holistic paradigm will require strengthening the educational and organizational dimensions, developing leadership capable of promoting sustainable culture, and integrating environmental criteria into strategic decision-making processes.

Despite its contributions, this study has limitations. The sample, although composed of qualified experts, may not fully represent all sectors or organizational realities. Additionally, the use of linguistic scales, while appropriate for subjective evaluations, may introduce nuances not entirely captured by fuzzy modeling. Future research could expand the sample, incorporate longitudinal data, or explore hybrid qualitative–quantitative approaches to better understand the barriers and enablers of green ergonomics adoption. Furthermore, applying alternative multicriteria methods or integrating environmental performance indicators could offer additional insights into the operationalization of green ergonomics.

In conclusion, this work advances the discussion on sustainable work systems by demonstrating how the principles of green ergonomics are perceived and implemented in practice. By identifying gaps between importance and adoption, the study provides actionable insights for researchers, practitioners, and organizations seeking to foster work environments that are simultaneously safe, efficient, and environmentally responsible.

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