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SOBRE O PERIÓDICO MIX SUSTENTÁVEL

O Periódico Mix Sustentável nasceu da premissa de que o projeto englobando os preceitos da sustentabilidade é a única solução possível para que ocorra a união entre a filosofia da melhoria contínua com a necessidade cada vez maior de preservação dos recursos naturais e incremento na qualidade de vida do homem. A sustentabilidade carece de uma discussão profunda para difundir pesquisas e ações da comunidade acadêmica, que tem criado tecnologias menos degradantes na dimensão ambiental; mais econômicas e que ajudam a demover injustiças sociais a muito estabelecidas.
O periódico Mix Sustentável apresenta como proposta a publicação de resultados de pesquisas e projetos, de forma virtual e impressa, com enfoque no tema sustentabilidade. Buscando a troca de informações entre pesquisadores da área vinculados a programas de pós-graduação, abre espaço, ainda, para a divulgação de profissionais inseridos no mercado de trabalho, além de entrevistas com pesquisadores nacionais e estrangeiros. Além disso publica resumos de teses, dissertações e trabalhos de conclusão de curso defendidos, tendo em vista a importância da produção projetual e não apenas textual.
De cunho essencialmente interdisciplinar, a Mix tem como público-alvo pesquisadores e profissionais da Arquitetura e Urbanismo, Design e Engenharias. De acordo com a CAPES (2013), a área Interdisciplinar no contexto da pós-graduação, decorreu da necessidade de solucionar novos problemas que emergem no mundo contemporâneo, de diferentes naturezas e com variados níveis de complexidade, muitas vezes decorrentes do próprio avanço dos conhecimentos científicos e tecnológicos. A natureza complexa de tais problemas requer diálogos não só entre disciplinas próximas, dentro da mesma área do conhecimento, mas entre disciplinas de áreas diferentes, bem como entre saberes disciplinares e não disciplinares. Decorre daí a relevância de novas formas de produção de conhecimento e formação de recursos humanos, que assumam como objeto de investigação fenômenos que se colocam entre fronteiras disciplinares.
Desafios teóricos e metodológicos se apresentam para diferentes campos de saber. Novas formas de produção produção de conhecimento enriquecem e ampliam o campo das ciências pela exigência da incorporação de uma racionalidade mais ampla, que extrapola o pensamento estritamente disciplinar e sua metodologia de compartimentação e redução de objetos. Se o pensamento disciplinar, por um lado, confere avanços à ciência e tecnologia, por outro, os desdobramentos oriundos dos diversos campos do conhecimento são geradores de diferentes níveis de complexidade e requerem diálogos mais amplos, entre e além das disciplinas.
A Revista Mix Sustentável se insere, portanto, na Área Interdisciplinar (área 45), tendo como áreas do conhecimento secundárias a Arquitetura, Urbanismo e Design (área 29), a Engenharia Civil (área 10) e, ainda, as engenharias em geral.

CLASSIFICAÇÃO QUALIS

No quadriênio 2017-2020 a revista MIX Sustentável está classificada como A3 em todas as áreas de avaliação.

MISSÃO

Publicar resultados de pesquisas e projetos, de forma virtual e impressa, com enfoque no tema sustentabilidade, buscando a disseminação do conhecimento e a troca de informações entre acadêmicos, profissionais e pesquisadores da área vinculados a programas de pós-graduação.

OBJETIVO

Disseminar o conhecimento sobre sustentabilidade aplicada à projetos de engenharia, arquitetura e design.

POLÍTICAS DE SEÇÃO E SUBMISSÃO

A) Seção Científica

Contém artigos científicos para socializar a produção acadêmica buscando a valorização da pesquisa, do ensino e da extensão. Reúne 12 artigos científicos que apresentam o inter-relacionamento do tema sustentabilidade em projetos

de forma interdisciplinar, englobando as áreas do design, engenharia e arquitetura. As submissões são realizadas em fluxo contínuo em processo de revisão por pares. A revista é indexada em sumários.org e no google acadêmico.

B) Seção Resumo de Trabalhos de Conclusão de Curso de Graduação, Iniciação Científica e Pós-graduação
Tem como objetivo a divulgação de Teses, Dissertações e Trabalhos de Conclusão de Curso na forma de resumos expandidos e como forma de estimular a divulgação de trabalhos acadêmico-científicos voltados ao projeto para a sustentabilidade.

C) Seção Mercadológica
É um espaço para resenhas e entrevistas (espaços de diálogo). Apresenta pelo menos duas entrevistas com profissionais atuantes no mercado ou pesquisadores de renome, mostrando projetos práticos que tenham aplicações na esfera da sustentabilidade. Deverá ainda disponibilizar conversas com especialistas em sustentabilidade e/ou outros campos do saber. Todas os números possuem o Editorial, um espaço reservado para a apresentação das edições e comunicação com os editores.

PROCESSO DE AVALIAÇÃO PELOS PARES

A revista conta com um grupo de avaliadores especialistas no tema da sustentabilidade, doutores em suas áreas de atuação. São 211 revisores, oriundos de 67 instituições de ensino Brasileiras e 8 Instituições Internacionais. Os originais serão submetidos à avaliação e aprovação dos avaliadores (dupla e cega).
Os trabalhos são enviados para avaliação sem identificação de autoria. A avaliação consiste na emissão de pareceres, da seguinte forma:

- aprovado
- aprovado com modificações (a aprovação dependerá da realização das correções solicitadas)
- reprovado

PERIODICIDADE

Publicação quadrimestral com edições especiais. São publicadas três edições regulares ao ano. Conta ainda com pelo menos uma edição especial anual.

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MIX SUSTENTÁVEL VOL. 10 N. 4 – EDIÇÃO ESPECIAL ENSUS 2024

AS "DIMENSÕES" DA SUSTENTABILIDADE

Participar de um evento como o ENSUS é sempre uma experiência única. E desta vez estávamos na condição mais de expectadores do que de organizadores. É claro que sempre nos envolvemos com o evento. Não há como não se envolver... seria como não se envolver com um filho (um pouco de exagero acadêmico aqui). Mas quando o ENSUS acontece em outra universidade que não na UFSC, nós temos a oportunidade de ter um olhar "de fora" para com o evento, o que nos permite ver com mais clareza o que está funcionando bem e o que pode ficar (ainda) melhor. As edições do evento na Unisul, na UNIFESSPA e a agora na UFMG/UEMG são essenciais para incrementar a dinâmica do evento, proporcionando aprendizados comuns a todos os envolvidos.

Penso que um dos grandes pontos positivos do ENSUS é reunir em um só lugar pessoas que tem o ato de projetar como função laborativa, quer seja prática ou acadêmica. Então temos engenheiros, arquitetos e designers (entre outras profissões) compartilhando de um mesmo espaço físico, assistindo as mesmas palestras, debatendo juntos assuntos que embora semelhantes, são tratados (na condição restritiva de "área do conhecimento") de forma muito diferente, a depender das especificidades de cada área.

A integração proporcionada por essa "colcha de retalhos" do saber talvez seja a única solução ao nosso futuro enquanto habitantes da Terra. Isso em um mundo já totalmente globalizado e com as questões ambientais cada vez mais impactando na economia, na sociedade, no futuro, no bem-estar, enfim... na vida de cada habitante de nosso planeta, não importando se moramos numa grande cidade industrializada norte americana, num bairro pitoresco das ilhas gregas, numa favela no Rio de Janeiro, numa aldeia no coração de Moçambique, ou mesmo numa cidade enorme e poluída na China.

Os recentes incêndios que acometeram o mundo, com destaque na mídia às queimadas em dois importantíssimos biomas brasileiros (Amazônia e Pantanal) são exemplos disso. Além do Brasil, regiões da Sibéria, Austrália, Canadá, Chile, Bolívia, Portugal e Indonésia (para citar os mais comentados) tiveram incêndios alarmantes nos últimos meses. E isso é apenas um dos exemplos que poderíamos citar. Basta assistirmos aos jornais diários para ver isso, onde eventos climáticos que antes eram "raridade", hoje são noticiados como fatos cotidianos e esperados. Já não nos surpreendemos mais com tufões, tempestades, alagamentos, calor excessivo, problemas respiratórios em larga escala e por aí vai.

E como o mundo é dinâmico e as pessoas esperam sempre por novidades (e isso inclui novas tragédias), antes mesmo de resolver minimamente os problemas de uma tragédia ambiental, a grande mídia já "esquece" o assunto para tratar de um novo, e talvez mais alarmante caso (exemplo as cheias no RS que vitimaram milhares de pessoas afetando mais da metade de um dos maiores estados brasileiros e onde muitos permanecem alocados em acampamentos).

Então é muito interessante ver o modo como cada pesquisador aborda o problema, e principalmente as várias conexões que isso traz. Diferente do que acontece em congressos ou encontros específicos, onde engenheiros debatem com engenheiros; arquitetos debatem com arquitetos e designers debatem com designers, no ENSUS temos a interdisciplinaridade vivenciada em cada palestra, em cada sessão temática, quando observamos, por exemplo, designers e arquitetos debatendo ou tirando dúvidas com o apresentador de um trabalho de engenharia... ou vice-versa. Preconceitos e tabus são combatidos deste modo, quando entendemos que o que fazemos é muito bom; mas que o que o colega de outra área faz é igualmente bom e importante. Na nossa realidade atual, as visões diferentes

não podem mais ser conflitantes, mas sim, complementares. Essa é a essência do que se pensou em 1987 quando foi publicado o Relatório Brundtland: Nosso Futuro Comum, como título do relatório final da Comissão Mundial sobre Meio Ambiente e Desenvolvimento (CMMAD), promovida pela ONU.

Esse tipo de vivência é essencial aos mestrandos e doutorandos que participam do evento, e principalmente aos graduandos, porque nos PPGs já existe uma maior diversidade nos temas, mas na graduação ainda temos situações muito específicas de cada área. Isso promove não só um desconhecimento do que "o outro" é capaz, como também dificulta a integração projetual tão necessária nos dias de hoje.

O ENSUS vem ano após ano se consolidando como o principal evento de sustentabilidade em projeto do Brasil, e a prova disso é a quantidade de revistas parceiras do evento. Ampliar o número de revistas científicas para publicação de versões estendidas dos artigos previamente disponibilizados nos anais tem dois objetivos principais: (1) ampliar a divulgação das pesquisas para outras fontes, principalmente quando se publica a versão do artigo ampliado, revisado e em língua inglesa; (2) combater as publicações "caça-níqueis", que lotam nossas caixas de mensagens com ofertas de publicações de artigos "selecionados". É inacreditável que tais revistas tenham QUALIS atribuído pelas instâncias avaliativas, algumas inclusive no extrato A (o que prova que o sistema avaliativo brasileiro no que se refere a produção científica e pós-graduação tem confiabilidade bastante subjetiva).

Tais órgãos deveriam ser responsáveis no sentido de coibir isso, pois as mensagens "seduzem" especialmente os novos pesquisadores, pela facilidade de se ter um artigo publicado em QUALIS A, pagando-se até R$1000,00 em um processo rápido de até 48 horas. Em contrapartida a um processo tradicional e sério, que envolve revisão por pares, e, às vezes, mais do uma rodada de ajustes, com um tempo que pode atingir até 9 meses de fluxo editorial, estas revistas oferecem a publicação imediata, com fluxo editorial diminuto. Um verdadeiro absurdo, infelizmente ao que parece, chancelado pelos órgãos avaliativos.

Por fim, convidamos aos leitores que confiram os artigos desta edição, e desde já anunciamos o que o envio de artigos ao ENSUS 2025 iniciará em novembro de 2024. Acompanhe as novidades na página do evento e na revista MIX Sustentável. Boa leitura!!!!!

Paulo Ferroli e Lisiane Librelotto – editores.

3D PRINTING WITH NATURAL MATERIALS IN CIVIL CONSTRUCTION: APPLICATIONS FOR THE THERMAL PERFORMANCE OF BUILDINGS

IMPRESSÃO 3D COM MATERIAIS NATURAIS NA CONSTRUÇÃO CIVIL: APLICAÇÕESVOLTADAS AO DESEMPENHO TÉRMICO DE EDIFICAÇÕES

IMPRESIÓN 3D CON MATERIALES NATURALES EN LA CONSTRUCCIÓN CIVIL: APLICACIONES ENFOCADAS EN EL RENDIMIENTO TÉRMICO DE LAS EDIFICACIONES

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ABSTRACT
The construction industry has experienced a number of transformations due to the use of digitalization and automation. Additive manufacturing, also known as 3D printing, is a current example. The purpose of this paper is to analyze the use of natural materials based on soil applied to 3D printing technology, with a focus on the thermal performance of buildings. A exploratory literature review was used to identify applied research that has explored these materials. The data obtained was systematized in a comparative table to identify the main strategies used. The analysis of applied research indicates that construction using 3D printing with materials based on soil is promising, taking advantage of the soil's natural thermal insulation properties and being able to incorporate parametric design and digital fabrication strategies to create complex, customized solutions for different contexts.

KEYWORDS
Civil Construction; Additive Manufacturing; Soil; Earth construction; Thermal Performance.

RESUMO
A construção civil tem passado por diversas transformações devido ao emprego da digitalização e automação. Um exemplo atual é a manufatura aditiva, também chamada de impressão 3D. Este artigo visa analisar o uso de materiais naturais a base de solo e argila aplicados à tecnologia de impressão 3D com foco no desempenho térmico das edificações. Utilizou-se de revisão bibliográfica exploratória para identificar pesquisas aplicadas que têm explorado esses materiais. Os dados obtidos foram sistematizados em um quadro comparativo para identificar as principais estratégias utilizadas. A análise das pesquisas aplicadas indica que a construção com o uso da impressão 3D com materiais a base de solo e argila é promissora, aproveitando as propriedades naturais do solo de isolamento térmico, podendo incorporar estratégias de design paramétrico e fabricação digital para criar soluções complexas e personalizadas para os diferentes contextos.

PALAVRAS-CHAVE
Construção Civil; Manufatura Aditiva; Solo; Construção com Terra; Desempenho Térmico.

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RESUMEN

La construcción civil ha experimentado diversas transformaciones debido al empleo de la digitalización y la automatización. Un ejemplo actual es la manufactura aditiva, también conocida como impresión 3D. Este artículo tiene como objetivo analizar el uso de materiales naturales a base de suelo y arcilla aplicados a la tecnología de impresión 3D con un enfoque en el rendimiento térmico de las edificaciones. Se utilizó una revisión bibliográfica exploratoria para identificar investigaciones aplicadas que han explorado estos materiales. Los datos obtenidos fueron sistematizados en un cuadro comparativo para identificar las principales estrategias utilizadas. El análisis de las investigaciones aplicadas indica que la construcción con el uso de la impresión 3D con materiales a base de suelo y arcilla es prometedora, aprovechando las propiedades naturales del suelo para el aislamiento térmico, pudiendo incorporar estrategias de diseño paramétrico y fabricación digital para crear soluciones complejas y personalizadas para diferentes contextos.

PALABRAS CLAVE

Construcción Civil; Manufactura Aditiva; Suelo; Construcción con Tierra; Desempeño Térmico.

1. INTRODUCTION

According to the International Energy Agency (IEA), the building sector is responsible for 36% of global final energy consumption and 39% of total direct and indirect CO2 emissions (INTERNATIONAL ENERGY AGENCY, 2018). In addition, cooling systems represent 60% of total energy in buildings worldwide, as thermal comfort is one of the main priorities, especially in hot climates (AL-OBAIDI *et al*., 2017). Due to this, various studies have sought alternatives for more optimized construction, with less environmental impact and better thermal performance, as well as greater savings in time, materials and costs, seeking to promote energy conservation and reduce carbon emissions (ALHUMAYANI *et al*., 2020; WENG *et al*., 2020). In this sense, one technology that has been increasingly explored is additive manufacturing, which combines manufacturing with digital fabrication, also known as 3D printing (COSTA; RIBEIRO, 2020; PESSOA *et al*., 2021).

The use of additive manufacturing in construction meets current issues such as Smart Cities, Sustainable Development and Digital Transformation, incorporating the concepts of digitization, automation and connectivity of Industry 4.0. 3D printing could make construction more efficient and provide sustainable growth, stimulating the principles of circularity, with the use of recycled and environmentally friendly materials (PESSOA *et al*., 2021). Cement-based materials have proven to be suitable for 3D printing, but they are one of the biggest contributors to the environmental footprint of construction, due to their high energy consumption and CO2 emissions during clinker production (COSTA; RIBEIRO, 2020).

Because of this, applied research has been carried out using alternative materials in order to reduce the environmental impact of buildings (AKMAN; SADHU, 2024; FIGLIOLA; BATTISTI, 2021). The materials that have been most studied and which have properties similar to those of concrete are: Portland cement-based materials with mineral additions; geopolymeric materials; gypsum-based materials; and soil-based materials (TEIXEIRA *et al*., 2023).

Environmental and sustainability concerns are central to discussions about the future of construction, and soil-based building materials are among the most eco-friendly options available. Earth is a widely available resource, and structures made from local soils can be found in nearly every part of the globe. Over the past twenty years, numerous building codes, guidelines, and standards for earthen construction have been developed worldwide. These are based on extensive research and field observations on the seismic, thermal, and moisture durability of earthen buildings, paving the way for a burgeoning revival in earth-based construction (FRATELLO; RAEL, 2020).

Therefore, the aim of this study is to analyze the use of natural materials based on soil applied to 3D printing technology with a focus on the thermal performance of buildings, in order to identify the main design and construction strategies that have been used.

In 2015, the UN established the "2030 Agenda for Sustainable Development", with the definition of 17 Sustainable Development Goals, to be implemented worldwide over the next 15 years. Among the goals of this agenda, this research adheres to those numbered 9 "Industry, innovation and infrastructure", 11 "Sustainable cities and communities", 12 "Responsible consumption and production", 13 "Action against global climate change" and 15 "Life on land" (NAÇÕES UNIDAS, 2024). Thus, this study addresses current problems affecting social well-being around the world, especially considering the major impact of the construction sector on the environment and the thermal performance of buildings.

2. METHODOLOGICAL PROCEDURES

The methodology applied is based on an exploratory literature review to identify applied research using 3D printing technology with natural materials based on soil. The following categories of analysis were evaluated in each case: a) general characteristics; b) composition of the printing material; and c) aspects related to thermal performance.

The selection of more than one case allowed for a comparative analysis, highlighting aspects of convergence and divergence between them. The qualitative analysis of the data was carried out through the process of analysis-reflection-synthesis (PATRICIO-KARNOPP, 2004), using the content analysis technique (BARDIN, 1991) to evaluate the information.

3. RESULTS AND DISCUSSIONS

Although the use of 3D printing technology is still relatively new in large-scale construction, with some limitations, it promotes the reuse of traditional materials. This could revitalize the use of natural materials in order to replace energy- and carbon-intensive industrial materials (EL-MAHDY; GABR; ABDELMOHSEN, 2021). Natural materials based on soil are increasingly being used in 3D printing construction as they are recyclable, low-cost and have a low environmental impact (ALHUMAYANI *et al*.,

2020; KONTOVOURKIS; TRYFONOS, 2020; LIBRELOTTO *et al*., 2023; PERROT; RANGEARD; COURTEILLE, 2018). Their application is similar to cement-based digital construction technology (GOMAA *et al*., 2019).

The main properties of these materials highlighted in the literature are (ALHUMAYANI *et al*., 2020; KONTOVOURKIS; TRYFONOS, 2020; PERROT; RANGEARD; COURTEILLE, 2018; TEIXEIRA *et al*., 2023):

- Fresh state properties: biopolymers such as alginate can be used to improve shape retention;
- Mechanical performance and durability: the material achieves mechanical performance similar to conventional earth construction;
- Texture: they are smoother when printed with a circular nozzle; and
- Color possibilities: shades of brown and yellow.

In order to evaluate aspects related to thermal performance, which is another important property of soil-based materials applied to 3D printing technology, the results of some applied research were analyzed and will be described below.

3.1 WASP 3D printing technology

a) General characteristics:

The Italian company WASP (World's Advanced Saving Project) has a humanitarian character and environmental principles of ecology and sustainability. Its aim is to develop ecologically sustainable buildings and structures, using natural materials such as soil and agricultural waste, and to build houses in poor, densely populated areas or those devastated by natural disasters, with low costs, energy consumption and environmental pollution (WASP, 2024).

One of the technologies developed by the company is the WASP Crane system, which is a collaborative modular manufacturing system consisting of a main printer unit that can be assembled in various configurations, depending on the printing area and the size of the architectural object to be built. The single module has a diameter of 6.60 m and a height of 3 m and can be extended by adding crossbars and printer arms. This construction strategy implies a potentially infinite print area, as the individual modules can be reconfigured and advanced with a generative attitude (WASP, 2024).

One of the main projects developed by WASP is the "Gaia" houses (Figure 1a and 1b), printed in 2018 in Italy. The walls of the houses were printed layer by layer using the WASP Crane system. The houses have an area of 30 m^2 and it took 10 days to build the external walls, which are 40 cm thick. The roof of the houses was made of wood and the foundations were printed in concrete. Door and window frames were installed during the construction process, as well as the electrical and plumbing systems. The total cost of the materials used in the wall construction was 900 euros (VALENTE; SIBAI; SAMBUCCI, 2019).

b) Printing material:

Material composed of a mixture of 25% local soil (mixture of sand, soil and silt), 40% chopped rice straw, 10% rice husk and 10% hydraulic lime. Muller (SOOD, 2018) was used to make the mixture homogeneous and workable.

c) Aspects related to thermal performance:

In the process of printing the walls, internal vertical cavities were created and filled with waste from rice production (Figure 2a), such as chopped rice husks and straws, filling the voids for thermal insulation. In addition, the walls were designed with the aim of integrating natural ventilation systems and thermoacoustic insulation systems (VALENTE; SIBAI; SAMBUCCI, 2019).

According to the WASP company, this method of insulation keeps the internal temperature of the house comfortable, avoiding the need for heating or cooling. Rice husks have also been used to create a cladding for the inside of walls and as an insulation layer on the top of the roof (Figure 2b) (JORDAHN, 2019).

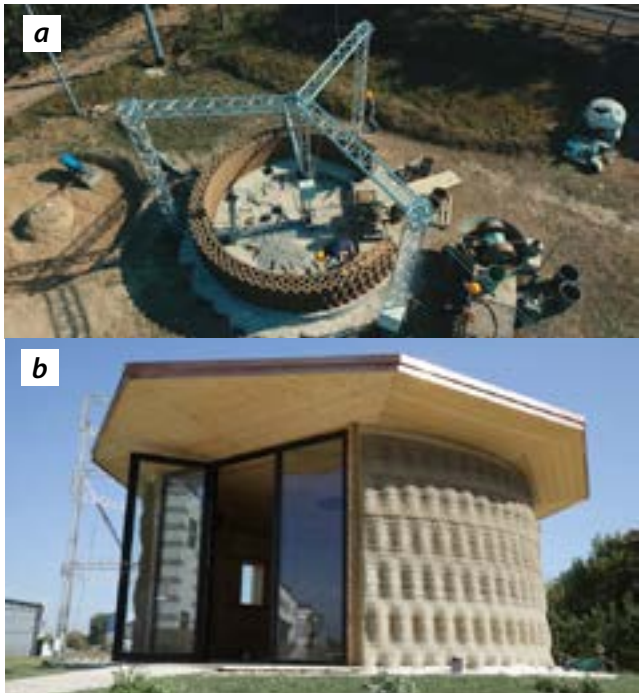

Figure 1: (a) Gaia House being built; (b) Gaia House finished.
Source: (JORDAHN, 2019).

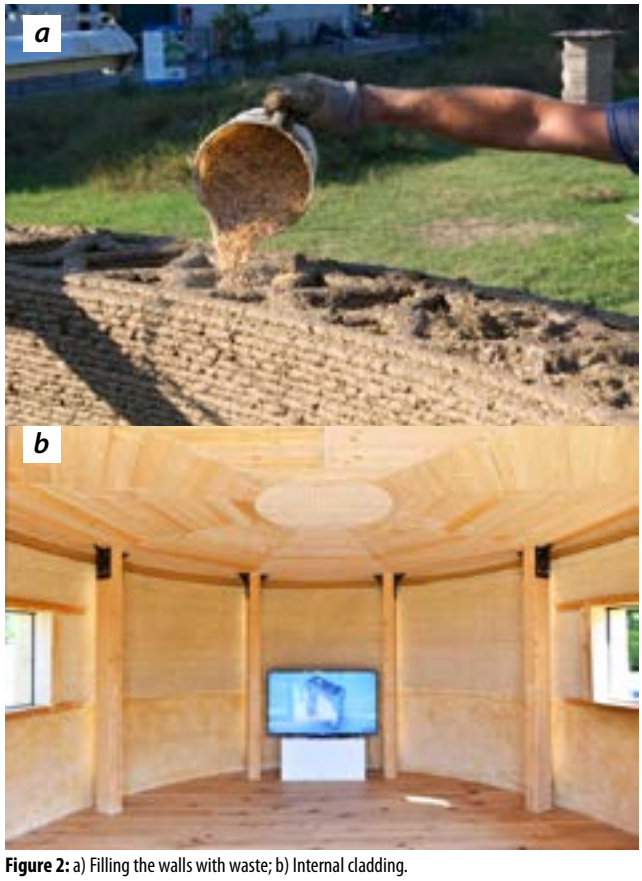

Figure 2: a) Filling the walls with waste; b) Internal cladding.
Source: (JORDAHN, 2019).

3.2 TECLA - 3D Printed House
a) General characteristics:

The TECLA (Technology and Clay) House is the result of a collaboratige research made by the SOS (School of Sustainability), the Mario Cucinella Architects and the 3D printing technology of WASP. The house is located in Massa Lombarda, Ravenna-Italy, and it aims to responds to the increasingly climate emergency, to the need for sustainable homes at Km0 and to the great global issue of the housing emergency, particularly in the context of urgent crises generated by large migrations or natural disasters (PINTOS, 2021).

For the building WASP's 3D printing technology Crane WASP was used. The 3D printer is modular and multilevel. It consists of a stationary fixture with two synchronized printer arms that can simultaneously print an area of 50 m^3 each (Figura 3b). The TECLA house brings together research on vernacular construction practices, the study of bioclimatic principles and the use of natural materials. It is a nearly zero-emission project that uses entirely local material, combining the matter and spirit of timeless ancient homes with the world of 21st-century technological production (PINTOS, 2021; WASP, 2019).

The TECLA House project is the result of a composition of two continuous elements that through a sinuous and uninterrupted sine curve culminate in two circular skylights (Figura 3a e b) (PINTOS, 2021).

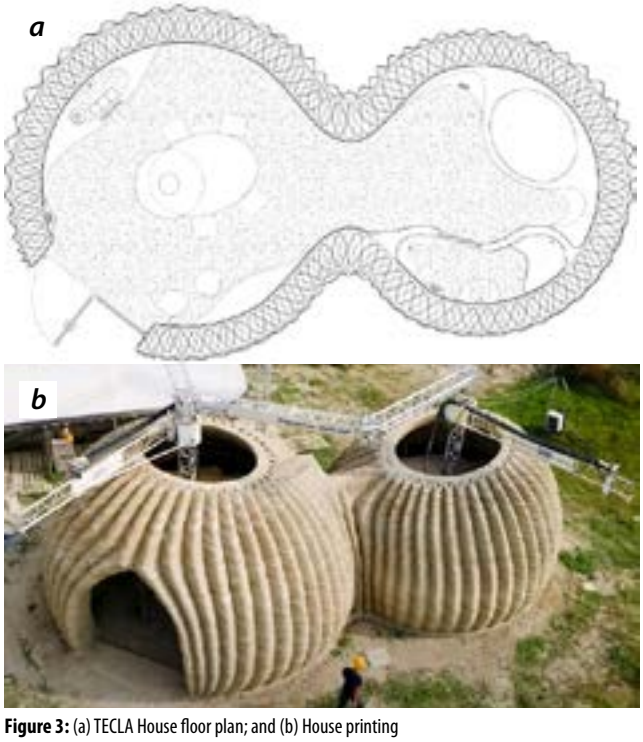

Figure 3: (a) TECLA House floor plan; and (b) House printing
Source: (PINTOS, 2021)

The shape designed enabled the structural balance of the construction, both during the 3D printing phase of the envelope and once the covering is completed (Figura 4a) (PINTOS, 2021).

With an area of about 60 m², it comprises a living zone with a kitchen and a night zone which includes services. The furnishings were partly printed in local soil and integrated into the raw-earth structure, and partly designed to be recycled or reused (Figura 4b). The house can be delivered with 200 hours of printing, 350 12 mm layers, 150 km of extrusion, 60 cubic meters of natural materials for an average consumption of less than 6 kW (PINTOS, 2021).

Figure 4: (a) TECLA house finished externally; (b) internally
Source: (PINTOS, 2021)

b) Printing material:

Mapei (2019) developed a specific mix-design with locally sourced soil in order to obtain a mix with rheological properties suitable for the printing phase and with mechanical properties suitable for the type of use. The mix is composed by a powdered stabilising agent used to consolidate soil (MAPESOIL, 100), a super-plasticising admixture (DYNAMON SR4), a synthetic latex rubber (PLANICRETE), and a ready-mixed water-repellent (PLANISEAL WR 100) applied with a spray bottle on dry facing walls, highly effective in waterproofing structures after just 12 hours.

c) Aspects related to thermal performance:

The composition of the earth mixture and the building's shape were designed to respond to local climatic conditions. The geometry of the envelope is parametrically optimised to balance thermal mass, insulation and ventilation according to the local climate needs (Figure 5a e b). The infilling material for thermal insulation consists of rice husk and rice straw from rice cultivation waste (PINTOS, 2021; WASP, 2019).

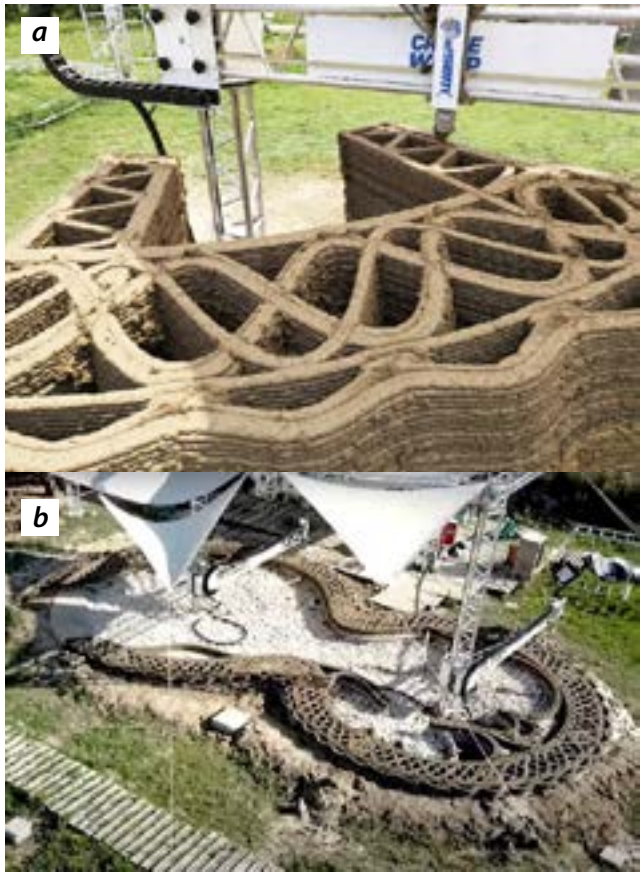

Figure 5: (a) and (b) Wall section geometry
Source: (WASP, 2019)

3.3 IAAC's Pylos, Digital adobe and TerraPerforma projects

a) General characteristics:

The Institute of Advanced Architecture of Catalonia (IAAC) has developed a series of applied research projects related to the digitization of soil-based materials produced using 3D printing. The Pylos project was the first to be developed by the IAAC, aimed at large-scale construction based on the use of biodegradable and recyclable soil, seeking to optimize the mix by using locally available natural materials. The research aimed to build printed soil columns to explore the potential for customizing the shape according to performance criteria and the technical advantages of the robotic production procedure (FIGLIOLA; BATTISTI, 2021; IAAC, 2024c). In addition, the project's main objective is to develop solutions for housing construction in developing countries, or in densely urbanized areas in developed countries. Due to the associated low cost, it should provide easier and cheaper access to housing for the neediest people. The estimated price is 0.5 euros per kilogram .

The project focuses on the natural properties of soil, whose main advantages are thermal insulation, fire protection, air circulation, low initial cost, recyclable structures, structural rigidity, low CO2 emissions and climate control. The importance of the chosen material (soil) for this additive manufacturing research is not only related to the unlimited quantity available, but also to the decrease in the emerging degree of energy incorporated into the manufacturing process, transportation risks, independent production of electricity and the availability of fuel (IAAC, 2024c; VALENCIA, 2015).

Based on the results of the Pylos project, the IAAC continues to examine the correlation between performance-based morphologies and robotic additive manufacturing through the Open Thesis Fabrication (OTF) research program. The Digital Adobe and TerraPerforma projects use the same material and method as Pylos, but with a focus on full-scale printing of unconventional shapes, such as modular curved walls, with self-shading properties and climate-appropriate performance design (IAAC, 2024a, 2024b; KONTOVOURKIS; TRYFONOS, 2020).

During OTF 2016/2017, TerraPerforma built a 1:1 scale experimental prototype (Figure 6a and b) to study optimized geometric patterns for thermal and structural performance, as well as analyzing a module to enable an easy and quick assembly process, directly on site. The modular approach was considered best due to the difficulties of taking a robot outdoors and facing adverse weather conditions. The modules are designed parametrically to perform optimally depending on solar radiation, wind behavior and the structural reasoning of 3D printing, both on their own and as a complete project (FIGLIOLA; BATTISTI, 2021).

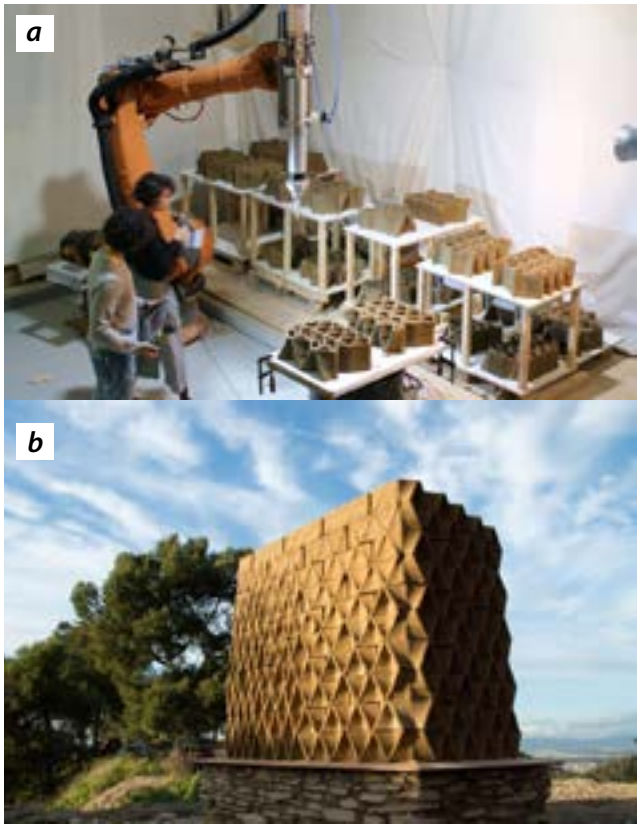

Figure 6: a) and b) Modules and 1:1 scale prototype of the TerraPerforma project.
Source: (IAAC, 2024a)

b) Printing material:

The material created by the IAAC is made up of 96% soil, plus additives to improve its characteristics.

c.1) Aspects related to the thermal performance of the TerraPerforma project:

The complex morphology of the external surface of the prototype developed by TerraPerforma was defined considering the angle of incidence of direct solar radiation and natural ventilation. The aim was to reduce the temperature of the external surface through self-shading in order to minimize radiation from the east and west directions, thereby reducing the thermal load required to provide cooling for a building (FIGLIOLA; BATTISTI, 2021). This way, during winter the conductivity of the facade

is maximized as there is maximum penetration, also, in comparison to a straight wall, there is a 436% rise in total radiation (GIRAUD, 2017).

The interior infill is divided into two zones. One zone is primarily optimized for structural performance with some thermal optimization, featuring small closed cavities that act as insulation. The other zone is optimized solely for thermal performance, containing large cavities of stagnant air. These large cavities, combined with the branched infill, significantly increase the thermal lag of the wall (GIRAUD, 2017).

In addition, the modules were designed to incorporate various types of openings in order to maximize the potential of natural light (the openings are strategically positioned and range from micro-openings to complete openings between the elements). The same panels were also designed to aid wind behavior through convection properties, as well as the placement of the micro-perforation that would direct the airflow. To this end, simulations and physical tests were carried out on prototype walls (Figure 7a and b), testing solar radiation, daylight, thermal conductivity, convection, thermal mass and structural behavior (DUBOR; CABAY; CHRONIS, 2018).

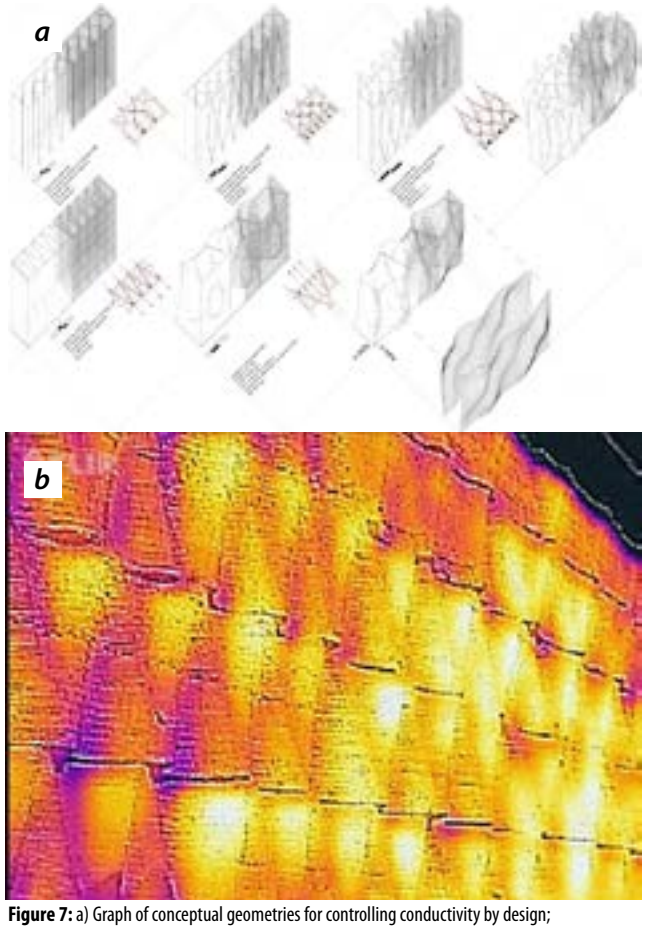

Figure 7: a) Graph of conceptual geometries for controlling conductivity by design; b) thermographic analysis.
Source: (IAAC, 2024a)

In general, the research conducted by TerraPerforma investigates how thermal properties can be integrated into wall sections through the intelligent design of infill. Specifically, it examines the potential for controlling thermal lag by managing conductance. This goal can be achieved by exploring the relationship between various infill patterns and the air-filled hollow cavities within the wall (GIRAUD, 2017).

Digital Adobe:

Digital Adobe is a research project on 3D printing for Performative Habitat, which was developed in the OTF 2017-18 program. The research concluded with the construction of a 1:1 prototype (Figure 8a and b) of a wall that adapts its morphology to local structural and climatic needs (IAAC, 2024a).

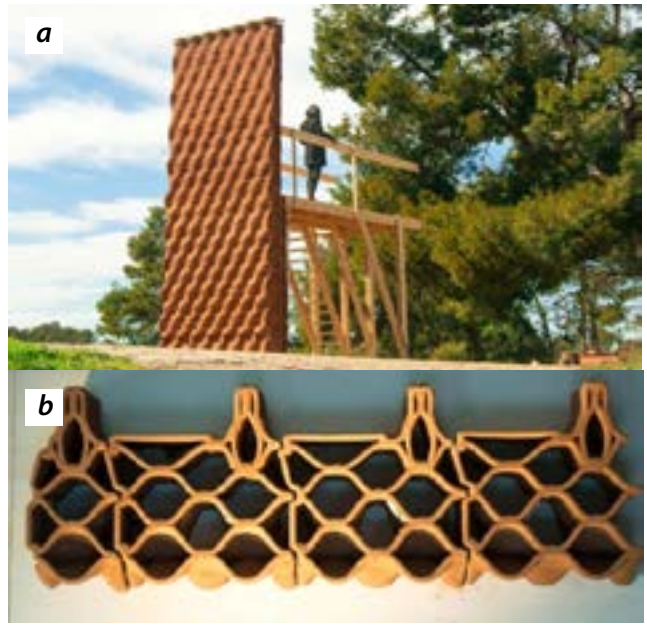

Figure 8: a) Wall built by the Digital adobe; b) wall modules.
Source: (IAAC, 2024a)

c.2) Aspects related to the thermal performance of the Digital Adobe project:

In this study, a ventilated wall design was developed, with operable openings at the top and bottom, to reduce heat gain in summer through convection between the openings and to retain heat in winter when the openings are closed. The external geometry consists of a surface of protrusions for self-shading, optimizing cooling in summer and the absorption of solar radiation in winter, taking into account the solar incidence angles of the site (Barcelona), so that the west direction has greater heat

gain, while the east direction has less heat gain depending on the solar incidence throughout the day. Thus, there is more thermal mass and less ventilation on the west wall, and less thermal mass and more ventilation on the east wall. The internal wall cavities are filled with earth to act as thermal mass and with air for insulation. The final project resulted in 99 individual elements, assembled in 5 days on the campus of the IAAC Laboratory in 2018 (IAAC, 2024a).

3.4 3D printed Cob

a) General characteristics:

3D printed Cob is an applied research that explores a construction technique based on robotically extruded subsoil and local organic fibers. This technique is an attempt to examine the transition from vernacular construction to a digitally enabled process. In a study carried out by researchers (GOMAA *et al*., 2019), the thermal conductivity of four 3D-printed samples is evaluated and the result is then compared with seven samples that were built using manual techniques. The printed samples have dimensions of 300×300×90 mm and the manually constructed samples have 300×300×70 mm. The samples were printed at Cardiff University, UK, using a Kuka KR60HA robot and a customized material extrusion system.

Each sample took around two hours to produce and was designed to represent a different thermal wall insulation solution. The first was designed as a solid wall; the second as a double-layer wall with a single continuous air space; the third as a triple-layer wall with air pockets; and the fourth was designed as a double-layer wall with straw-filled pockets (Figure 9) (GOMAA *et al*., 2019).

b) Printing material:

Mixture of subsoil (72-73 %), fiber (2 %) and water (25-26 %). The subsoil used is composed of clay (21.5 %) and aggregate/sand (79.5 %) (GOMAA *et al*., 2019).

c) Aspects related to thermal performance:

To assess the thermal performance of the material, thermal conductivity tests were carried out with a heat flow meter. The results show that the four samples have approximate thermal conductivity (0.32, 0.37, 0.40, 0.48 W/mk), with a 10% difference between them. However, it can be seen that the cavities in the three samples affect their performance and provide relatively better conductivity in relation to their density manufacturing (GOMAA et al., 2019).

In addition, the results indicate that the combination of air cavities with the addition of straw significantly improves conductivity in relation to its density. Specifically, the straw-filled airlock sample showed a 15.0% improvement in conductivity (0.32 W/mk) and an 8.0% increase in density compared to the airlock sample without straw. In terms of absolute conductivity, this sample showed the best result among the printed samples due to its lower conductivity, regardless of density. Although the 3D printed samples did not significantly outperform the handmade samples, the research results suggest that 3D printing can be used without compromising construction performance, revealing further research opportunities by exploring the additional benefits of robotic manufacturing (GOMAA et al., 2019).

Figure 8: Solid prototype, single slit prototype with straw filling and double slit prototype.
Source: (GOMAA et al., 2019)

3.5 Analytical overview

Based on the 5 cases analyzed in this research, an analytical synthesis was made in Table 1 with the main strategies used to improve the thermal performance of the buildings.

Case	Printing material	Strategies
3D WASP	Soil (25%), rice straw (40%), rice husk (10%), hydraulic lime (10%) and muller	- Internal cavities filled with rice waste for thermal insulation. - Rice husks used for internal lining and as an insulation layer on the top of the roof. - Roof with eaves to protect from direct solar radiation.
Terra Perfor-ma	Soil (96%) and additives (4%)	- Complex morphology of the external surface designed for self-shading. - Modules designed to incorporate various types of openings: micro-openings and windows. - Micro-perforations that direct air flow
Digital Adobe		- Ventilated wall with operable openings. - External geometry with protrusions for self-shading. - Internal wall cavities filled with earth for thermal mass and air for thermal insulation.
TECLA House	Soil, powdered stabilising agent, super-plasticising admixture, synthetic latex rubber, ready-mixed water-repellent	- Composition of the earth mixture. - Building shape. - Wall section geometry. - Infilling material: rice husk and rice straw.
3D Printed Cob	Subsoil (72-73 %), fiber (2 %) and water (25-26 %)	- Walls with air cavities and added straw showed the best conductivity in relation to density.

Table 1: Synthesis of the main strategies for improving the thermal performance of applied research

Source: Authors

4. FINAL CONSIDERATIONS

The analysis of the applied research carried out in this study indicates that additive manufacturing with soil-based materials has the potential to reintroduce traditional materials into contemporary design, and can meet current demands for sustainability, energy efficiency and cost in construction, with greater precision and surface quality, which is often not possible with traditional techniques.

The printing materials used in the research analyzed vary in terms of composition and percentage of additives and additions, demonstrating a wide range of possibilities. It also uses local resources in the composition of the mixture, which indicates the possibility of adapting soil-based 3D printing to the local context.

With regard to thermal performance, it was observed that, in general, the applied research that was analyzed in this study takes advantage of the natural properties of the soil, which has thermal insulation as one of its main advantages. However, they use different design and construction strategies to improve the thermal performance of fences using 3D printing technology, such as: filling internal cavities with materials such as rice waste, earth or straw (3D WASP, TETRA house, Digital Adobe and 3D Printed Cob); using parametric design and digital fabrication to create complex self-shading morphologies (TETRA house, TerraPerforma and Digital

Adobe); ventilated wall systems with operable openings (Digital Adobe), among other strategies.

It is observed that the complex geometries and the ability to control matter on a large scale can only be achieved thanks to the precision of 3D printing technology, giving the necessary liberty to integrate the design parameters into the final design and construction.

Finally, this study highlights the potential solutions that can be explored with Additive Manufacturing to improve the thermal performance of 3D-printed buildings using soil-based materials, adapting building elements in a personalized and optimized way to local needs.

REFERENCES

AKMAN, A.; SADHU, A. Recent Development of 3D-Printing Technology in Construction Engineering. **Practice Periodical on Structural Design and Construction**, v. 29, n. 1, 2024.

ALHUMAYANI, H. et al. Environmental assessment of large-scale 3D printing in construction: A comparative study between cob and concrete. **Journal of Cleaner Production**, v. 270, p. 122463, 2020.

AL-OBAIDI, K. M. et al. Biomimetic building skins: An adaptive approach. **Renewable and Sustainable Energy Reviews**, v. 79, p. 1472–1491, 2017.

BARDIN, L. **Análise de conteúdo**. Rio de Janeiro: Edições 70, 1991.

COSTA, F. N.; RIBEIRO, D. V. Reduction in CO2 emissions during production of cement, with partial replacement of traditional raw materials by civil construction waste (CCW). **Journal of Cleaner Production**, v. 276, p. 123302, 2020.

DUBOR, A.; CABAY, E.; CHRONIS, A. Energy Efficient Design for 3D Printed Earth Architecture. In: HUMANIZING DIGITAL REALITY. Singapore: Springer Singapore, 2018. p. 383–393.

EL-MAHDY, D.; GABR, H. S.; ABDELMOHSEN, S. SaltBlock as a 3D printed sustainable construction material in hot arid climates. **Journal of Building Engineering**, v. 43, 2021.

FIGLIOLA, A.; BATTISTI, A. **Post-industrial Robotics**. Singapore: Springer Singapore, 2021.

FRATELLO, V. S.; RAEL, R. Innovating materials for large scale additive manufacturing: Salt, soil, cement and chardonnay. **Cement and Concrete Research**, v. 134, p. 106097, 2020.

GIRAUD, I. **Incorporating thermal performance in clay 3D printing**. 2017. Disponível em: https://www.iaacblog.com/programs/incorporating-thermal-performance-clay-3d-printing/. Acesso em: 14 jul. 2024.

GOMAA, M. et al. Thermal performance exploration of 3D printed cob. **Architectural Science Review**, v. 62, n. 3, p. 230–237, 2019.

IAAC. **Digital Adobe.** 2024. Disponível em: https://iaac.net/project/digital-adobe/. Acesso em: 20 fev. 2024a.

IAAC. **PYLOS.** 2024. Disponível em: https://iaac.net/project/Pylos/. Acesso em: 20 fev. 2024b.

IAAC. T**erraPerforma – OTF 2016/2017.** 2024. Disponível em: https://iaac.net/project/terraperforma/. Acesso em: 20 fev. 2024c.

INTERNATIONAL ENERGY AGENCY. **Global energy & CO2 status report**. 2018. Disponível em: https://www.iea.org/reports/global-energy-co2-status-report-2019. Acesso em: 20 fev. 2024.

JORDAHN, S. **3D-printed Gaia house is made from biodegradable materials**. 2019. Disponível em: https://www.dezeen.com/2019/02/27/gaia-wasp-3d-printed-house-biodegradable-video/. Acesso em: 20 fev. 2024.

KONTOVOURKIS, O.; TRYFONOS, G. Robotic 3D clay printing of prefabricated non-conventional wall components based on a parametric-integrated design. **Automation in Construction**, v. 110, p. 103005, 2020.

LIBRELOTTO, L. I.; et a. O Design, Os Materiais Naturais E As Bolhas: Alternativas Mais Sustentáveis Para A Construção. **Plural Design**, v. 6, p. 5-17, 2023

LOPES, G. T. F. **Exploração das possibilidades da impressão 3D na construção**. 2016. Mestrado em Engenharia Civil - Faculdade de Engenharia da Universidade do Porto, 2016. Disponível em: https://core.ac.uk/download/pdf/143393036.pdf. Acesso em: 20 fev. 2024.

MAPEI. **Mapei research and technology for TECLA**. 2019. Disponível em: https://www.mapei.com/it/en/news/event-detail/2019/11/04/mapei-research-and-technology-for-tecla. Acesso em: 14 jul. 2024.

NAÇÕES UNIDAS. **Os Objetivos de Desenvolvimento Sustentável no Brasil**. 2024. Disponível em: https://brasil.un.org/pt-br/sdgs. Acesso em: 20 fev. 2024.

PATRICIO-KARNOPP, Z. M. **O processo ético e estético de pesquisar: um movimento qualitativo transformando conhecimentos e a qualidade da vida individual-coletiva**. Florianópolis: Núcleo de Estudos das Águas/UFSC/CNPq, 2004.

PERROT, A.; RANGEARD, D.; COURTEILLE, E. 3D printing of earth-based materials: Processing aspects. **Construction and Building Materials**, v. 172, p. 670–676, 2018.

PESSOA, S. et al. 3D printing in the construction industry - A systematic review of the thermal performance in buildings. **Renewable and Sustainable Energy Reviews**, v. 141, p. 110794, 2021.

PINTOS, P. **TECLA Technology and Clay 3D Printed House / Mario Cucinella Architects**. 2021. Disponível em: https://www.archdaily.com/960714/tecla-technology-and-clay-3d-printed-house-mario-cucinella-architects. Acesso em: 14 jul. 2024.

SOOD, G. **Gaia is the World's First 3D Printed Mud House**. 2018. Disponível em: https://www.homecrux.com/gaia-is-the-worlds-first-3d-printed-mud-house/110107/#google_vignette. Acesso em: 20 fev. 2024.

TEIXEIRA, J. et al. A road map to find in 3D printing a new design plasticity for construction – The state of art. **Frontiers of Architectural Research**, v. 12, n. 2, p. 337–360, 2023.

VALENCIA, N. https://www.archdaily.com.br/br/776401/pylos-a-impressora-3d-que-imprime-com-terra. 2015. Disponível em: https://www.archdaily.com.br/br/776401/pylos-a-impressora-3d-que-imprime-com-terra. Acesso em: 20 fev. 2024.

VALENTE, M.; SIBAI, A.; SAMBUCCI, M. Extrusion-Based Additive Manufacturing of Concrete Products: Revolutionizing and Remodeling the Construction Industry. J**ournal of Composites Science**, v. 3, n. 3, p. 88, 2019.

WASP. **DeltaWASP Crane**. 2024. Disponível em: https://deltawasp.com.au/shop/deltawasp-crane/. Acesso em: 20 fev. 2024.

WASP. **TECLA**. 2019. Disponível em: https://www.3dwasp.com/en/3d-printed-house-tecla/. Acesso em: 14 jul. 2024.

WENG, Y. *et al*. Comparative economic, environmental and productivity assessment of a concrete bathroom unit fabricated through 3D printing and a precast approach. **Journal of Cleaner Production**, v. 261, p. 121245, 2020.

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CRediT Taxonomy (http://credit.niso.org/)

LTC: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, visualization, writing - original draft, writing - review & editing.

BMT: conceptualization, funding acquisition, methodology, project administration, supervision, visualization, writing - review & editing;

LIL: conceptualization, methodology, visualization, writing - review & editing;

MBF: conceptualization, methodology, visualization, writing - review & editing;

TGFG: conceptualization, funding acquisition, methodology, project administration, supervision, visualization, writing - review & editing.

Conflict declaration: nothing has been declared.

SUSTAINABLE URBAN TRANSFORMATION: THE CONNECTION BETWEEN ELECTRIC MOBILITY AND SMART GRID

TRANSFORMAÇÃO URBANA SUSTENTÁVEL: A CONEXÃO ENTRE MOBILIDADE ELÉTRICA E REDES INTELIGENTES

TRANSFORMACIÓN URBANA SOSTENIBLE: LA CONEXIÓN ENTRE MOVILIDAD ELÉCTRICA Y REDES INTELIGENTES

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ABSTRACT
The integration of electric mobility with Smart Grids represents a transformative strategy for the development of sustainable urban systems, characterized by a reduced carbon footprint and high energy efficiency. This article carries out a systematic review with a bibliometric approach on the intersection between these two concepts, exploring not only the operational and environmental advantages, but also the social and economic implications of this synergy in building smart cities. The results indicate that the combination of electric mobility and Smart Grids is a rapidly growing area of study, with a significant increase in publications in high-impact scientific journals. Authors from globally renowned institutions have contributed to the consolidation of this field of research, reinforcing its relevance in the context of sustainable urban policies. Furthermore, an analysis of the literature reveals that Smart Grids, by incorporating new communication and information technologies, not only enable the large-scale adoption of electric mobility, but also promote the integrated and efficient management of urban infrastructure. This interconnectivity between systems allows for better optimization of the use of resources, as well as supporting the transition to more sustainable and resilient urban mobility.

KEYWORDS
Electric Mobility Integrated. Smart Infrastructure. Multi-Level Adoption.

RESUMO
A integração da mobilidade elétrica com as Smart Grids representa uma estratégia transformadora para o desenvolvimento de sistemas urbanos sustentáveis, caracterizados por uma pegada de carbono reduzida e alta eficiência energética. Este artigo realiza uma revisão sistemática com abordagem bibliométrica sobre a interseção entre esses dois conceitos, explorando não apenas as vantagens operacionais e ambientais, mas também as implicações sociais e econômicas dessa sinergia na construção de cidades inteligentes. Os resultados indicam que a combinação de mobilidade elétrica e Smart Grids é uma área de estudo em rápido crescimento, com um aumento significativo de publicações em periódicos científicos de alto impacto. Autores de instituições renomadas globalmente têm contribuído para a consolidação desse campo de pesquisa, reforçando sua relevância no contexto das políticas urbanas sustentáveis. Além disso, a análise da literatura revela que as Smart Grids, ao incorporar novas tecnologias de comunicação e informação, não apenas viabilizam a adoção em larga escala da mobilidade elétrica, mas também promovem uma gestão integrada e eficiente

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da infraestrutura urbana. Essa interconectividade entre sistemas permite uma melhor otimização do uso de recursos, além de suportar a transição para uma mobilidade urbana mais sustentável e resiliente.

PALAVRAS-CHAVE
Mobilidade Elétrica Integrada. Infraestrutura Inteligente. Adoção Multinível.

RESUMEN
La integración de la movilidad eléctrica con las Smart Grids representa una estrategia transformadora para el desarrollo de sistemas urbanos sostenibles, caracterizados por una huella de carbono reducida y una alta eficiencia energética. Este artículo realiza una revisión sistemática con enfoque bibliométrico sobre la intersección entre estos dos conceptos, explorando no sólo las ventajas operativas y medioambientales, sino también las implicaciones sociales y económicas de esta sinergia en la construcción de ciudades inteligentes. Los resultados indican que la combinación de movilidad eléctrica y Smart Grids es un área de estudio en rápido crecimiento, con un aumento significativo de publicaciones en revistas científicas de alto impacto. Autores de instituciones de renombre mundial han contribuido a la consolidación de este campo de investigación, reforzando su relevancia en el contexto de las políticas urbanas sostenibles. Además, un análisis de la literatura revela que las Smart Grids, al incorporar nuevas tecnologías de comunicación e información, no sólo permiten la adopción a gran escala de la movilidad eléctrica, sino que también promueven la gestión integrada y eficiente de las infraestructuras urbanas. Esta interconectividad entre sistemas permite optimizar mejor el uso de los recursos, así como apoyar la transición hacia una movilidad urbana más sostenible y resistente.

PALABRAS CLAVE
Movilidad eléctrica integrada. Infraestructura inteligente. Adopción multinivel.

1. INTRODUCTION

At present, numerous automotive manufacturers and other key stakeholders are channeling substantial resources into the advancement and mass production of electric vehicles, positioning electric mobility as a central topic in global discourse and a significant driver of policy-making and political decision-making processes (Liu et al., 2013; Morte, 2016; Santos et al., 2021). Despite this progress, the establishment of a robust and efficient recharging infrastructure continues to be one of the pivotal challenges that must be addressed to facilitate the widespread dissemination of this transformative technology, which holds the potential to revolutionize urban mobility on a global scale (Ala et al., 2020).

Consequently, it becomes imperative to reconfigure and modernize the power grid to support the integration of novel technologies and accommodate the evolving load profiles that accompany electric mobility. In this regard, Smart Grids are emerging as a crucial innovation within global electricity networks (Santo et al., 2015), offering an advanced and intelligent infrastructure that can seamlessly integrate and efficiently manage the growing demands for electrical energy in a sustainable manner (De Abreu, D'Agosto and Marujo, 2024).

The transition to a low-carbon society necessitates significant advancements in complementary domains: renewable energy generation and electric mobility can only realize their full potential through the deployment of Smart Grids, which are indispensable for managing the complexities and variabilities inherent in these emerging technologies (Hu et al., 2016). Moreover, the integration of these intelligent networks not only enhances the efficiency of electric vehicle recharging but also fortifies the stability and resilience of the power grid, enabling dynamic and real-time coordination between energy production and consumption. This capability is essential for ensuring the sustainability and long-term viability of the urban environments of the future.

Smart Grids seek to transform the traditional electricity network using advanced automatic control and communication techniques and other forms of information technology. The main objective of a Smart Grid is to deliver the optimum amount of information and load control to customers, distributors and grid operators in order to reduce system demands and costs while increasing energy efficiency (Cecati et al., 2010). This study aims to carry out a literature review with a bibliometric approach to identify studies that address the benefits of electric mobility, which enables and is enabled by Smart Grid, through direct searches in the Web of Science database. The specific objectives are: (i) to present the evolution of publications and citations over the years; (ii) to identify the main journals and countries that publish the most studies on the subject; (iii) to verify the most recurrent keywords, including the interconnection network between them; and (iv) to provide an overview of the benefits of implementing the two technologies concurrently.

In order to fulfill its objectives, this study is structured as follows. Section 1 deals with the context, importance and objectives of the study. Section 2 deals with the methodological procedure used to conduct bibliographic searches, with a focus on bibliometrics. Section 3 discusses bibliometric analysis. Section 4 describes some of the main results of the research included in the research repository, highlighting the main potential of the union between electric mobility and the Smart Grid. Finally, Section 5 contains the final considerations, which contain recommendations for future studies.

2. METHODOLOGICAL PROCEDURE

This study consists of a literature review using a bibliometric approach to map the main studies dealing with the role of the Smart Grid in promoting electric mobility and vice versa. A growing number of studies have used bibliometric techniques in various disciplines to track the state of the art of a field and its evolution over time. In this sense, the search terms, inclusion and qualification criteria used, as well as the details for the search and extraction of the database, are presented in Table 1, where TS = Topic, which means the words that are searched in the titles, abstracts and keywords of the studies.

It was decided to use keywords in English due to the greater number of relevant studies in English. In addition, even studies published in other languages, such as Portuguese, Spanish or French, mostly have at least an Abstract in English. It is also worth noting that the keyword Smart Grid was combined with variations of electric mobility to further increase the sample coverage. It was decided to use the Web of Science databases, belonging to Clarivate Analytics, as the main search tool due to their diffusion in the academic community and the reliability of their selection standards (Ameen et al., 2018; Caviggioli and Ughetto, 2019). In addition, this database has satisfactory reach and coverage (Chen, 2010).

As a limitation, it is worth mentioning that the study used only one database (Web of Science) and did not consider publications in other databases such as Science Direct, Scielo and Scopus. It is also important to note that search terms can influence the results, so the articles included in the research repository are limited by the database and search terms used.

Criteria	Description
Topicst	TS= (Smart Grid* AND e-mobility) OR TS= (Smart Grid* AND electric vehicle*) OR TS= (Smart Grid* AND electric mobility)
Database	Web of Science
Indexes	SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI
Inclusion	(I) Time of coverage: all years of the database (1945 - 2021); and (II) Fit with the proposed objective.
Qualification	(I) Does the research present a well-founded literature review? (II) Does the study present technical innovation? (III) Are the contributions discussed? (IV) Are the limitations explicitly stated? and (V) Are the results and conclusions consistent with the pre-established objectives?
Date of Search	May 09, 2021, at 7:00 p.m.

Table 1: Description of the search strategies.

3. BIBLIOMETRIC RESULTS

The research of the Web of Science database revealed that a significant 2,806 publications were suitable for inclusion in the research repository, i.e. they met the inclusion and qualification criteria (quality and applicability). Figure 1 shows the evolution of publications on the subject over the years. This analysis is essential for assessing the level of expansion of the topic, as well as new opportunities for studies. Figure 1 shows that the first publication was recorded in 2008, with only 2 (0.07%) publications, which shows that the subject is extremely current. In addition, the subject continues to expand, peaking in 2018 with 352 (12.54%) publications.

It is also pertinent to evaluate the articles by source of publication, in order to identify which scientific journals and congresses are most interested in the subject. This allows researchers to direct their publication efforts towards scientific dissemination media that have a direct focus on the subject under study, avoiding the necessary waste of time. In this sense, Figure 2 shows the journals with a publication volume greater than or equal to 36. It shows that the publication sources that most deal with the subject are: IEEE - Transactions On Smart Grid, with 125 publications, Energies, with 112 publications, and IEEE - Power And Energy Society General Meeting PESGM, with 92 publications. It should also be noted that a total of 1,352 sources of publication on the subject were identified, which indicates a significant participation of the topic in the scope of relevant journals and congresses.

It was also considered pertinent to assess the countries of origin of the authors' educational institutions that have produced the most relevant articles on the subject. This shows which countries are doing the most research on the subject under investigation, as well as demonstrating the lack of investment in other countries. The countries with the highest number of publications are shown in Figure 3, which was developed using Excel software.

Figure 3 shows that most publications are concentrated in the United States of America, with 578 publications, followed by the People's Republic of China with 467 publications, and Canada with 217 publications. European countries such as Italy (178), Germany (153), and England (133) also have significant contributions, along with Australia (153) and India (165). These numbers indicate a strong presence of research in developed countries, reflecting their robust research infrastructures and funding capabilities.

Interestingly, many developing countries are also making notable contributions. Brazil, for example, currently ranks eighteenth with 51 publications, highlighting its growing academic interest and strengthening research infrastructure. Other developing countries such as Iran (128), South Korea (94), Turkey (43), Pakistan (38), and Malaysia (32) have shown substantial engagement in research, contributing valuable perspectives and findings. This demonstrates significant and growing involvement of developing nations in the global research landscape, approaching their more developed counterparts.

Overall, the participation of 89 countries with at least one publication on the subject highlights the collaborative and global nature of scientific research. Countries with fewer publications, such as Bangladesh, Morocco, and Vietnam, still add to the diversity of research perspectives. This global engagement is crucial for addressing complex transnational challenges and promoting innovation through a rich fabric of cultural and intellectual diversity. The combined efforts of developed and developing countries enhance collective knowledge and advance the field in a more inclusive and comprehensive manner.

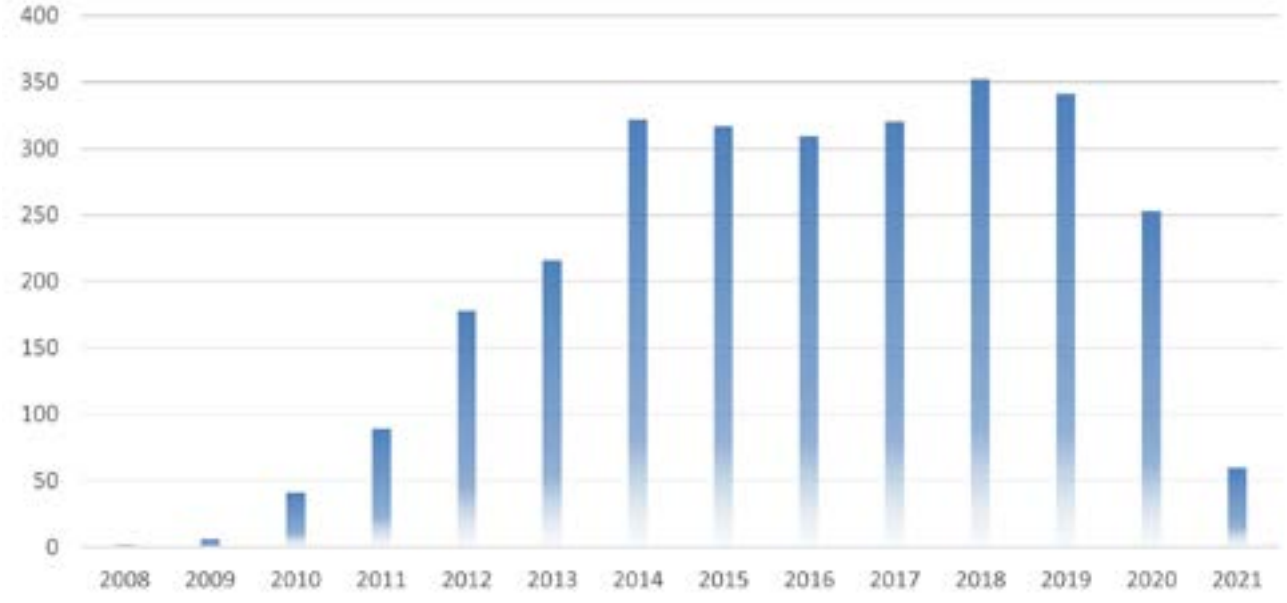

Figure 1: Evolution of publications by year.

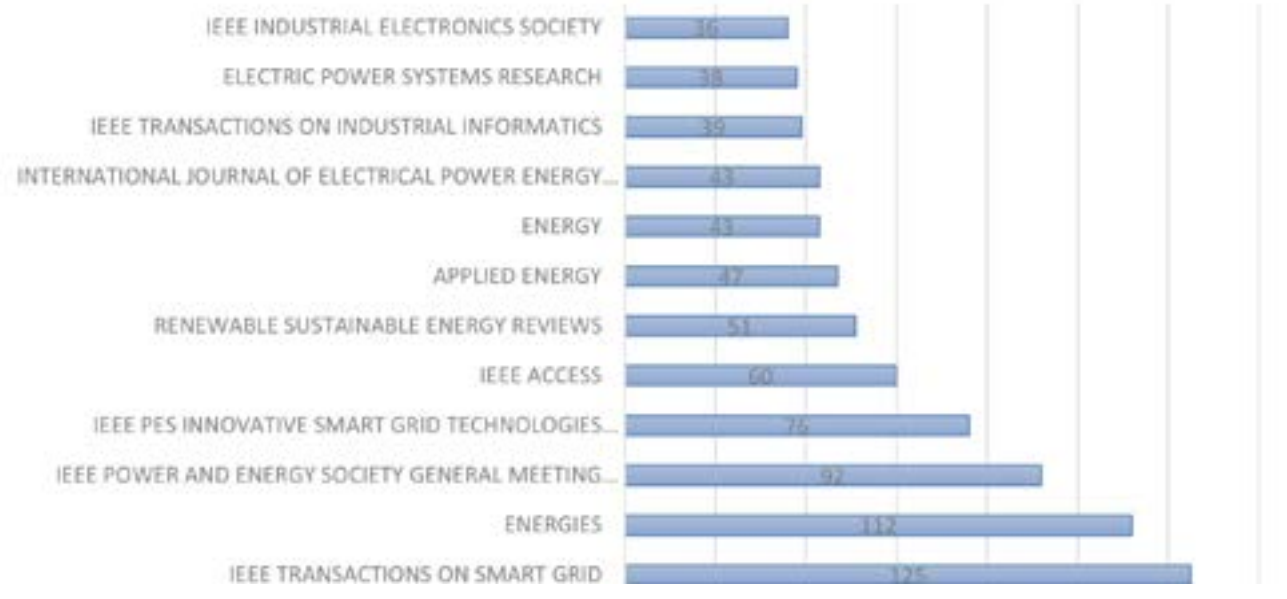

Figure 2: Main sources of publication of studies.

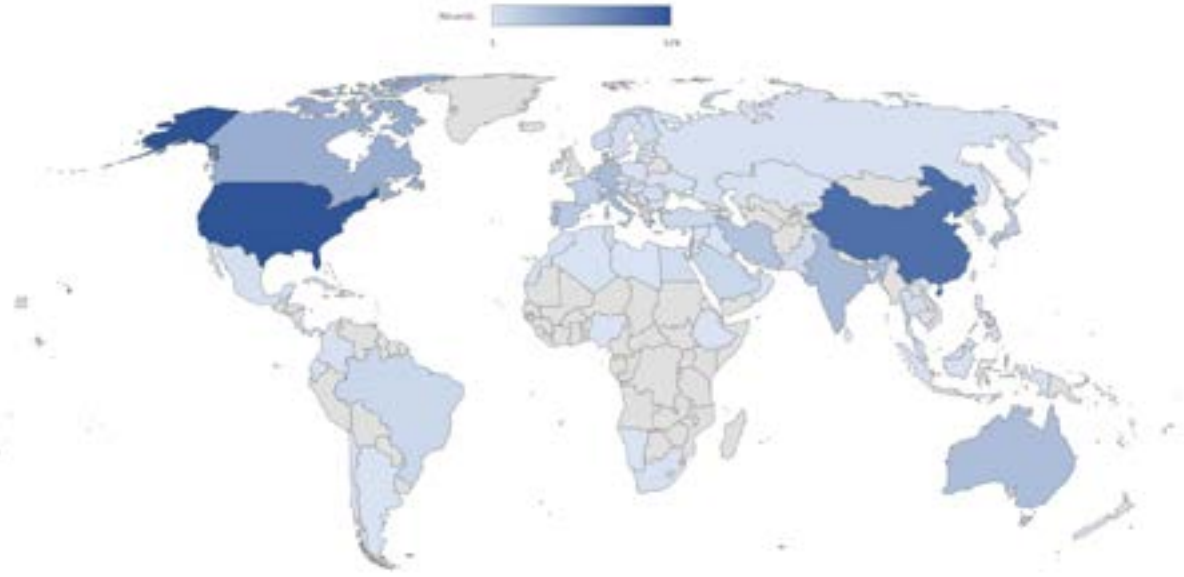

Figure 3: Main countries.

We also believe it is interesting to evaluate the main keywords found in the articles included in the research repository, as identified in the interconnection network between the keywords shown in Figure 4, developed with the help of the VOSviewer software. This strategy allows researchers to more easily find studies directly related to the subject under investigation, as well as to identify new research directions that can be taken.

In Figure 4, the network visually represents several key aspects: the prominence of specific keywords, indicated by the size of each sphere representing them; the relationships and interconnections between these keywords, illustrated by the connections between spheres; and the temporal relevance of these keywords, represented by the color coding of each sphere.

This visualization provides insights into various facets of research or discussion within the domain. It prominently features keywords related to advanced vehicle technologies, including plug-in electric vehicles, lithium-ion batteries, and power electronics. These technologies are pivotal in the development of sustainable transportation solutions and are central to ongoing research and innovation efforts worldwide.

Moreover, the network diagram includes keywords associated with electric charging infrastructure, such as smart charging strategies, smart charging schedules, and considerations for managing electrical peak demand. These aspects are critical in optimizing the efficiency and reliability of electric vehicle charging systems, addressing challenges related to grid integration and user convenience.

Additionally, the diagram highlights keywords related to network and user security, underscoring the importance of safeguarding data and ensuring secure interactions within smart mobility ecosystems. Terms like privacy, authentication protocols, and blockchain technology signify ongoing efforts to enhance cybersecurity and protect user information in the context of connected vehicle systems.

In summary, Figure 4 serves as a comprehensive visual representation that elucidates the multidimensional landscape of research and development in the field of advanced mobility technologies. It not only showcases the focal points of current discussions and innovations but also underscores the interconnectedness of various technological and security-related considerations shaping the future of smart transportation systems.

Another crucial aspect of analysis pertains to the number of citations per year, illustrated in Figure 5. This analysis, alongside the evolution of publications across different years, provides valuable insights into the increasing interest and impact of the subject over time. Figure 5 demonstrates that the first citation appeared in 2010, marking a significant milestone just two years after the initial publication. Since then, the number of citations has steadily increased each year, reflecting a growing recognition and relevance of the topic within academic and research communities. Notably, the peak in citations occurred in 2020, with a remarkable count of 1,250 citations, underscoring a substantial culmination of interest and engagement in the subject matter.

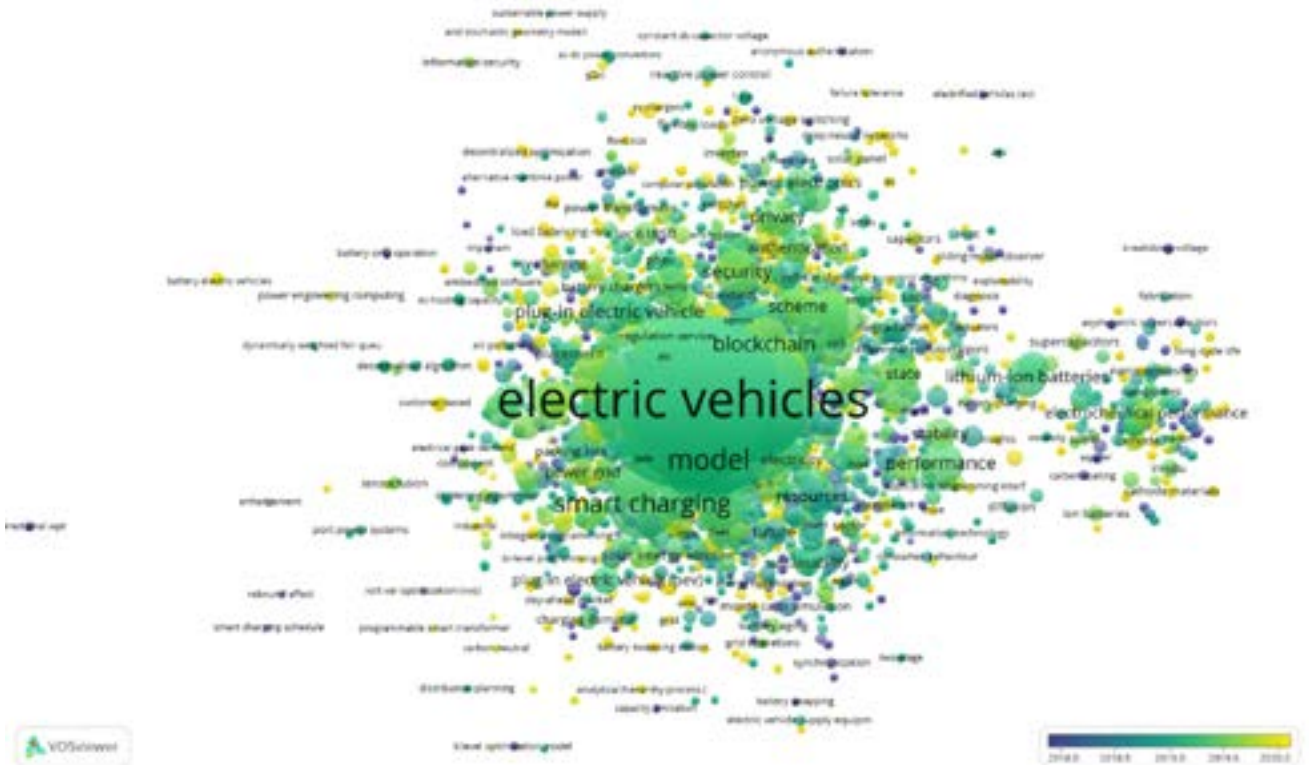

Figure 4: Main keywords.

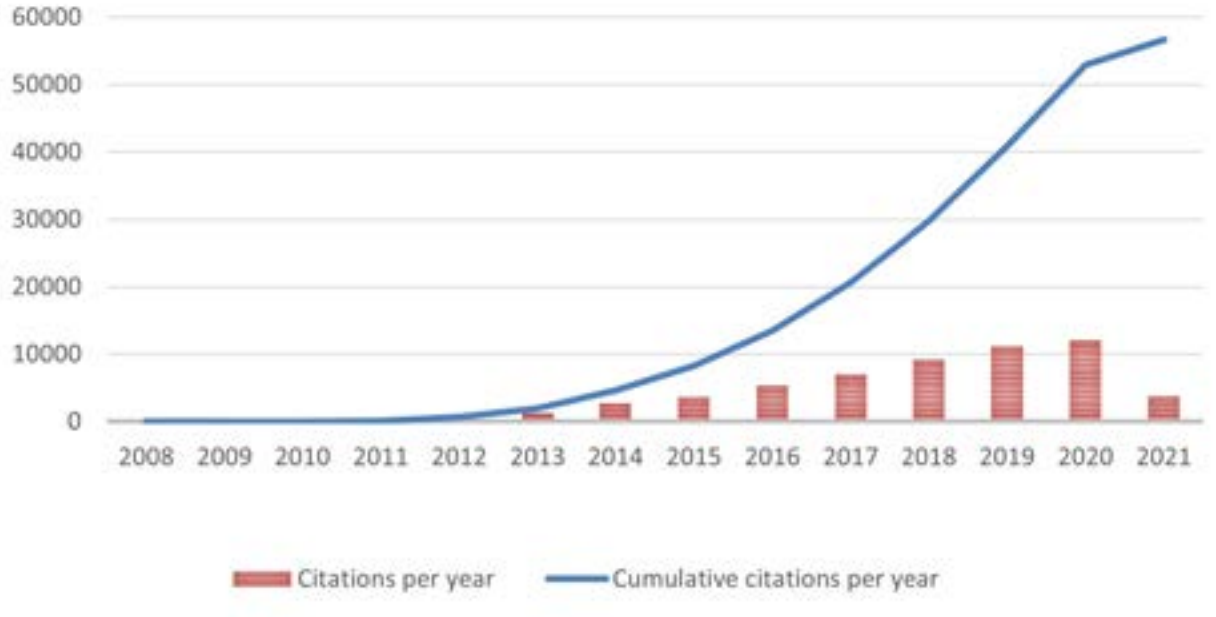

Figure 5: Evolution of citations by year.

This data reinforces the ongoing growth trajectory and sustained interest in the field. It highlights how research contributions have not only expanded but also garnered significant attention and acknowledgment within scholarly discourse. Such trends affirm the enduring importance and impact of the subject, motivating further exploration and advancement in related areas of study. It is also possible to determine the dispersion of citations of the most relevant studies in the database using Figure 6. It shows how the citations of each of the 10 most cited studies (TOP 10)

are distributed over the years. The study by Deilami et al. (2011) is the most significant in the database, with a certain stability in citations from 2012 to the present day. Other publications such as Tie and Tan (2013) and Su et al. (2012) also occupy a considerable part of the graph.

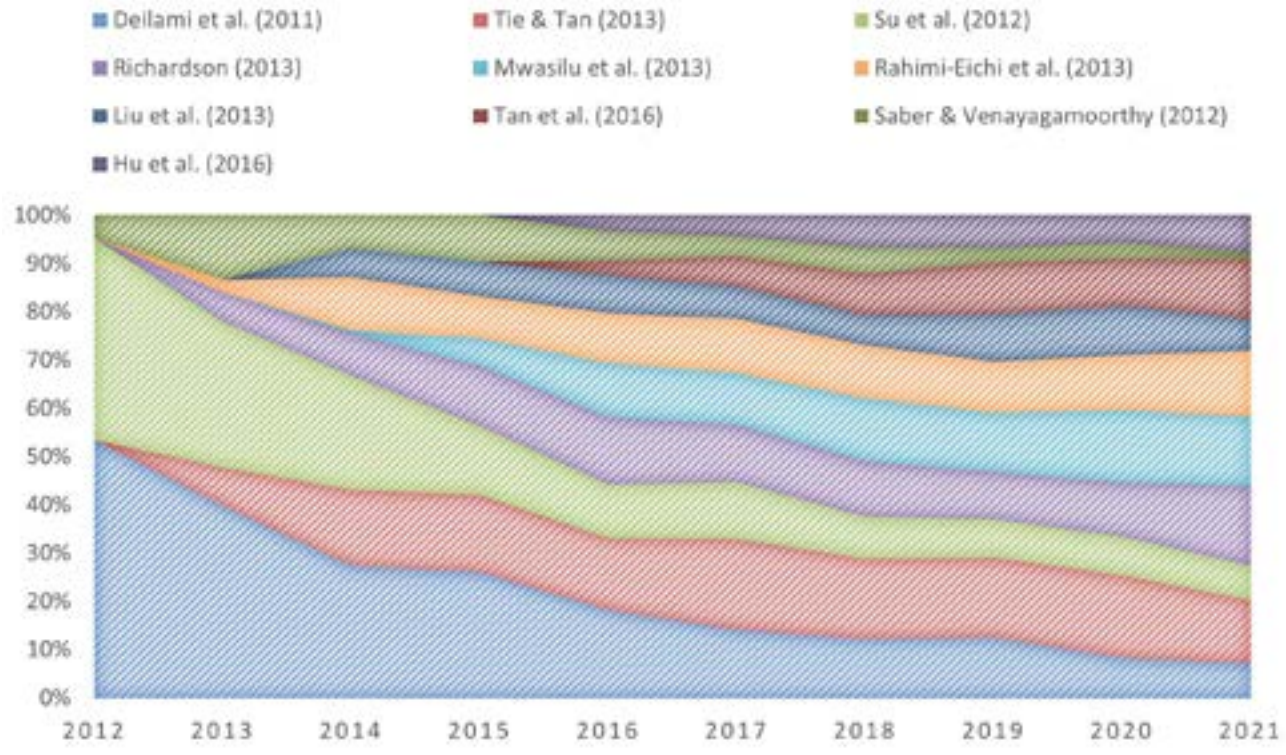

Figure 6: Distribution of citations of the most relevant studies by year (TOP 10).

4. ADVANTAGES OF INTEGRATING ELECTRIC MOBILITY AND THE SMART GRID

The modern network infrastructures employed in Smart Grids can play a key role in enabling innovative, sustainable and user-friendly urban services for all those involved in the business, allowing for energy efficiency, low carbon footprint systems and a more efficient city in terms of use (Hu et al., 2016), essential aspects for the development of a Smart City. Smart Grid is thus an electricity network capable of integrating actions by all stakeholders (e.g. customers, suppliers, government, etc.) in order to enable the recharging of electricity in a sustainable way (Curiale, 2014).

Smart grids are essential for integrating multiple forms of distributed generation of electricity from renewable sources, diversifying the energy matrix, reducing transmission losses and improving the reliability, security and efficiency of the power system (Carvalho, Perez and Granados, 2012; Richardson, 2013). These characteristics are achieved through automated controls, modern communication infrastructure and energy sensing, monitoring and management technologies, which are related to the Internet of Things - IoT (Gungor et al., 2011).

The irregular availability of most renewable energy sources requires the storage of electricity, usually using dedicated batteries (De Abreu, D'Agosto and Marujo, 2024). With the help of advanced electricity system management systems based on the Smart Grid, batteries can be used to store electricity and act as a "rotating power reserve" when peak demand occurs, for example by using the resources of electric vehicles that are idle (Ala et al., 2020). In a complementary way, for electricity providers, the electrification of vehicles offers a way to solve peak demand by supporting the stability of the local grid, without having to intervene in distant power generation facilities, thus reducing the burden on the grid structure at peak times (Aziz, Oda and Ito, 2016; Hu et al., 2016).

In addition, when electric vehicles are progressively integrated into Smart Grids, large amounts of data and information will be available to everyone involved with infrastructure and communication systems, providing new opportunities for companies operating in the automotive sector, such as influencing the competitiveness, market shares, business models and marketing strategies of current car manufacturers (Ala et al., 2020).

According to Curiale (2014), Smart Grids must: (i) modernize the energy system through self-healing projects, automation, remote monitoring and control; (ii) inform and educate consumers about energy use, costs and alternative options, to empower them to make decisions autonomously about how and when to use electricity and fuels; and (iii) provide secure and reliable integration of renewable and distributed energy resources. All this adds up to a more reliable, sustainable and resilient energy supply infrastructure.

The Smart Grids vision combines the use of traditional technology with innovative digital solutions that make the management of the existing distribution network more flexible through more effective information exchange (Rahimi-Eichi et al., 2013). Electricity grids are renewed to better accommodate the flow of all energy sources, especially renewables, optimize electricity flows, enable new services such as electric mobility and active demand (Curiale, 2014, De Abreu, D'Agosto and Marujo, 2024). Thus, the connections between electric vehicles and the Smart Grid are illustrated in Figure 7.

In the scheme shown in Figure 7, developed by Dileep (2020), the grid operator (labeled ISO) receives electricity from its electricity suppliers/generators (wind power plants, solar power plants, hydroelectric power plants, etc.) and transmits it to the urban infrastructure (consumers/customers) via the Smart Grid. This energy transmission can be supplied to electric vehicles both at individual recharging points (homes, for example) and in parking lots that have collective recharging stations. It is worth mentioning that all types of electric vehicles such as bicycles, scooters, cars and buses can be charged via Smart Grids.

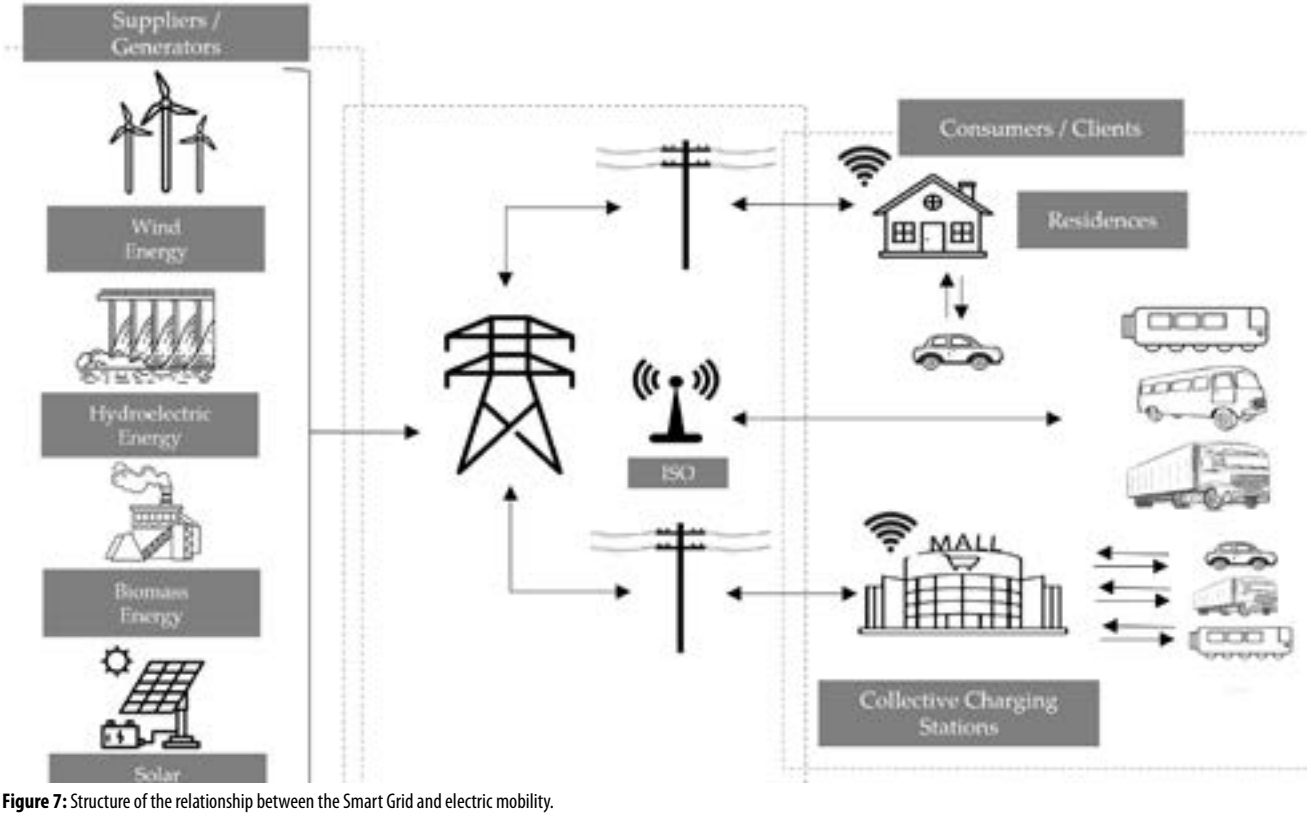

Figure 7: Structure of the relationship between the Smart Grid and electric mobility.
Source: Adapted from Dileep (2020).

The infrastructure for charging electric vehicles continues to expand. In 2019, there were around 7.3 million chargers worldwide, of which around 6.5 million were slow chargers for private light vehicles in single-family homes, multi-dwelling buildings and workplaces, due to benefits such as convenience, savings and a variety of support policies (such as preferential rates, incentives for equipment purchases and discounts) (International Energy Agency - IEA, 2020).

In addition, electric vehicles themselves can be used to store and subsequently supply electricity (in a bidirectional flow) when the system needs it and sends a control signal (Tan and Yong, 2016). This indicates that there are two possible types of energy interactions between the vehicle and the power grid: (i) G2V (Grid to Vehicle), which consists of a power grid supplying energy to the plug-in electric vehicle via a charging port; and (ii) V2G (Vehicle to Grid), in which a vehicle is able to supply energy back to the power grid, i.e. it stores energy that is used to compensate for peaks and valleys in electricity supply and demand and thus help optimize grid management (Mwasilu et al., 2014).

According to Dileep (2020), there are three main versions of the V2G concept, all involving an on-board battery, which are: (i) a hybrid or fuel cell vehicle; (ii) a battery-powered hybrid vehicle or a plug-in battery electric vehicle; or (iii) a solar vehicle. V2G technology can be employed, transforming each vehicle with its 20 to 50 kWh battery into a distributed load balancing device or emergency power source.

In addition to electricity suppliers, the company that owns the Smart Grid service and consumers/customers, other stakeholders also have an influence on the relationship between the Smart Grid and electric mobility, such as the government, regulatory bodies, society in general, the affected community, among others. The integration between electric mobility and the urban energy distribution network in a Smart Grid structure can favor the construction of a multi-stakeholder and multi-Internet ecosystem (Internet of Information, Internet of Energy and IoT) with cutting-edge computing resources supported, for example, by cloud-level services and with clean mapping between the logical and physical entities involved and their stakeholders (De Abreu et al., 2023; D'elia et al., 2015).

Figure 8 presents the necessary elements for effective integration between Electric Mobility Systems, including the interoperability of charging infrastructures, the compatibility of vehicles with different charging standards, and efficient communication between vehicles, power grids, and energy management systems. Additionally, it highlights the importance of cybersecurity, intelligent data management, and collaboration among manufacturers, energy providers, and regulatory authorities.

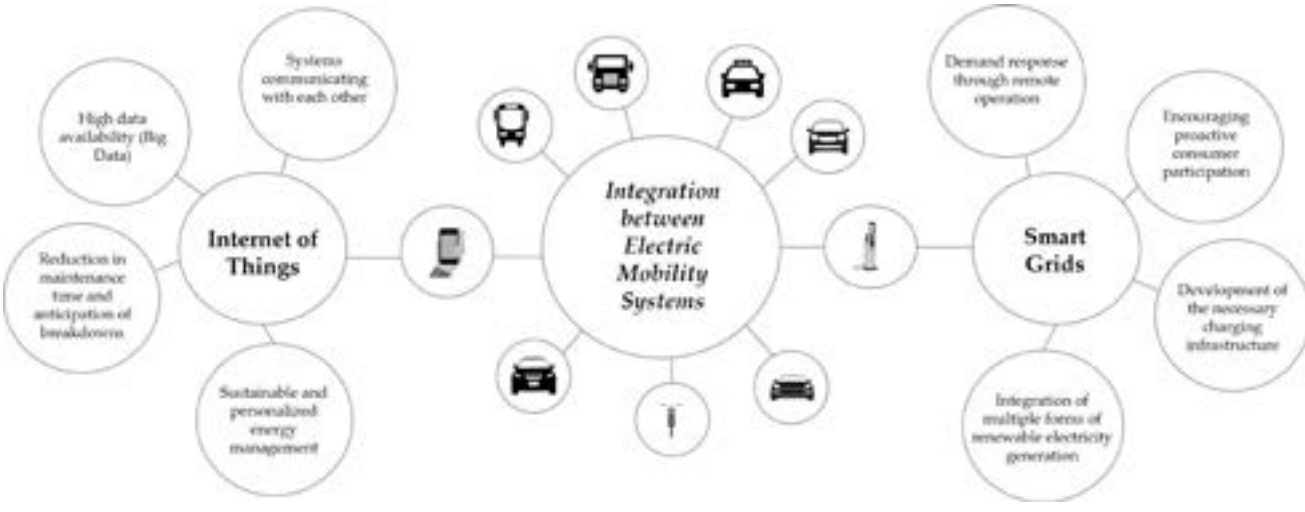

Figure 8: Elements for effective integration between Electric Mobility Systems.

It should also be noted that the Smart Grid has the potential to promote the multi-level adoption of electric mobility because, through the new communication and information technologies implemented, there is the possibility of better interaction between the systems that make up the urban mobility infrastructure, allowing various levels of access to transport facilities, which enable the same user to make use of different levels of electric vehicles (bicycles, scooters, cars, buses, etc.) in an integrated and intelligent way in cities of different sizes and technological profiles (De Abreu et al., 2023).

A Smart City that combines multi-level electric mobility and Smart Grids can help overcome the limits and contradictions of the current urban development model, characterized by a poor connection between the different resources available. However, it should not just be seen as a list of solutions, but as a multi-year holistic approach, therefore based both on planning projects and investments with a medium to long-term time horizon, and on involving multiple stakeholders (Ruggieri et al., 2021).

Through this multi-level adoption of electric mobility, the customer service system as a whole is expected to improve in terms of service level (accessibility, travel time, comfort, safety, etc.) and with tariff integration and service cost reduction (De Abre et al., 2023; De Assis et al., 2022a; De Assis et al., 2022b; Da Costa et al., 2022). In an efficient, open and constantly evolving Smart Grid system, customers become protagonists thanks to the use of electronic supports that make consumption transparent, encourage active participation in the energy market, improve the level of service and promote the conscious use of energy (Curiale, 2014).

Thus, according to Dileep (2020), the Smart Grid has the potential to: (i) reduce electricity prices paid by consumers; (ii) improve accessibility to services by consumers; (iii) increase the opportunities for choice of supply and information conveyed to the consumer; (iv) integrate renewable/unconventional distributed energy resources; (v) improve security by reducing the consequences and likelihood of natural disasters and man-made attacks; (vi) facilitate greater penetration of alternate sources of power generation; (vii) reduce loss of life and injury in grid-related events, thus reducing safety problems; (viii) improve overall efficiency by reducing energy losses and waste; and (ix) decrease environmental pollution by reducing greenhouse gas and air pollutant emissions and providing cleaner energy by promoting the deployment of renewable distributed energy resources.

According to the Department of Energy & Climate Change (Department of Energy & Climate Change, 2014), as the Smart Grid evolves, there will be more active roles for customers of different profiles - for example, domestic customers with smart meters can choose tariffs and make use of smart appliances that shift demand at peak times (for example, electric vehicles can be refueled at times with lower demand for energy and, consequently, a lower charge for energy consumption can be directed to the customer); large industrial and commercial customers can participate in a wide range of demand response and capacity market schemes, and small-scale generators can participate in demand response and capacity market schemes by adjusting exports to a grid.

Smart grids are thus the key to the success of a new idea of urban living: advanced, shared and sustainable (Mwasilu et al., 2014). In a smart, open and constantly evolving electricity grid system, customers become protagonists thanks to the use of electronic supports that make consumption transparent, encourage active participation in the energy market and promote the conscious use of energy (Curiale, 2014). These updated electricity grids with smart metering and monitoring capabilities, as well as two-way digital communication between supplier and consumer, have the capacity to predict and respond intelligently to the behavior and actions of all users connected to them, resulting in the efficient delivery of reliable, cost-effective data and sustainable electricity supply services (European Commission, 2011).

However, it is also worth mentioning that in order for all the aforementioned benefits to be met, it is necessary to increase the field of application of technologies by raising consumer awareness, especially among those who are unable to find relevant information or are exposed to confusing, untrustworthy or conflicting information about the use of electric vehicles, which reduces the rates of their diffusion and acceptance (Augenstein, 2015; Biresselioglu, Demirbag Kaplan and Yilmaz, 2018). This is because the ways in which individuals subjectively perceive technological innovation and how it can be integrated into their daily lives shape diffusion processes (Costa et al., 2021).

In this way, solutions to change the transportation habits and preferences of end users require an integrated approach, combining technological innovation, policy incentives, and user education (Künle and Minke, 2022). This approach involves the development and deployment of advanced electric vehicle technologies, improvements in battery efficiency, and the expansion of reliable charging infrastructure. Policy incentives, such as tax

rebates, subsidies, and grants for both manufacturers and consumers, play a critical role in reducing the initial cost barriers and making electric vehicles more accessible (De Abreu, D'Agosto and Marujo, 2024).

User education is also essential, as it helps to increase awareness and understanding of the benefits of electric mobility, addressing common misconceptions and highlighting long-term savings and environmental impacts. Effective communication strategies, community engagement programs, and demonstration projects can further enhance user acceptance and encourage behavior change. When designing models to encourage users to make a faster transition to electric mobility, it is crucial to consider a range of constraints:

- Technical Constraints: These include the development of efficient battery technologies with longer life spans and shorter charging times, the establishment of a widespread and accessible charging infrastructure, and the integration of electric vehicles with smart grids and renewable energy sources.
- Economic Constraints: Addressing the high upfront costs of electric vehicles through financial incentives, subsidies, and financing options is vital. Additionally, the economic implications of transitioning from fossil fuels to electric energy, such as impacts on employment in traditional automotive industries and energy sectors, must be managed.
- Social Constraints: Understanding and addressing social resistance to change, influenced by factors such as cultural attitudes, habits, and perceived reliability of electric vehicles, is essential. Efforts should be made to engage communities, provide adequate information, and create positive experiences with electric mobility.

Moreover, successful implementation depends on the collaboration between various stakeholders, including government bodies, industry players, and the public. Government policies and regulations need to support innovation and infrastructure development, while industry stakeholders must focus on producing affordable and high-quality electric vehicles. Public participation and feedback can guide improvements and ensure that the transition meets the needs and preferences of end users. Ultimately, a holistic and well-coordinated approach that integrates these elements is key to achieving a sustainable and widespread adoption of electric mobility (Pavić, Pandžić, and Capuder, 2020).

5. FINAL CONSIDERATIONS

This work aims to collect, collate, and evaluate the main studies on the implementation of electric mobility in parallel with the development of Smart Grids through a bibliographic review with a bibliometric approach. The bibliometric results indicate that the subject continues to expand, with a significant increase in publications peaking in 2018 and a surge in citations in 2020, ten years after the first publications on the topic. Notably, high-impact journals have published extensive studies on this subject, with IEEE Transactions on Smart Grid being the most recurrent in the database, demonstrating its central role in this research area.

Furthermore, this article underscores the complementary nature of electric mobility and Smart Grids, highlighting their combined potential to drive the development of sustainable and intelligent cities. This synergy not only enhances the overall quality and efficiency of the energy system but also empowers users to play a pivotal role as active participants. Through vehicle-to-grid (V2G) technologies, users can even become electricity suppliers, contributing to grid stability and resilience. These advancements are integral to the realization of smart cities that prioritize sustainability, energy efficiency, and an improved quality of life for their residents.

Given the ongoing evolution of this field and the significant potential it holds, there is a pressing need for further research. In Brazil, in particular, research on this subject remains limited. Therefore, it is advisable to conduct more extensive studies, including both narrative and systematic bibliographical reviews, to deepen the understanding of the interaction between electric mobility and Smart Grids. Future research should focus on critical aspects such as network security, user safety, and practical applications, including case studies of Smart Grid and electric mobility projects currently in the design phase. These studies will provide valuable insights and guide the successful implementation of these technologies, ensuring their contributions to a sustainable and intelligent future.

REFERENCES

Ala, G., Di Filippo, G., Viola, F., Giglia, G., Imburgia, A., Romano, P., … Miceli, R. (2020). **Different Scenarios of Electric Mobility:** Current Situation and Possible Future Developments of Fuel Cell Vehicles in Italy. Sustainability, 12(2), 564. https://doi.org/10.3390/su12020564

Ameen, W., Ghaleb, A. M., Alatefi, M., Alkhalefah, H., & Alahmari, A. (2018, October 2). An overview of selective laser sintering and melting research using bibliometric indicators. **Virtual and Physical Prototyping**, Vol. 13, pp. 282–291. Taylor and Francis Ltd. https://doi.org/10.1080/17452759.2018.1489973

Augenstein, K. (2015). Analysing the potential for sustainable e-mobility – The case of Germany. **Environmental Innovation and Societal Transitions**, 14, 101–115. https://doi.org/10.1016/j.eist.2014.05.002

Aziz, M., Oda, T., & Ito, M. (2016). Battery-assisted charging system for simultaneous charging of electric vehicles. **Energy**, 100, 82–90. https://doi.org/10.1016/j.energy.2016.01.069

Biresselioglu, M. E., Demirbag Kaplan, M., & Yilmaz, B. K. (2018). Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes. **Transportation Research Part A**: Policy and Practice, 109, 1–13. https://doi.org/10.1016/j.tra.2018.01.017

Carvalho, M., Perez, C., & Granados, A. (2012). An adaptive multi-agent-based approach to smart grids control and optimization. **Energy Systems**, 3(1), 61–76. https://doi.org/10.1007/s12667-012-0054-0

Caviggioli, F., & Ughetto, E. (2019, February 1). A bibliometric analysis of the research dealing with the impact of additive manufacturing on industry, business and society. International Journal of Production **Economics**, Vol. 208, pp. 254–268. Elsevier B.V. https://doi.org/10.1016/j.ijpe.2018.11.022

Cecati, C., Mokryani, G., Piccolo, A., & Siano, P. (2010). An overview on the smart grid concept. IECON 2010 - **36th Annual Conference on IEEE Industrial Electronics Society**, 3322–3327. IEEE. https://doi.org/10.1109/IECON.2010.5675310

Chen, X. (2010). **The Declining Value of Subscription-based Abstracting and Indexing Services in the New Knowledge Dissemination Era**. Serials Review, 36(2), 79–85. https://doi.org/10.1080/00987913.2010.10765288

Costa, E., Horta, A., Correia, A., Seixas, J., Costa, G., & Sperling, D. (2021). Diffusion of electric vehicles in Brazil from the stakeholders' perspective. **International Journal of Sustainable Transportation**, 15(11), 865–878. https://doi.org/10.1080/15568318.2020.1827317

Curiale, M. (2014). **From smart grids to smart city**. 2014 Saudi Arabia Smart Grid Conference (SASG), 1–9. IEEE. https://doi.org/10.1109/SASG.2014.7274280

da Costa, M. G., de Abreu, V. H. S., de Assis, T. F., da Costa, V. X., de Almeida D'Agosto, M., & Santos, A. S. (2022). Life Cycle Assessment and Circular Economy Strategies for Electric Vehicle: A Systematic Review on Mitigating Climate Change and Reducing Resource Depletion in Road Transportation. In **Environmental Footprints and Eco-Design of Products and Processes** (pp. 113–137). Springer. https://doi.org/10.1007/978-981-19-7226-3_5

De Abreu, V. H. S., D'Agosto, M. de A., Angelo, A. C. M., Marujo, L. G., & Carneiro, P. J. P. (2023). Action Plan Focused on Electric Mobility (APOEM): A Tool for Assessment of the Potential Environmental Benefits of Urban Mobility. **Sustainability**, 15(13), 10218. https://doi.org/10.3390/su151310218

De Abreu, V. H. S., D'Agosto, M. de A., Marujo, L. G. (2024). Strategic Connection: Exploring the Relationships between Electric Mobility and Smart Grid to Transform Urban Mobility. **ENSUS 2024 - XII Encontro de Sustentabilidade em Projeto**, Belo Horizonte, MG. https://doi.org/ 10.29183/2596-237x.ensus2024.v12.n1.p504-517

de Assis, T. F., Monteiro, T. G. M., de Abreu, V. H. S., D'Agosto, M. de A., & Santos, A. S. (2022a). **Enabling the Green Bonds Market for Sustainable Transport Projects Based on the Measure/Monitoring, Reporting and Verification Method**. https://doi.org/10.1007/978-981-19-7226-3_1

de Assis, T. F., Ricci, L. M., Monteiro, T. G. M., de Abreu, V. H. S., D'Agosto, M. de A., & Santos, A. S. (2022b). **Sustainable Transport Indicators and Mitigation Actions Applied to the Green Bond Principles**. https://doi.org/10.1007/978-981-19-7226-3_6

Deilami, S., Masoum, A. S., Moses, P. S., & Masoum, M. A. S. (2011). Real-Time Coordination of Plug-In Electric Vehicle Charging in Smart Grids to Minimize Power Losses and Improve Voltage Profile. **IEEE Transactions on Smart Grid**, 2(3), 456–467. https://doi.org/10.1109/TSG.2011.2159816

D'elia, A., Viola, F., Montori, F., Di Felice, M., Bedogni, L., Bononi, L., … Salmon Cinotti, T. (2015). **Impact of Interdisciplinary Research on Planning, Running, and Managing Electromobility as a Smart Grid Extension**. IEEE Access, 3, 2281–2305. https://doi.org/10.1109/ACCESS.2015.2499118

Department Of Energy & Climate Change. (2014). Smart Grid Vision and Routemap.

Di Santo, K. G., Kanashiro, E., Di Santo, S. G., & Saidel, M. A. (2015). **A review on smart grids and experiences in Brazil. Renewable and Sustainable Energy Reviews**, 52, 1072–1082. https://doi.org/10.1016/j.rser.2015.07.182

Dileep, G. (2020). A survey on smart grid technologies and applications. **Renewable Energy**, 146, 2589–2625. https://doi.org/10.1016/j.renene.2019.08.092

European Commission. (2011). E-mobility and Smart Grids at the JRC. The European Commission's in-house science service.

Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. (2011). Smart Grid Technologies: Communication Technologies and Standards. **IEEE Transactions on Industrial Informatics**, 7(4), 529–539. https://doi.org/10.1109/TII.2011.2166794

Hu, J., Morais, H., Sousa, T., & Lind, M. (2016). Electric vehicle fleet management in smart grids: A review of services, optimization and control aspects. **Renewable and Sustainable Energy Reviews**, 56, 1207–1226. https://doi.org/10.1016/j.rser.2015.12.014

International Energy Agency – IEA. (2020). Global EV Outlook 2020, IEA, Paris.

Künle, E., & Minke, C. (2022). Macro-environmental comparative analysis of e-mobility adoption pathways in France, Germany and Norway. **Transport Policy**, 124, 160–174. https://doi.org/10.1016/j.tranpol.2020.08.019

Liu, C., Chau, K. T., Wu, D., & Gao, S. (2013). **Opportunities and Challenges of Vehicle-to-Home, Vehicle-to-Vehicle, and Vehicle-to-Grid Technologies**. Proceedings of the IEEE, 101(11), 2409–2427. https://doi.org/10.1109/JPROC.2013.2271951

Morte, M. (2016). E-mobility and multiagent systems in smart grid. **2016 17th International Scientific Conference on Electric Power Engineering (EPE)**, 1–4. IEEE. https://doi.org/10.1109/EPE.2016.7521718

Mwasilu, F., Justo, J. J., Kim, E.-K., Do, T. D., & Jung, J.-W. (2014). Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. **Renewable and Sustainable Energy Reviews**, 34, 501–516. https://doi.org/10.1016/j.rser.2014.03.031

Pavić, I., Pandžić, H., & Capuder, T. (2020). Electric vehicle based smart e-mobility system – Definition and comparison to the existing concept. **Applied Energy**, 272, 115153. https://doi.org/10.1016/j.apenergy.2020.115153

Rahimi-Eichi, H., Ojha, U., Baronti, F., & Chow, M.-Y. (2013). Battery Management System: An Overview of Its Application in the Smart Grid and Electric Vehicles. **IEEE Industrial Electronics Magazine**, 7(2), 4–16. https://doi.org/10.1109/MIE.2013.2250351

Richardson, D. B. (2013). Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration. **Renewable and Sustainable Energy Reviews,** 19, 247–254. https://doi.org/10.1016/j.rser.2012.11.042

Ruggieri, R., Ruggeri, M., Vinci, G., & Poponi, S. (2021). Electric Mobility in a Smart City: European Overview. **Energies**, 14(2), 315. https://doi.org/10.3390/en14020315

Saber, A. Y., & Venayagamoorthy, G. K. (2012). Resource Scheduling Under Uncertainty in a Smart Grid With Renewables and Plug-in Vehicles. **IEEE Systems Journal**, 6(1), 103–109. https://doi.org/10.1109/JSYST.2011.2163012

Santos, A. S., de Abreu, V. H. S., de Assis, T. F., Ribeiro, S. K., & Ribeiro, G. M. (2021). **An Overview on Costs of Shifting to Sustainable Road Transport:** A Challenge for Cities Worldwide. In Environmental Footprints and Eco-Design of Products and Processes (pp. 93–121). Springer. https://doi.org/10.1007/978-981-15-9577-6_4

Su, W., Eichi, H., Zeng, W., & Chow, M.-Y. (2012). **A Survey on the Electrification of Transportation in a Smart Grid Environment.** IEEE Transactions on Industrial Informatics, 8(1), 1–10. https://doi.org/10.1109/TII.2011.2172454

Tan, K. M., Ramachandaramurthy, V. K., & Yong, J. Y. (2016). Integration of electric vehicles in smart grid: A review on vehicle to grid technologies and optimization techniques. **Renewable and Sustainable Energy Reviews**, 53, 720–732. https://doi.org/10.1016/j.rser.2015.09.012

Tie, S. F., & Tan, C. W. (2013). A review of energy sources and energy management system in electric vehicles. **Renewable and Sustainable Energy Reviews**, 20, 82–102. https://doi.org/10.1016/j.rser.2012.11.077

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ECOINFORMATION STRATEGIES PRESENT IN BRAZILIAN PACKAGING FOR CHILDREN

ESTRATÉGIAS DE ECOINFORMAÇÃO PRESENTES EM EMBALAGENS BRASILEIRAS VOLTADAS PARA O PÚBLICO INFANTIL

ESTRATEGIAS DE ECOINFORMACIÓN PRESENTES EN ENVASES BRASILEÑOS DIRIGIDOS AL PÚBLICO INFANTIL

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ABSTRACT

This paper aims to investigate how packaging design has been incorporated eco-information targeting children, as well as whether the verbal and non-verbal strategies used align with guidelines for promoting sustainability education. The research reported in this article has an exploratory bias and consisted of three phases. Initially, a field study was conducted in 7 supermarkets to collect and document packaging containing eco-information aimed at children. This was followed by data analysis focusing on the location and emphasis of eco-information on packaging surfaces. Lastly, an analysis was conducted using the instrument proposed by the research group to relate eco-information to guidelines for promoting sustainable education. The results highlighted the relation between verbal and non-verbal strategies adopted in packaging design for children and the guidelines for promoting sustainability education. They emphasized packaging as a vehicle for disseminating eco-information and its contribution to changing habits in the children's context.

KEYWORDS

Packing design; Ecoinformation; Design for sustainable behavior; promoting sustainability education.

RESUMO

O presente artigo objetivou investigar como o design de embalagem vem trabalhando a ecoinformação com foco no público infantil, bem como se as estratégias verbais e não verbais utilizadas estão alinhadas às diretrizes para promoção da educação em sustentabilidade. A pesquisa relatada neste artigo tem viés exploratório e consistiu em três fases, sendo inicialmente realizado um estudo de campo em 7 supermercados para coleta e registro de embalagens contendo ecoinformação com foco no público infantil, seguido pelo tratamento dos dados a partir da localização e ênfase das ecoinformações nas superfícies das embalagens e por fim, foi conduzida uma análise a partir do instrumento proposto pelo grupo de pesquisa a fim de relacionar as ecoinformações às diretrizes para promoção de educação sustentável. Os resultados apresentados expuseram a relação das estratégias verbais e não-verbais adotadas no design de embalagem voltadas ao público infantil às diretrizes para promoção da educação em sustentabilidade, enfatizando a embalagem como veículo para difusão de ecoinformação e sua contribuição para a mudança de hábitos no contexto infantil.

PALAVRAS-CHAVE

Design de embalagem; Ecoinformação; Design para o comportamento sustentável; promoção da educação em sustentabilidade.

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RESUMEN

El presente artículo tuvo como objetivo investigar cómo el diseño de envases ha estado trabajando la ecoinformación con enfoque en el público infantil, así como si las estrategias verbales y no verbales utilizadas están alineadas con las directrices para la promoción de la educación en sostenibilidad. La investigación reportada en este artículo tiene un enfoque exploratorio y consistió en tres fases: inicialmente se realizó un estudio de campo en 7 supermercados para la recolección y registro de envases que contienen ecoinformación con enfoque en el público infantil, seguido por el tratamiento de los datos a partir de la ubicación y énfasis de las ecoinformaciones en las superficies de los envases, y finalmente se llevó a cabo un análisis basado en el instrumento propuesto por el grupo de investigación con el fin de relacionar las ecoinformaciones con las directrices para la promoción de la educación sostenible. Los resultados presentados expusieron la relación de las estrategias verbales y no verbales adoptadas en el diseño de envases dirigidos al público infantil con las directrices para la promoción de la educación en sostenibilidad, enfatizando el envase como vehículo para la difusión de ecoinformación y su contribución al cambio de hábitos en el contexto infantil.

PALABRAS CLAVE

Diseño de envases; Ecoinformación; Diseño para el comportamiento sostenible; promoción de la educación en sostenibilidad.

1. INTRODUCTION

The environmental issue has prompted the development of strategies aimed at making products less harmful to the environment. In design, project guidelines based on the principles of environmental sustainability have led to the emergence of a new category of products known as "ecologically oriented products." These products provide greater environmental benefits or impose lower environmental costs compared to others (Orsato, 2002).

In the context of packaging design, the Brazilian Packaging Association (ABRE, 2023) defines "sustainable packaging" as those that protect the contents through solutions that optimize the use of environmental resources, while also allowing for the closure of the life cycle and the recycling or reuse of raw materials. With this approach, packaging has begun to reduce the damage caused by the high volume of consumption associated with its ephemeral nature.

However, while adopting sustainable design strategies is of great importance, the Akatu Institute (2019) emphasizes the role of information as a means to break down barriers between sustainable products and consumers. According to research conducted by the institute, access to information about sustainability acts as a trigger for conscious consumption.

Packaging design can provide solutions that contribute to promoting conscious consumption through strategies capable of informing consumers about sustainability-related topics. This is possible because packaging design considers not only functional and production aspects but also communicational aspects (Teixeira, 2011).

Eco-information involves strategies aimed at making sustainability-related information visible, understandable, and accessible, enabling users to reflect on their habits (Bhamra; Lilley; Tang, 2011). It falls within the dimension of design for sustainability, which aims to empower and promote responsible and sustainable consumption through education (Bhamra; Lilley; Tang, 2011).

The objective of this paper is to investigate whether and how packaging design has been incorporating eco-information on sustainability, with a focus on children. This is particularly relevant given that "one of the most important actions to protect the environment is to ensure that future generations also seek and practice ways to protect the environment" (Da Silva et al., 2022). To foster such attitudes, the role of early childhood education is crucial, as it is considered by UNESCO as a key period for establishing sustainable habits (Folque, 2017). This article questions whether packaging aimed at children adopts strategies that align with the guidelines for sustainability education through eco-information.

2. PACKAGING DESIGN AND ECOINFORMATION

To promote sustainability education, it is necessary to develop solutions that contribute to consumer learning, enabling them to acquire skills that make them aware of the impacts of their decisions (Santos et al., 2019). This approach is significant for systemic discontinuity, which seeks to shift the norm from the constant growth of production and material consumption to a society capable of developing even with a reduction in the consumption of material goods (Manzini, 2008). Manzini (2008) asserts that it is essential to guide individuals through a long, yet inevitable, process of social learning towards sustainable development. According to Santos et al. (2019), fostering learning about conscious consumption is central to systemic discontinuity, as only then will society truly become sustainable. The authors further state that:

> Opinions, attitudes, and the profile of everyday activities performed by consumers are directly affected by the effectiveness of educational actions. Therefore, actions in this direction have an amplified impact beyond the individual alone, influencing the habits and behaviors of other individuals and communities.

Bhamra, Lilley, and Tang (2011) argue that design can contribute to sustainability education through communicative elements that encourage consumers to reflect on their habits. Santos et al. (2019) suggest that consumer activities, opinions, and attitudes can be positively influenced by information related to social and environmental ethics. As an example, the author cites packaging, which, either subliminally or explicitly, demonstrates the capacity to guide consumers towards less harmful practices through communicative resources such as structural, graphic, and verbal elements - materials, colors, textures, and labels (Santos et al., 2019). This is possible because direct contact with the user has made packaging a valuable communication tool (Mestriner, 2002).

From this perspective, packaging is addressed not only from a functional dimension but also from an informational one, through the adoption of aspects that come together to create a visually perceived product that meets the demands of practical, aesthetic, and symbolic functions (Löbach, 2001). Regarding these aspects, Martins (2014) asserts that packaging permeates various types of communication, as observed in the following table:

Visual communication in packaging	
Types	**Description**
Verbal	Literal components such as: product designation, ingredients, nutritional information, specific characteristics, usage instructions, among others.
Non verbal	Literal components such as: product designation, ingredients, nutritional information, specific characteristics, usage instructions, among others.
Shape	Literal components such as: product designation, ingredients, nutritional information, specific characteristics, usage instructions, among others.

Table 01: Visual communication in packaging.
Source: Authors.

Munari (2009) states that visual communication occurs through various messages and can have an intentional character, achieved through prior planning. In this way, it is possible to develop messages aimed at conveying specific information, ideas, or values using visual resources that contribute to the promotion of sustainability education

The potential of packaging design to disseminate sustainability education becomes evident, by crafting messages that encourage consumers to: understand the concept of sustainability and its importance in building a healthy society; adopt conscious attitudes regarding the selection, use, and consumption of products offered in the market; take positions, according to their own value judgments, in relation to the objects that constitute their material culture; understand the implications of human behavior on current social and environmental issues and the environmental impacts generated by human activity (Anthropocene); and comprehend the relationships between society and the environment in modern society (Santos et al., 2019).

The aforementioned guidelines are associated with promoting sustainability education according to Santos et al. (2019). For the authors, these strategies are effective in "altering not only isolated consumption patterns but also in comprehensively adopting new lifestyles".

3. METHODOLOGICAL PROCEDURES

The research presented in this article was guided by a phenomenological approach, aiming to understand the variables and their nature. "Knowledge according to this philosophical perspective is developed from a holistic, socially constructed, and multidimensional viewpoint" (Santos, 2018). As for the nature of the research, it is characterized as applied, aiming to generate knowledge directed toward praxis, focused on solving specific problems (Prodanov; Freitas, 2013), with a focus on eco-information strategies used on packaging surfaces to promote sustainability education among children. In terms of objectives, the research has an exploratory bias, aimed at providing information on the investigated topic, enabling the formulation of hypotheses (Prodanov; Freitas, 2013). The research development occurred through the execution of the following phases:

Methodological Procedures	
Phases	**Description**
1. Data collection	Field study conducted in 7 supermarkets located in the city of Campina Grande for photographic documentation of food packaging, following the parameters: (1) Focus on the child audience; and (2) Graphic, verbal, or non verbal information with an educational appeal regarding sustainability, excluding those that only used labels or certifications.
2. Data processing	Visual organization of the packaging images to highlight the eco-information found on the surfaces and insertion of a code for analysis.
3. Data analysis	Stage 1: Development of an analysis framework based on guidelines associated with the promotion of sustainability education (Santos, 2019). Stage 2: Evaluation of the packaging and classification of eco-information.

Table 02: Methodological Procedures.
Source : Authors.

Data collection consisted in a field study conducted in 7 supermarkets in the city of Campina Grande - PB, from October 2023 to February 2024, with the aim of selecting, among the packaging focused on children available in the market, those that featured eco-information on their surfaces capable of contributing to the promotion of sustainability education. Thus, packaging that only displayed labels and certifications was excluded due to its inadequacy for the objectives of the study.

The selected packaging was documented and graphically processed to generate images that would contribute to the analysis phase, highlighting both verbal and non-verbal eco-information present on the surfaces.

An analysis tool was developed that combines guidelines associated with the promotion of sustainability education with the packaging to be evaluated, with the aim of generating results on strategies used in packaging design that align with the guidelines for sustainability education for children.

Cases	Guidelines				
Nº	A	B	C	D	E
C1					
...					
C17					

Table 03: Analysis tool.
Source : Authors.

The instrument established the following understanding of the guidelines for promoting sustainability education, in order to align the analysis:

Guidelines for promoting sustainable education (Santos et al., 2019)	Understanding of the guidelines
(A) Understanding the concept of sustainability and its importance for the formation of a healthy society	Strategies that assist in educating consumers by presenting concepts/terms related to sustainability, such as "conscious consumption," "sustainable materials," among others
(B) Adopting conscious attitudes regarding the selection, use, and consumption of products available in the market	Strategies that encourage practical actions in favor of sustainability, such as reuse and recycling
(C) Taking positions, according to one's own value judgment, regarding the objects that constitute one's material culture	Strategies that stimulate positions aligned with sustainable attitudes and/or sustainable lifestyles
(D) Understanding the implications of human behavior on current social and environmental issues and the environmental impacts generated by human activity (anthropocene)	Strategies that present the positive or negative implications/effects associated with individual actions
(E) Understanding the relationships between society and the environment in modern society	Strategies that invite reflection on the existing relationships of exploitation and collaboration between society and the environment

Table 04: Guidelines for promoting sustainable education and understanding of the guidelines.
Source : Authors.

The tool was expanded to include various types of verbal and non-verbal communication, aiming to identify which strategies are being used in the Brazilian market. The tool was also enhanced to specify on which panel of the packaging the eco-information was positioned, in order to compare with previous studies that observed only small spaces allocated for sustainability-related information (Clementino and Silva, 2016). The tool was adopted by the researchers to thoroughly understand the presented issue.

4. RESULTS ANALYSIS

Based on the conducted study, 17 packages were selected that featured eco-information targeted at the child audience. These included categories such as gelatins, dairy drinks, juices, snacks, cookies, and cereals.

All types of foods found are part of the daily diet of children, which reinforces the potential of packaging as a tool for disseminating eco-information capable of positively guiding children towards behavioral change regarding sustainability, as observed in the following cases:

Figure 1: C1 to C5 - Dr. Oetker Powdered Gelatin.
Source : Authors.

The first case presented (C1 to C5) involves the Dr. Oetker Powdered Gelatin packages, which feature both verbal and non-verbal eco-information on all available flavors about sustainable practices, guiding children on how to behave/act to achieve a more sustainable lifestyle (Figure 1).

Similarly, the Betânia Dairy Drink packages (C6 to C8) also display a series of eco-information on the back portion of the product, which complement each other and provide continuous access to suggestions for more sustainable behaviors for children.

Figure 2: C6 to C8 - Betânia Dairy Drink.
Source : Authors.

Other cases found in the beverage category include Toddynho Dairy Drink (C9), which features eco-information related to the brand's strategies for making the product less harmful to the environment, as well as suggestions for adopting more sustainable behaviors; Vigor Apple Juice (C10), with indications for more sustainable actions regarding packaging disposal; and Piracanjuba Dairy Drink (C11), which also provides suggestions for environmentally correct disposal practices.

Figure 3: C9 – Toddynho Dairy Drink; C10 - Vigor Apple Juice; C11 – Piracanjuba Dairy Drink
Source : Authors.

In the savory snacks segment, eco-information was also found on the Elma Chips Snack packaging (C12), which clarifies the type of material used and specifies the correct color of the bin for disposal; Kró Semalo Snack (C13) emphasizes the importance of selective waste collection for city maintenance; and Pippo's Snack (C14) focuses on disposal information, as demonstrated in the figure:

Figure 4: C12- Elma Chips Snack s; C13 - Kró Semalo Snack; C14 - Pippo's Snack
Source : Authors.

In the biscuit segment, two cases of eco-information were identified. The Passatempo Cookie (C15) encourages reflection on attitudes, linking this message to information about the recyclability of the packaging; the Marilan Cookie (C16), on the other hand, addresses disposal. Lastly, the Sucrilhos Original Cereal packaging (C17) highlights the use of sustainable materials in its composition and also provides a recycling alert, as shown in the following image:

Figure 5: C15 - The Passatempo Cookie; C16 - Marilan Cookie; C17 - Sucrilhos Original Cereal.
Source : Authors.

4.1. Analysis of ecoinformation based on guidelines for sustainable education

In order to characterize the approaches to eco-information found on packaging as strategies associated with the guidelines for promoting sustainability education, analyses were conducted using the instrument developed by the research group leading this study.

The instrument includes criterion A as strategies capable of assisting in the education of children through the presentation of concepts/terms related to sustainability, such as "conscious consumption," "sustainable material," among others; criterion B as strategies that encourage practical actions for sustainability, such as reuse and recycling; criterion C as the stimulation of positions aligned with sustainable attitudes and/or sustainable lifestyles; criterion D as strategies that present the positive or negative implications/effects associated with individual actions; and criterion E as strategies that invite reflection on the relationships of exploitation and collaboration between society and the environment. Both verbal and non-verbal communication strategies were considered for the analyses, with the results presented below:

Cases	Guidelines				
Nº	A	B	C	D	E
C1		■	■	■	
C2		■	■		
C3		■	■	■	
C4	■	■	■	■	
C5	■	■	■	■	
C6		■	■	■	
C7		■	■		
C8		■	■		
C9	■	■	■		
C10		■	■		
C11		■	■		
C12		■	■		
C13		■	■	■	
C14		■	■		
C15		■	■		
C16		■	■		
C17	■	■	■		

Legend: Cases found

C1 to C5 - Dr. Oetker Powdered Gelatin; C6 to C8 - Betânia Dairy Drink; C9 – Toddynho Dairy Drink; C10 – Vigor Apple Juice; C11 – Piracanjuba Dairy Drink; C12 – Elma Chips Snacks; C13 - Kró Semalo Snack; C14 - Pippo's Snack; C15- Passatempo Cookie; C16 – Marilan Cookie; C17 - Sucrilhos Original Cereal

Table 5: Analysis of strategies found in packaging for children.
Source : Authors.

From the analysis, it is observed that the packaging features strategies aligned with the guidelines for promoting sustainability education. All of them included visual verbal and non-verbal information related to adopting conscious attitudes (Criterion B) and presented approaches capable of encouraging favorable positions towards environmental sustainability through the handling of the product (Criterion C).

Some packaging provided information that aids in understanding terms/concepts related to sustainability (C4, C5, C9, and C17), contributing to "educating" children about the topic. Some packaging presented information on the implications associated with sustainable and unsustainable attitudes/actions (Criterion D), alerting children to the impacts of choices regarding consumption, use, and disposal of the packaging, thus enabling children to see themselves as part of the process of moving towards a more sustainable society. No eco-information associated with Criterion E was found. This is summarized in the following chart:

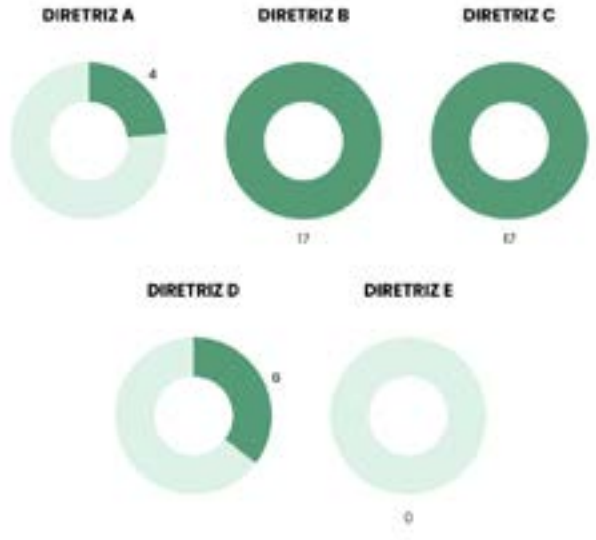

Figure 6: Guidelines chart.
Source : Authors.

Throughout the analysis, six strategies were identified among the types of visual communication on packaging, with two of them being verbal and four non-verbal. Among the verbal strategies, conative expressions and informational texts were found. The non-verbal strategies included the presence of icons, illustrations, characters, and symbols, aiming to identify which strategies are being most utilized. The following table shows the types and strategies of visual communication found:

Types	Strategies	Understanding of strategies
Verbal	Conative expression	A type of linguistic expression aimed at influencing the receiver, used to persuade, convince, direct, or affect the actions, attitudes, or emotions of the interlocutor, through direct commands that induce them to perform a specific action, such as "place the straw inside the box" or "throw the trash in the correct place"
	Informational text	A type of text whose main purpose is to provide information on a specific subject in a clear, objective, and precise manner. This type of text aims to convey knowledge, explain concepts, report facts, describe events, or outline procedures in a way that is understandable to the reader.
Non verbal	Icon	A graphic or pictorial representation of an object, concept, idea, or entity
Non verbal	Ilustration	A visual representation that accompanies or complements a text, concept, or idea. The purpose of illustrations can vary widely, from providing visual examples of abstract concepts to demonstrating step-by-step procedures, explaining complex information in a more accessible manner, or simply making the content more engaging and appealing to the audience. Illustrations are a part of visual communication.
	Character	A fictitious or imaginary entity that plays a role within a narrative. Characters contribute to conveying the message, developing themes, or engaging the audience
	Symbol	An object, image, word, or concept that represents something beyond its literal meaning. Symbols are widely recognized within a specific culture or community and have meanings shared by a group of people.

Table 6: Types, strategies and understanding of visual communication in packaging.
Source : Authors.

A total of 43 types of strategies were found across the 17 analyzed packages, with 22 of these being verbal strategies and the remaining 21 being non-verbal strategies, as presented in the following chart:

Figure 7: Chart of verbal and non verbal strategies.
Source : Authors.

Among the verbal strategies, both conative expressions and informational texts were utilized, with each being used in equal measure.

Figure 8: Chart of verbal strategies.
Source : Authors.

On the other hand, the non-verbal strategies predominantly featured characters, followed by illustrations and symbols, with icons being the least used.

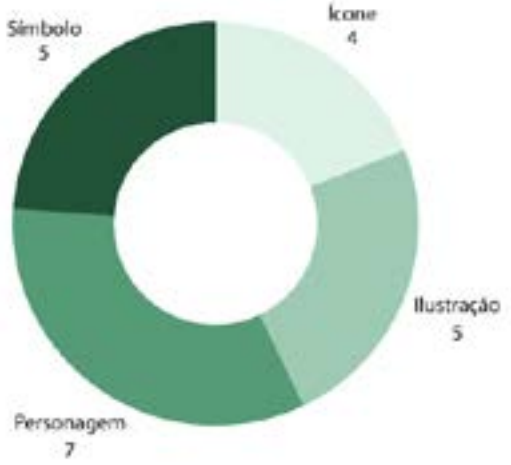

Figure 9: Chart of non-verbal strategies
Source : Authors.

Another important finding was related to the space allocated for ecoinformation on the surfaces of the packages. This indicated a shift in the sector, which previously reserved small areas for sustainability-related information, typically limited to small sections on the rear panels (Clementino and Silva, 2016). Currently, there is a trend towards using other faces of the packaging (Figure 10), as well as adopting larger dimensional spaces on surfaces for ecoinformation display.

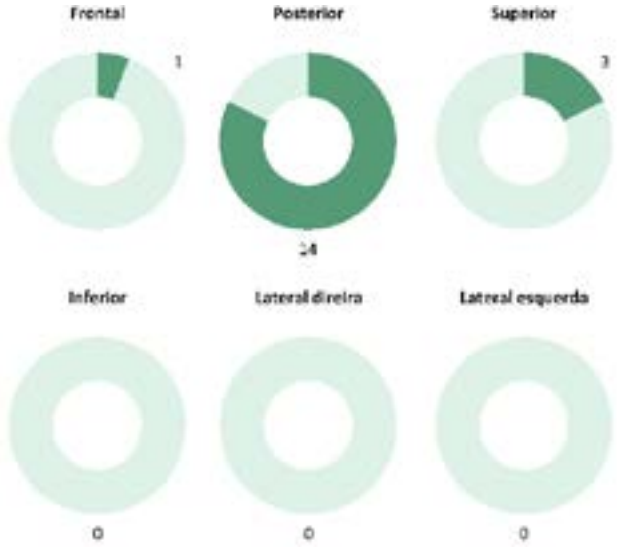

Figure 10: Chart of ecoinformation positioning.
Source : Authors.

In some of the analyzed samples, entire faces of the packaging were used to display ecoinformation, usually located on the rear panel, as exemplified by the packages shown in Figure 5, where each package featured ecoinformation covering the entire dimension of the rear face, incorporating both verbal and non-verbal elements associated with the guidelines for promoting sustainability education:

Figure 11: C1 to C5 - Dr. Oetker Powdered Gelatin.
Source : Authors.

In other examples, ecoinformation was distributed across multiple faces of the packaging, as seen with the Vigor apple juice, which included sustainability-related information on both the front and rear faces.

Figure 11: C10 - Suco de maçã Vigor.
Source : Authors.

This observation suggests an increasing interest among companies in using packaging as a means to disseminate ecoinformation, thereby contributing to the promotion of sustainability education and adding environmental and social value to their brands.

4.2. Ecoinformation Strategies: Guidelines A, B, C, and D

During the analysis of the packaging, ecoinformation related to Guidelines A, B, C, and D was identified. Packaging that included Guideline A presented concepts/terms associated with sustainability, such as "sustainable alternatives" and "conscious consumption," among others (Figure 12).

Figure 12: Guideline A - Adopting conscious attitudes towards selection, use, and consumption.
Source : Authors.

The use of Guidelines B and C was manifested through invitations to practical actions in favor of sustainability, such as "Let's adopt conscious consumption?" or instructions like "Place the straw in the recycling box," thereby encouraging positions aligned with sustainable attitudes and/or sustainable lifestyles (Figure 13).

Figure 13: Guideline B - Adopting conscious attitudes towards selection, use, and consumption of products and guideline C - Taking positions on objects
Source : Authors.

Packaging featuring Guideline D presented the positive or negative implications associated with consumer actions, prompting reflection on the impact of their choices (Figure 14).

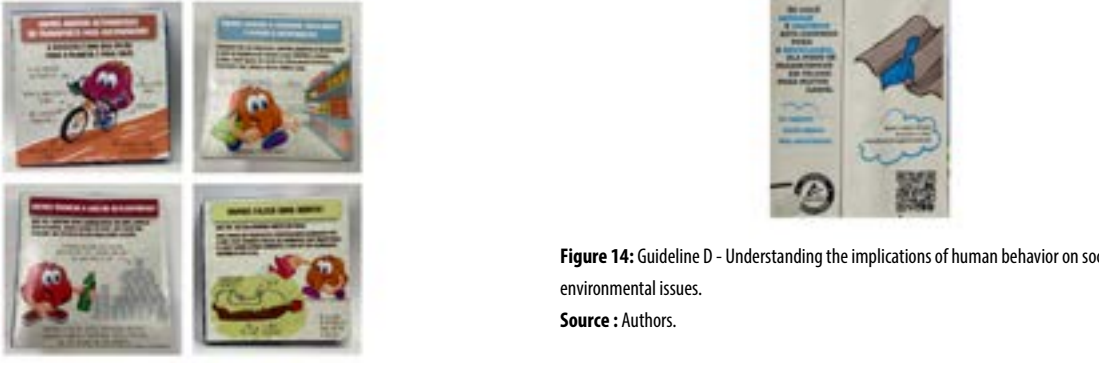

Figure 14: Guideline D - Understanding the implications of human behavior on social and environmental issues.
Source : Authors.

5. CONCLUSION

From the analysis conducted using the proposed instrument, it was possible to relate the verbal and non-verbal strategies adopted in packaging design aimed at the child audience to the guidelines for promoting sustainability education. This demonstrates the packaging as an important vehicle for displaying ecoinformation on various topics and thus capable of contributing to the social change required for systemic discontinuity.

The ecoinformation displayed on the packaging employed strategies designed to make sustainability information visible, understandable, and accessible to children, allowing them to learn and reflect on sustainable habits in a playful manner. Various visual strategies were adopted from this perspective, such as using characters practicing sustainable behaviors or teaching about sustainability through informational texts, and making the content more attractive and engaging for the audience. Visual strategies were also found where graphic elements emphasized ecoinformation and strategies involving terms related to the theme.

The parper indicates that the presence of packaging with ecoinformation in children's daily lives can have a positive impact on sustainability education and contribute to changing this audience's behavior, helping children engage with information aligned with the demands for improving the relationship between humans and the environment.

This paper is part of the research conducted by the Packaging and Sustainability research group at UFCG, aiming to relate the ecoinformation present on packaging to criteria for promoting sustainability education. However, ongoing research aims to conduct visual analyses to understand the behavior of ecoinformation associated with each guideline for promoting sustainability education within the context of packaging design. This will expose packaging designers to existing strategies based on applicable design guidelines, effectively addressing the demands for sustainability education targeted at children.

Furthermore, future research is suggested to apply learning evaluation methods to investigate the real impact of ecoinformation on the education of individuals interacting with these packages.

REFERENCES

ABRE (Associação Brasileira de Embalagens). **Eco-design de embalagem: qual é a embalagem sustentável?** Disponível em: <https://www.abre.org.br/abresustentabilidade/ciclo2_d/. Acesso em: 01 de fevereiro de 2023.

BHAMRA, T.; LILLEY, D.; TANG, T. Design for Sustainable Behaviour: Using Products to Change Consumer Behaviour. **The Design Journal,** v. 14, n. 4, p. 427-445, 1 dez. 2011. Disponível em: <http://www.tandfonline.com/doi/full/10.2752/175630611X13091688930453>. Acesso em: 28 março 2023.

CLEMENTINO, T.O.; SILVA. Itamar, F. Embalagens Sustentáveis: Análise da Exposição de Embalagens do Setor Alimentício em Gôndolas de Supermercado. **DESIGN E TECNOLOGIA**, v. 12, p. 78-88, 2016

DA SILVA, B. M; PEREIRA, C. A; RIBEIRO, D. S. V.; ALVES, J. E. F. C. MIYAHARA, L. M; RAFAEL, N. B. NAKAMURA, Ricardo. Trabalhando a sustentabilidade no desenvolvimento infantil. **Revista Educação em Foco**. Edição nº 14, 2022.

FOLQUE, Maria A.; ARESTA, Fátima; MELO, Isabel. Construir a Sustentabilidade a partir da infância. **Cadernos de Educação de Infância**, v. 112, p. 82-91, 2017.

INSTITUTO AKATU. **Pesquisa Akatu 2018: panorama do consumo consciente no brasil: desafios, barreiras e motivações.** Disponível em:< https://www.akatu.org.br/arquivos/Pesquisa_akatu_apresentacao.pdf. Acesso em: 10 jan 2019.

LÖBACH, B. **Design Industrial: bases para a configuração de produtos industriais**. São Paulo: Edgard Blücher, 2001. 208 p. ISBN 85-212-0288-1.

MANZINI, Ezio; VEZZOLI, Carlo. **O desenvolvimento de Produtos Sustentáveis: os requisitos ambientais dos produtos industriais**. 4 ed. São Paulo: Editora da Universidade de São Paulo, 2016. 366 p.

MARTINS, Ana Raquel Dias. **O design de embalagem como elemento diferencial de marketing: estudo de caso de marcas portuguesas**. 2014. 196 f. Dissertação (mestrado) – Universidade Lusófona de Humanidades e Tecnologias, Lisboa, 2014.

MUNARI, Bruno. **Design e Comunicação visual**. 1 ed. São Paulo: Martins fontes, 2009.

MESTRINER, Fábio. **Design de embalagem: curso avançado**. São Paulo: Pearson Education do Brasil, 2002.

ORSATO, Renato J. Posicionamento ambiental estratégico. Identificando quando vale a pena investir no verde. **REAd – Revista Eletrônica de Administração**. UFRGS, v. 8, n. 6, p. 1-29, nov. 2002.

PRODANOV, Cleber Cristiano; FREITAS, Ernani Cesar de. **Metodologia do trabalho científico [recurso eletrônico]: métodos e técnicas da pesquisa e do trabalho acadêmico**. 2 ed. Novo Hamburgo: Feevale, 2013. 273 p. ISBN 978-85-7717-158-3.

SANTOS et al. **Design para a sustentabilidade: dimensão social**. Curitiba, PR: Insight, 2019.

SANTOS, Agnaldo dos. **Seleção de método de pesquisa: guia para pós-graduandos em design e áreas afins**. Curitiba, PR: Insight, 2018. ISBN: 978-85-62241-46-8.

TEXEIRA. In:_____ (org). **Embalagens: Design, materiais, processos, máquinas e sustentabilidade**. Barueri, SP: Instituto de Embalagens, 2011. p.35-40.

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CARTOGRAPHY AS A METHOD FOR REGENERATIVE AND RELATIONAL DESIGN

CARTOGRAFIA COMO MÉTODO PARA O DESIGN REGENERATIVO E RELACIONAL

CARTOGRAFÍA COMO MÉTODO PARA EL DISEÑO REGENERATIVO Y RELACIONAL

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ABSTRACT
We find especially relevant to the development of alternative forms of conducting research those types which seek to overcome the subject-object dichotomy typical of traditional ways of scientific and design work, as well as those which allow us to consider the plurality of ecosystemic relationships involved in a territory to be investigated. This article presents cartography with its theoretical and design references through a review of various publications, scientific works, project reports, and websites. Also, certain conceptions of cartography are summarized to make an ethical and methodological proposition for a regenerative design oriented towards a relational and ecological worldview.

KEYWORDS
Cartography; design processes; regenerative design.

RESUMO
Entendemos como muito relevante o desenvolvimento de outras formas de fazer pesquisa, que busquem a superação da dicotomia sujeito-objeto, tão marcada no tradicional fazer científico e projetual, e que permitam considerar a pluralidade de relações ecossistêmicas implicadas no território a ser pesquisado. Este artigo tem como objetivo apresentar a cartografia e suas referências teóricas e projetuais a partir da revisão de diferentes documentos: publicações científicas, obras de divulgação, relatórios projetuais e sites. Além disso, sumarizam-se algumas compreensões sobre a cartografia, a fim de propô-la como ética projetual e proposição metodológica para um design regenerativo orientado a uma visão de mundo relacional e ecológica.

PALAVRAS-CHAVE
Cartografia; processos projetuais; design regenerativo.

RESUMEN
Entendemos como muy relevante el desarrollo de otras formas de hacer investigación, que busquen superar la dicotomía sujeto-objeto, tan marcada en el hacer científico y proyectual tradicional, y que permitan considerar la pluralidad de relaciones ecosistémicas implicadas en el territorio a ser investigado. Este artículo tiene como objetivo presentar la cartografía y sus referencias teóricas y proyectuales a partir de la revisión de diferentes documentos: publicaciones científicas, obras de divulgación, informes proyectuales y sitios web. Además, se resumen algunas comprensiones sobre la cartografía, con el fin de proponerla como ética proyectual y proposición metodológica para un diseño regenerativo orientado a una visión del mundo relacional y ecológica.

PALABRAS CLAVE
Cartografía; procesos proyectuales; diseño regenerativo.

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1. CARTOGRAPHY

Cartography is a powerful way of considering and intervening in territories that maps existing forces and, in so doing, co-produces new relationships and new agency. It is of utmost importance for a design that proposes to be regenerative (Garcia; Freire; Franzato; 2023) to consider a territory in its entirety, that is, in its plurality of actors and ecosystemic relationships. Such actors are not only human, but also all things biotic and abiotic, and all forms, both material and immaterial, in the relationships that make up reality, or rather, existence.

Cartography was initially proposed by the philosophers Deleuze and Guattari in their book "A Thousand Plateaus" (Deleuze, Guattari, 1995). Here they describe a research ethic that confronts the traditional forms of science and academia which are often inadequate for dealing with the complexity of our world. In traditional science, the researcher adopts a supposed neutrality when collecting data. Implicit in this is an imagined division between the one who researches and the one who is researched (subject and object). However, this division is impossible because, in fact, we are completely embedded in the subject of our research. Furthermore, our critical viewpoint is created from our personal repertoire and perspectives on what is being researched, and even more beyond this.

To address these limitations, Deleuze and Guattari proposed a way of doing things that did not represent reality as static, but instead mapped processes as they happened and located them in mapped space by perceiving the lines of force that run through it (Deleuze; 1996). These forces could be social, environmental, and subjective dynamics, and this subjectivity either individual or collective (Nadaud, 2015; Guattari, 1992). Though the term cartography was borrowed from the field of geography and broadly used to refer to map-making, the act itself regards more than arranging geographic data: it is the living process of mapping any type of reality that cartographers encounter.

Academics and researchers have embraced this proposal of Guattari and Deleuze and created qualitative research methods and practices. Brazilian researchers have even launched movements on this example, including Suely Rolnik, Virginia Kastrup, Eduardo Passos, and Luciano da Costa (Rolnik, 2016; Passos; Kastrup; Escóssia, 2009; Passos; Kastrup; Tedesco, 2014; Costa, 2014, 2020; Costa; Amorim, 2019).

In this article, we summarize conceptions of cartography as they are applied in the fields of research and design, and illustrate traces of these using projects that perceive and act in this new way while maintaining a relationship with the design field.

2. CONCEPTIONS OF CARTOGRAPHY

Research that adopts cartographic ethics is not limited to the collection of pre-determined types of data using pre-determined procedures. It is a process of investigating and co-producing material which seeks emergence. Cartography, in fact, emerges from an inventive attitude because as it maps it also acts and alters. Through cartography, one observes, shows, reflects, criticizes and acts. Cartography serves as a principle, "entirely focused on experimentation anchored in reality," (Deleuze; Guattari, 1995, p. 21).

> The map is open and connectable in all of its dimensions; it is detachable, reversible, susceptible to constant modification. It can be torn, reversed, adapted to any kind of mounting, reworked by an individual, group, or social formation. It can be drawn on a wall, conceived of as a work of art, constructed as political action or as a meditation (Deleuze; Guattari, 1995, p. 21).

Unlike traditional research, in cartography we do not start from hard hypotheses but instead allow existential territories to reveal themselves, which can and should change the course of our investigation (Kastrup; Passos; Escóssia, 2009).

> Methodology, when imposed as a principle, is defined by previously established rules. Hence the traditional meaning of methodology embedded in the word's etymology: meta-hódos. With this direction, the search is defined as a path (hódo) predetermined by the goals given at the outset. In turn, cartography proposes a methodological reversal: transforming the meta-hódos into hódos-meta. This reversal takes a chance on a thought experiment, which is a method not to be applied but to be experienced and assumed as an attitude. This does not surrender any rigor, but instead gives new meaning. The rigor of the path, its precision, is closer to the movements of life or the normativity of living which Canguilhem

> speaks of. Precision is not taken as accuracy, but as commitment and interest, as an implication in reality, as an intervention (Kastrup; Passos; Escóssia, 2009, p. 11).

According to Costa (2020), cartography is more than a possible research method, and can be understood as an ethical-political inspiration which seeks to complement and strengthen qualitative research. "This is an ethical position because it calls into question the subject who operates an intervention, as he also assumes himself to be an institution to be analyzed," (Costa, 2020, p. 14).

Through cartography, we can follow processes through the analysis of their lines. Such lines are articulations, which are combined with each other, and the great challenge is to disentangle them, what Deleuze (1996) calls mapping:

> We have as many tangled lines as a hand. We are complicated in a different way from a hand. What we call by different names—schizoanalysis, micro-politics, pragmatics, diagrammatism, rhizomatic, cartography—has no other object than the study of these lines, in groups or as individuals (Deleuze; Parnet, 1998, p. 148)

We settle on these lines, traveling through unknown territories, drawing maps. Costa and Amorim (2019), based on Deleuze-Guattarian proposals and concepts, present a theory of three lines which are in all living processes: hard lines, flexible lines and lines of flight.

Hard lines are segmentary, are territorial limits, binaries, protocols. "Hard lines demarcate identities, duties, habits, conventions, crystallized opinions, in short, they represent the safest and most violent modes of existence" (Costa; Amorim, 2019, p. 918).

Flexible lines and lines of flight are deviations and emanations which arise in a molecular way and do not demarcate territories, but instead can lead to transition between territories and devices, or even to their deconstruction or transformation.

Flexible lines are often in the order of the unconscious, the unspoken; lines of flight represent a decisive rupture, a search for transformation, escaping prior categorizations and judgments. For Deleuze (1996), lines of flight are subjectivation, configuring themselves as possible inventive paths of resistance and becoming. In short, Guattari and Deleuze ask us to look more at processes and relationships than at structures.

3. PROJECT REFERENCES RELEVANT FOR DESIGN

A few relevant projects are described below to assist in understanding cartography from a regenerative design perspective. This perspective regards ecosystemic relationships and it values the metamodel and the production of subjectivities. In each case, the details of which can be found with the associated links, we mention a trace that brings us closer to understanding cartography as a design proposal.

In New Social Cartography of the Amazon (Nova Cartografia Social da Amazônia) (Almeida, 2013) (http://novacartografiasocial.com.br/), we can find immense agency and collective power. Projects are carried out that involve mapping and preparing reports in collaboration with local communities, which, in turn, can self-map discourses, cultures, places, and conflicts, providing evidence for their singular and existential conditions and expressions (Figure 1).

Figure 1: Report on Children and Adolescents on the Riverside and in Quilombolas (fugitive slave communities) of Adaetetuba.
Source: http://novacartografiasocial.com.br/

This work of social cartography was developed within the scope of the Agreement signed between UNICEF and PNCSA (the New Amazon Social Cartography Project) and realized through IAGUA (Amazonia Institute of Urban and Environmental Management). According to Lima and Costa (2012):

> The product of social cartography is a report, material that brings together the written and illustrative content of the protagonists of social cartography. The information is generated in collectively organized meetings and, through audiovisual communication resources, the records of the descriptions of the subjects' daily experiences are transcribed into print. This is then reviewed by the social mapping participants themselves who authorize the use of the text, images and their personal data. The group then

> decides on the appropriate text formatting, color and composition of their images. Each report consists of text, images and a situational map. (Lima, Costa, 2012, p. 81)

The cartography method used with children and adolescents of the Amazonian quilombolas and riverside communities, according to Da Costa Lima and Da Costa (2012), involved several steps to guarantee an accurate and meaningful representation of the territory. Initially, social cartography workshops were held where participants learned basic cartography concepts and discussed the importance of sociocultural elements present in their territories. These workshops emphasized that the young people themselves create sketches which allowed them to draw preliminary maps of their communities. After these sketches, the next step was to georeference the sociocultural elements.

With the help of GPS, the young people, accompanied by researchers, marked the geographic coordinates of the points of interest identified in their drawings. This data was fed into digital mapping programs including Trackmaker and ArcGIS to create an accurate digital cartographic foundation. Next, the sketches were adapted graphically, by digitizing and vectorizing them to improve their visual quality and ensure that the original traces were preserved. This process also included the insertion of symbols and captions that represented significant aspects of the daily lives of children and adolescents, such as leisure places, environmental problems and work activities. Finally, a situational map was created integrating all the collected and adapted information. This map, together with the participants' transcribed experiences, served not only as a document of political demand, but also as an educational resource that reinforces the cultural identity and collective memory of the communities involved (Da Costa Lima; Da Costa; 2012).

In Cartography of the Participatory Budget of Belo Horizonte (Cartografia do Orçamento Participativo de Belo Horizonte) (https://opbh.cartografia.org/) applies a method called undisciplined cartography (Lopes; Rena; Sá, 2023; Rena; Souza; Sá, 2022a).

> Its principal actions and analyses are based in four dimensions. I) Spatial/Territorial: a) through the creation of collaborative digital maps that bring together georeferencing tools to enable acting in a network and in real time using software including Crowdmap, Google Maps and Vista Maps; b) producing collective cartography based on face-to-face meetings such as workshops; II) Temporal: through the production of timelines that analyze the chronology of the investigated phenomena and their relationship with parallel events/ occurrences in urban, national, and global dynamics; III) Conceptual and Informational: using Wiki pages to enable collaborative, procedural and networked knowledge production we organize the theoretical precepts that guide our research and also use this as a means of producing/storing databases ; IV) Communicational or Network Formation: with the tactical use of social networks and communication channels widely used online such as fan pages and social network events, blogs, etc. (RENA, et al., 2016, p. 3)
>
> Following the determination of these axes, visualizations of the mapped processes involving graphic and textual information as well as hyperlinks to other media and content were identified as Cartographic Narratives, articulating information such as maps, timelines and network graphs with the aim of illustrating not only the, "struggle movements, but also struggles in motion, that is: the developments of the disputes at stake, their advances and impasses, their weaknesses and contradictions" (LOPES, et al. 2019. cit., s.p.).
> The construction of such narratives is based on four questions drawn from the study of the cartography of controversies (LATOUR, 2012): what? (event), why? (narratives or representations), who? (human actors) and what? (non-human actors).
> Answers to these questions form the nodes of the networks under construction and through which the formation of groups (how?) and connections (what are the power relationships?) are mapped. By organizing the information along a timeline (when?), it becomes possible to map some of its most evident developments and controversies (LOPES, et al. 2019. cit., s.p.). (Rena et. al, 2022b, p. 125).

In this context, a territorial game was created as a cartographic device for interacting with the community (Rena et. al, 2022b). The game consists of modeled villages, cards and a timeline identifying public works, actors, narratives and other events regarding participatory budgets (Figure 2).

Figure 2: Images of the Cartographic Participatory Budget Game in the state of Belo Horizonte.
Source: https://opbh.cartografia.org/

Development of the Cartographic Participatory Budget Game involved identifying critical information about the budget with the help of community leaders, delegates from COMFORÇA (the Monitoring and Supervision Implementation Commission) and local residents. A survey was conducted through classroom debates and research meetings to define the essential materials for designing the game, such as modeled villages, cards with information about public works and events, a timeline, bells and a timer.

The game materials were carefully chosen to facilitate participant interaction and understanding of the territories. The modeled villages helped them visualize event locations, while letters identified public works and actors. The timeline was used to record the main participatory budget events, and the bells allowed teams to express themselves quickly, fostering an active and competitive dynamic.

The game divided participants into teams and a mediator who presented cards with questions. Teams earned points by ringing the bell and reporting narratives about the content of the cards that provided information about the modeled village. A member of the research team was responsible for recording on a timeline the events and narratives mentioned, ensuring that all details were captured during the game.

The objective of the game was to map information and collect reports from the population about the impact of participatory budget public works in a playful and relaxed way, and also to allow participants and researchers to get closer. This method allowed the emergence of common information and knowledge that would otherwise not be revealed using traditional approaches. This promoted a deeper understanding of the dynamics of citizen participation and the impacts of public works in these territories.

There are other examples of cartographies that rely on a more active inclusion of the subjectivities of citizens and participants in study cycles and immersive experiences, as in the following cases. Here, "composting" of images and illustrations is done, often with art direction and specialized editorial monitoring, and always guided by a clear theoretical and political proposal.

The publisher Subjective Atlas (https://www.subjectiveeditions.org/) organizes cartographic works on cities, territories, and countries. Their atlases are books composed of local subjectivities set within a global network. By mapping with collective intersubjectivity in a bottom-up approach that is rooted in real experiences, knowledge is generated from a specific place and the people who inhabit it.

Figure 3: Above, image of people leafing through various publications; Below, pages 20 and 21 of the eBook Subjective Atlas of Palestine.
Source: https://www.subjectiveeditions.org

Figure 4: Cover image and page 12 of the book Forest2 (Floresta2).
Source: https://www.academia.edu/

Also regarding arts and the political is Wild – Cycle of Studies on Life (Selvagem - Ciclo de Estudos sobre a Vida) in which cartography and audiovisual materials generate paths from collaboration, studies, and the exchange of knowledge that involve, first and foremost, ecological and indigenous thinking.

Figure 5: Regenerating Path and Sun Path.
Source: https://selvagemciclo.com.br/

Audiovisual composting is conducted in Wild Arrows (Flechas Selvagem) (https://selvagemciclo.com.br/flecha/), directed by Anna Dantes and narrated by Ailton Krenak. Such works inform, create meaning, and vindicate a cultural and existential territory.

Figure 6: . Arrow 6 - Time and Love (Flecha 6 - O tempo e o amor).
Source: https://www.youtube.com/

Cartography as a research process is explored in Cristina Ribas's visual essay (2017) which integrates its methods with militant and artistic research practices. The approach is based on Félix Guattari's schizoanalytic cartography which combines the transversalization of knowledge with collective subjectivation, allowing for the creation of models that influence both subjectivity and reality. This practice not only maps realities and relationships, but also acts as a tool for analyzing and transforming signs and forces in the contexts being studied.

Counter-mapping Queen Mary (Figure 7) is a good example of this approach. This was conducted in partnership with The Counter Cartographies Collective as a local intervention and collaborative research project at Queen Mary University of London. It produced maps and games that reveal hidden and unsystematized data from the global knowledge economy, highlighting

exploitation, gender inequalities, and fee disparities. Cartography, in this context, is not just a visualization tool, but a means of exposing and addressing complex structural issues.

Figure 7: . Counter-mapping Queen Mary, finding your way across borders and through filters, 2010.
Source: Ribas, 2017.

In sum, the method used in these works highlights the ability of cartography to generate cognitive, political and subjective effects through research. Schizoanalytic cartography allows researchers and participants to critically locate themselves in their contexts, mapping blockages and possibilities for reinvention. This process demonstrates cartography to be a dynamic and transformative resource that is instrumental for activism, education, and the collective production of knowledge.

4. FINAL CONSIDERATIONS: CARTOGRAPHIC INPUTS FOR REGENERATIVE DESIGN

In 1989, Guattari proposed Ecosophy as an ethical-aesthetic-political concept composed of three ecological registers: subjectivities, social relationships and the environment (Guattari, 2001). Even though he seems to allude to the environment in a generic way, the philosopher calls on us to organize ecosophical objects (Nadaud, 2015), that is, a confluence of the three ecological registers. In Guattari's view, we need to organize the production of subjectivities and subjective formations in an intentional and molecular way in order to create the conditions for escaping our socio-environmental crises. These crises arose from a homogenizing subjective impoverishment, which is, "general movement of implosion and regressive infantilization" (Guattari, 2009, p. 8).

By drawing upon Guattari in her master's degree research, the author developed an understanding of regenerative design focused on fostering the elaboration of human subjectivities with an ecological worldview in which the various ecosystemic relationships are understood and respected (that is, among human and non-human as well as living and non-living actors) (Garcia, 2021).

In conducting the associated fieldwork in the form of a cartography project, participants were invited to conduct design actions that could give rise to regenerative processes. Collaborating researchers sought a cartographic process and an intervention in which the subjects were involved in the territory, proposed transformations, and transformed themselves while mapping, prospecting, and catalyzing (Garcia; Freire; Franzato, 2023). A principal effort of regenerative design is seeking alternatives to markedly modern and anthropocentric thinking, and this fieldwork therefore experimented with cartography.

Held in a nature preserve in the Cantareira mountains in the state of São Paulo, Immersion Regeneration (Immersão Regeneração) lasted 4 days and involved 10 participants. A kit containing inputs and guidance related to cartographic ethics was distributed, and we proposed that participants write about themselves and their values, their points of view and expectations. We created an environment for horizontal and respectful dialogue to establish and strengthen bonds. We then proposed mapping the territory by involving ourselves in it. In an attitude of felt thinking, we walked throughout the location to experience it, heard its stories and learned about its relationships by interaction with the people inhabiting it.

Upon return from our excursion, the group silently mapped the territories we were witnessing emerge by way of their lines, traces of the environment, social relationships, and subjectivities (Figure 5).

This was followed by workshops employing conversation circles to articulate the principles of a regenerative practice which recognized interexistence and to establish dialogues that could identify skills for strengthening the aggregation of relationships of value to the ecosystems. We also co-created video manifestos (https://youtu.be/bhGTd0A6o_4 and https://youtu.be/mYmjX2QZoEE) that propose a vision of regeneration and its ethos, as well as an ecoperformance that maps the territory's narratives and conflicts in order to raise awareness among the group.

Figure 5: Images from Immersion Regeneration (Immersão Regeneração), an activity in which we carried out experiments with cartography.
Source: Garcia, 2021.

By understanding cartography as a design ethic for ecosystem mapping, not only are social relationships brought to the fore, but even more so the multiple relationships between biotic and abiotic actors that make up a place. We did not analyze systems in a technical manner as static objects separated from ourselves, but instead delved into and mapped interexistence to raise awareness, to make people see, to critique, and to foster agency. The products of this work are not just the typical visual artifacts of an artistic or design process, but are rather effects on relationships and ways of seeing, of thinking and of gaining agency.

Here we conclude that cartography, especially when applied in a schizoanalytic and regenerative way, has a unique ability to map and transform socio-political and cultural realities. The practice of cartography goes beyond the simple representation of spatial data and instead encompasses a process of critical and participatory engagement with contexts that are being studied. This approach is instrumental in exposing and addressing complex structural issues, which allows researchers and participants to critically position themselves in their contexts and to envision new possibilities for reinvention.

REFERENCES

ALMEIDA, A. Nova Cartografia Social: territorialidades específicas e politização da consciência das fronteiras. In: ALMEIDA, A.W. B. de; FARIAS JÚNIOR, E. de A. (orgs.). Povos e comunidades tradicionais: nova cartografia social. Manaus: UEA Edições, 2013.

COSTA, L. A cartografia parece ser mais uma ética (e uma política) do que uma metodologia de pesquisa. Paralelo 31, v. 2, n. 15, p. 10, 10 dez. 2020.

COSTA, L. Cartografia: uma outra forma de pesquisar. Revista Digital do LAV, [S. l.], v. 7, n. 2, p. 066–077, 2014. DOI: 10.5902/1983734815111. Disponível em: https://periodicos.ufsm.br/revislav/article/view/15111. Acesso em: 24 fev. 2024.

COSTA, L; AMORIM, A. Uma introdução à teoria das linhas para a cartografia. Atos de Pesquisa em Educação, [S. l.], v. 14, n. 3, p. 912-933, dez. 2019. Disponível em: https://proxy.furb.br/ojs/index.php/atosdepesquisa/article/view/8045. Acesso em: 24 jan. 2022.

DA COSTA LIMA, Marcos Vinícius; DA COSTA, Solange Maria Gayoso. Cartografia social das crianças e adolescentes ribeirinhas/quilombolas da Amazônia. Geografares, [S. l.], n. 12, p. 76–113, 2012. DOI: 10.7147/GEO12.3189. Disponível em: https://periodicos.ufes.br/geografares/article/view/3189. Acesso em: 24 fev. 2024.

DELEUZE, G. O que é um dispositivo? In: _____. O mistério de Ariana. Lisboa: Ed. Vega; Passagens, 1996. Disponível em: https://www.uc.pt/iii/ceis20/conceitos_dispositivos/programa/deleuze_dispositivo. Acesso em: 24 fev. 2024

DELEUZE, G.; GUATTARI, F. Mil Platôs: capitalismo e esquizofrenia. Tradução Aurélio Guerra Neto e Célia Pinto Costa. Rio de Janeiro: Ed. 34, 1995a. V. 1.

DELEUZE, G.; GUATTARI, F. Mil Platôs: capitalismo e esquizofrenia. Tradução Aurélio Guerra Neto e Célia Pinto Costa. Rio de Janeiro: Ed. 34, 1995b. V. 3.

DELEUZE, G; PARNET, C. Diálogos. São Paulo: Editora Escuta, 1998.

GARCIA, N. G.; FREIRE, K. M.; FRANZATO, C. Princípios e movimentos para processos projetuais regenerativos. Mix Sustentável, v. 9, n. 2, p. 63-74, 2023. Disponível em: https://ojs.sites.ufsc.br/index.php/mixsustentavel/article/view/5706. Acesso em: 15 maio 2024.

GUATTARI, F. As três ecologias. Campinas: Papirus, 2009.

GUATTARI, F. Heterogênese. In: _____. Caosmose: um novo paradigma estético. Rio de Janeiro: Ed. 34, 1992.

LOPES, M. S. B.; RENA, N. S. A.; SÁ, A. I. Método Cartográfico Indisciplinar: da topologia à topografia do rizoma. V!RUS, São Carlos, n. 19, 2019. [online] Disponível em: http://www.nomads.usp.br/virus/virus19/?sec=4&item=6&lang=pt. Acesso em: 15 nov. 2023.

NADAUD, S. Félix Guattari ¿Qué es la Ecosofía?: textos presentados y agenciados por Stéphane Nadaud. Buenos Aires: Cactus, 2015.

PASSOS, E.; KASTRUP, V.; ESCÓSSIA, L. Pistas do método da cartografia: pesquisa-intervenção e produção de subjetividade Porto Alegre: Sulinas, 2009. V. 1.

PASSOS, E.; KASTRUP, V.; TEDESCO, S. Pistas do método da cartografia: a experiência da pesquisa e o plano comum. Porto Alegre: Sulinas, 2014. V. 2.

RENA, N.; SOUZA, G.; SÁ, A.; NOBRE, M. Cartografia do Orçamento Participativo em BH. Belo Horizonte: Agência de Iniciativas Cidadãs, 2022a. V. 1.

RENA, N.; SOUZA, G.; SÁ, A.; NOBRE, M. Cartografia do Orçamento Participativo em BH. Belo Horizonte, MG: Agência de Iniciativas Cidadãs, 2022b. V. 2.

RIBAS, C. 'Cartography as Research Process: A Visual Essay.' In response toSohin Hwang and Pablo de Roulet, In: 'Bibliography(chorème)=' OAR Issue 1. OAR: The Oxford Artistic and Practice Based Research Platform, Issue 1, 2017. Disponível em http://www.oarplatform.com/cartography-research-process-visual-essay/ Acesso em: 13 fev 2024.

ROLNIK, Suely. Cartografia Sentimental: transformações contemporâneas do desejo. 2. edição. Porto Alegre: Sulina; Editora UFGRS, 2016.

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THE INFLUENCE OF GREEN AREAS ON THE USE OF PUBLIC SPACES: A CASE STUDY OF PRAÇA SANTOS DUMONT IN FLORIANÓPOLIS (SC), BRAZIL

A INFLUÊNCIA DAS ÁREAS VERDES NO USO DOS ESPAÇOS PÚBLICOS: UM ESTUDO DE CASO DA PRAÇA SANTOS DUMONT EM FLORIANÓPOLIS (SC), BRASIL

LA INFLUENCIA DE LAS ÁREAS VERDES EN EL USO DE LOS ESPACIOS PÚBLICOS: UN ESTUDIO DE CASO DE LA PLAZA SANTOS DUMONT EN FLORIANÓPOLIS (SC), BRASIL

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ABSTRACT
Tree cover in urban spaces plays an essential role in enhancing both their environmental and aesthetic value, while also making streets, squares, and parks more appealing. This study focuses on the distribution of trees in Praça Santos Dumont, Florianópolis (SC), Brazil, from the users' perspective, aiming to assess whether the current layout meets their needs. The research methodology involves on-site observation, mapping of the trees, and surveys conducted with regular visitors. The findings reveal concerns about the design of the space, particularly the lack of tree cover in large areas, which results in excessive sun exposure and reduces people's desire to use the space.

KEYWORDS
Urban Landscape. Environmental Psychology. Public Leisure Spaces.

RESUMO
A cobertura arbórea em espaços urbanos desempenha um papel essencial tanto no aumento do valor ambiental quanto estético, além de tornar ruas, praças e parques mais atrativos. Este estudo foca na distribuição das árvores na Praça Santos Dumont, em Florianópolis (SC), Brasil, a partir da perspectiva dos usuários, com o objetivo de avaliar se o layout atual atende às suas necessidades. A metodologia de pesquisa envolve observação in loco, mapeamento das árvores e questionários aplicados a visitantes regulares. Os resultados revelam preocupações com o design do espaço, especialmente a falta de cobertura arbórea em grandes áreas, o que resulta em exposição excessiva ao sol e reduz o desejo das pessoas de utilizar o espaço.

PALAVRAS-CHAVE
Paisagem Urbana. Psicologia Ambiental. Espaços Públicos de Lazer.

RESUMEN
El objetivo del artículo es analizar la viabilidad técnica de implementar una planta de reciclaje de residuos de construcción en Juazeiro do Norte, para ello se estudia inicialmente la viabilidad en términos de demanda de la planta, mediante el levantamiento del volumen anual de residuos de materiales reciclables de clase A civil. construcción en el municipio de Juazeiro do Norte, que albergaría esta hipotética planta. En un segundo paso, se estudió el camino que seguirán los residuos desde su generación hasta su destino final bajo la perspectiva legislativa local. También se realizaron estudios

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sobre el escenario nacional de las plantas de reciclaje de residuos de la construcción para señalar posibles características que debería tener la planta local para satisfacer las necesidades intrínsecas de Juazeiro. De esta manera, se pudo observar que el municipio brinda suficiente demanda para una planta de reciclaje de residuos, además de que aún falta en la legislación local una mayor regulación para el sector, pero con un escenario más alentador con el proceso de estudio y la implementación. de un consorcio intermunicipal para abordar los residuos sólidos urbanos.

PALABRAS CLAVE
Paisagem Urbana. Psicologia Ambiental. Espaços Públicos de Lazer.

1. INTRODUCTION

The continuous urban expansion in Brazilian cities has caused significant impacts, including the reduction of green areas. At the same time, the demand for these spaces in the urban environment has been increasing. This issue has gained more prominence in recent times due to the negative effects of the reduction of green areas on the population's quality of life, such as climate change and increased pollution (Oliveira; Mascaró, 2007).

Public leisure spaces are important components of the urban fabric and play a fundamental role in social relations and interactions among different users of urban space (Jacobs, 2011; Tenório, 2012). Therefore, it becomes essential to study the appropriation of these spaces and the aspects that directly influence this process. Appropriation is defined as a psychosocial process in which an individual uses a space and assigns it meaning (Cavalcante; Elias, 2011). Various urban elements influence this process, with vegetation being one of them. The location of trees in space, their ability to provide shade on urban furniture, and their influence on visibility can both attract and repel people.

Praça Santos Dumont (Figure 1), the empirical object of this study, functions as a central hub in the Trindade neighborhood of Florianópolis, Brazil. This space brings together a variety of daily activities and is valued by residents as a place for leisure, socialization, and holding fairs and events. In addition, the square attracts various commercial flows from the surrounding area, as well as students, professors, and staff from the Universidade Federal de Santa Catarina. The relevance of the square to the community, as well as its integration into the urban fabric, justifies the choice of this location as the object of study.

The objective of this article is to examine how Praça Santos Dumont, in Florianópolis (SC), Brazil, is appropriated by its visitors, with an emphasis on the influence of the distribution of vegetation in the space. For this purpose, a methodology was used that includes direct observations on-site, mapping of the design aspects of the space, with an emphasis on the distribution of trees, and questionnaires applied to users, aiming to identify their preferences regarding the landscape design aspects of the space.

Figure 1: Location of Praça Santos Dumont in Florianópolis.
Source: Prepared by the authors.

2. THE APPROPRIATION AND PRESENCE OF GREEN AREAS IN PUBLIC SPACES

Appropriation is a psychosocial process through which an individual establishes a personal connection with a specific place, assigning it personal meaning. It can be said that all human activities involve some degree of appropriation, manifested in different ways through perception, orientation, and action: the individual projects themselves into the space while assimilating it (Cavalcante; Elias, 2011). The individual dimension of appropriation can be subdivided into three main components: a sense of belonging, environmental appreciation, and affective investment, reflecting the emotional value attributed to the space (Kohlsdorf, 1996).

Among the aspects involving people's affective dimension with public spaces, those related to landscape and vegetation have been the focus of study by several researchers in urbanism and environmental psychology (Appleton, 1975; Nasar, 1992; Ulrich, 1986; Tuan, 2012; Kaplan and Kaplan, 2017). These studies indicate that people prefer to be in urban environments with vegetation and that greenery brings positive emotions related to tranquility and rest amidst the typical hustle and bustle of urban areas.

According to Mascaró and Mascaró (2002), the presence of trees plays a fundamental role in user comfort and in defining the different subspaces within a square. In addition to aesthetic benefits, trees provide practical aspects, especially regarding the shading of spaces, which alleviates climatic conditions, particularly in tropical climates.

Vegetation in urban spaces plays a significant role in advancing several Sustainable Development Goals (SDGs), notably emphasizing Goal 11 of "Sustainable Cities and Communities." This is reflected in specific target 11.7, which aims to ensure, by 2030, universal access to safe, inclusive, accessible, and green public spaces, with a special focus on women, children, the elderly, and persons with disabilities.

During the summer, vegetation plays an important role in providing shade and reducing direct sun exposure. This contributes to comfort by helping mitigate heat, resulting in a cooler climate. In winter, trees can be adapted to allow sunlight to enter spaces, contributing to natural warming (Mascaró; Mascaró, 2002).

Areas without vegetation receive significant solar incidence, which is particularly relevant in a climate like that of Florianópolis, the city where the study's object is located. This city is characterized by a subtropical climate classified as humid mesothermal. The annual average precipitation is 1506 mm, indicating a high value, and the annual average temperature is 20.8ºC. Precipitation levels are lower in August and higher in January. On average, the highest temperatures are recorded in February, reaching an average of 24.9ºC, while the lowest occur in July, with an average of 16.4ºC (Climate-Data, 2024).

3. PRAÇA SANTOS DUMONT

The Trindade neighborhood, located near the center of Florianópolis, Brazil, is home to Praça Santos Dumont and stands out as a strategic area, connecting the downton to neighboring districts, despite being separated from the center by the rugged topography of Morro da Cruz. The neighborhood is recognized for its importance, housing the campus of the Universidade Federal de Santa Catarina (UFSC), the University Hospital, and a variety of commercial and residential establishments that cater to both residents and the academic community.

The urban layout of the neighborhood follows a fishbone pattern, derived from its initial agricultural planning. Lauro Linhares street, which serves as the central axis of this pattern, is predominantly occupied by commercial establishments and mixed-use buildings (residential and commercial), connecting the perpendicular streets where residential use prevails. Figures 2 and 3 illustrate the central position of the Trindade neighborhood in Florianópolis, highlighting its role as a connecting point between the city center and adjacent neighborhoods, which is fundamental for urban integration.

Praça Santos Dumont faces intense urban flows, with heavy vehicular traffic on the three avenues that surround it and a considerable number of pedestrians on the surrounding streets, although the internal movement within the square is more moderate. This constant activity contributes to a bustling daily life, despite the reduced flows within the square itself.

These characteristics make the neighborhood and the square highly significant elements in analyzing the local urban dynamics. The neighborhood acts as a transition point between various adjacent neighborhoods and serves as a residential area for students, professors, and other professionals from UFSC, who are key users of the local facilities and the square.

Originally, the square was a gathering point for community events, such as the fruit and vegetable market

and the Festa do Divino Espírito Santo (or Orange Festival), which attracted large crowds with shows and sweet stalls. In the 1970s, "Bar do Pida" was established, making the square a popular spot for students and residents, giving it the nickname "Praça do Pida." However, after the bar's closure in 2010 due to legal issues, the square fell into decline, suffering from a lack of maintenance and an increase in the presence of homeless people, which led to feelings of insecurity.

In response, the Trindade Neighborhood Residents' Association initiated a revitalization project in 2012. Although the project presented to the city hall underwent changes, the revitalization completed in 2021 aimed to make the square more inclusive, with new rest areas, spaces for exercise and pets, a redesigned playground, and areas for temporary commerce. The furniture was renewed with new concrete benches, but the trees and the original structure, with minor modifications, were preserved.

Currently, Praça Santos Dumont remains an important venue for social and cultural events in the Trindade neighborhood, including the traditional Festa do Divino in June, as well as university pranks, student parties, rap battles, skateboarding competitions, and capoeira circles.

Figure 2: Location of Praça Santos Dumont in the Trindade Neighborhood..
Source: Adapted by the authors from Google Earth

Figure 3: Praça Santos Dumond in the context of the Trindade Neighborhood.
Source: Adapted by the authors from Google Earth

4. METHODS OF ANALYSIS

To analyze the tree coverage of Praça Santos Dumont and its relationship with the appropriation of the space, the study was divided into two distinct stages:

Survey of the design aspects of the square, highlighting activity areas, circulation spaces, and a photographic survey of the vegetation present in the square, with an emphasis on the distribution of trees. This survey was mapped to understand how vegetation was planned and arranged during the different interventions throughout the square's history.

Collecting users' perspectives on the space was conducted through online questionnaires using the Google Forms platform. This phase included questions related to users' preferences regarding the space and their opinions on possible modifications. The aim of the questionnaire was to understand how the distribution and specifications of the trees in the space affect how people use this environment. A total of 35 responses were received for 7 formulated questions, two of which were graded evaluations (scores from 0 to 5), while the others were open-ended responses. The questionnaires were distributed through social media channels of the Universidade Federal de Santa Catarina and in groups focused on residents of the Trindade neighborhood and surrounding areas. All responses were treated anonymously.

It is important to note that, for this stage, ethical aspects were observed in accordance with Resolution No. 466, of December 12, 2012, for research involving human subjects (Brasil, 2012), with approval from the Research Ethics Committee (CEP) of the educational institution.

Each phase contributed to a more comprehensive understanding of the relationship between the tree coverage of Praça Santos Dumont and its appropriation by users. Additionally, analyses were conducted on other aspects—such as furniture, coverings, etc.—that are also involved in this dynamic.

5. THE SPATIAL CONFIGURATION OF PRAÇA SANTOS DUMONT

Praça Santos Dumont is situated on a terrain characterized by rugged topography, marked by uneven levels that result in the distribution of activities across different levels. The space is traversed by a variety of ramps and stairs, as shown in Figure 4.

The square can be accessed from various points along the three streets that surround it, totaling fifteen access points marked in white, six of which are via ramps and stairs. These entrances provide access to the interior of the square, establishing the predominant flows that move through it. It is important to note that the square is not accessible along its entire perimeter. This is due to the design of the space and the uneven levels, which create elevated flowerbeds and barriers that restrict direct access around the entire perimeter.

The internal paths of the square are determined by the main access points, characterizing the primary flows of users and the distribution of amenities. Some of these paths are delineated by ramps and stairs, reflecting the unevenness of the terrain. The definition of these routes allows for identifying the predominant passage within the space and establishing the main pedestrian flows, revealing patterns such as the concentration of passage in areas without ramps or stairs.

The term "Activity places" in this study refers to spaces that provide conditions for performing activities of permanence. These locations are defined differently: areas where people do not enter, functioning as flowerbeds, wooded spaces, and so on; and areas where specific activities occur. These are delimited by various types of barriers: topographical barriers, flowerbeds, walls, ramps, steps, and low walls. These features are identified in Figure 5.

Among the activity places, 14 environments are identified for various functions in the square: outdoor gym (exercise area), pet place, parking lot, playground, seating areas, large areas designated for events such as craft and farmers' markets, small skateboarding competitions, rap battles, etc., commercial space, taxi stand and bus stop.

Identifying these places is essential to understand the process of appropriation, as it is in these spaces where the predominance of activities is likely to manifest. It is worth noting that not only these locations have equipment that can be appropriated; some paths also include benches, tables, and bike racks. Moreover, certain behaviors are observed in places not explicitly designated for activities, such as the use of low walls, flowerbeds, and lawns as seating by some people.

These design aspects are illustrated in Figure 6.

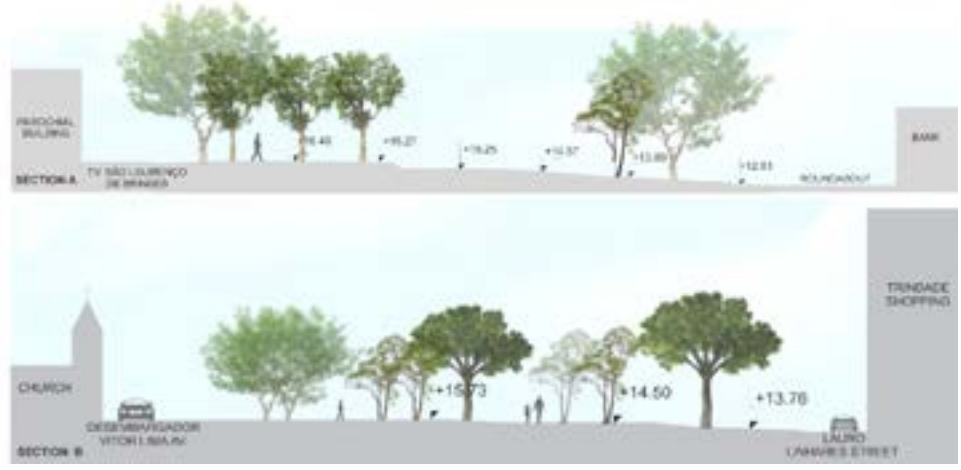

Figure 4: Schematic Section of Praça Santos Dumont.
Source: Prepared by the authors.

Figure 5: Equipment at Praça Santos Dumont.
Source: Prepared by the authors.

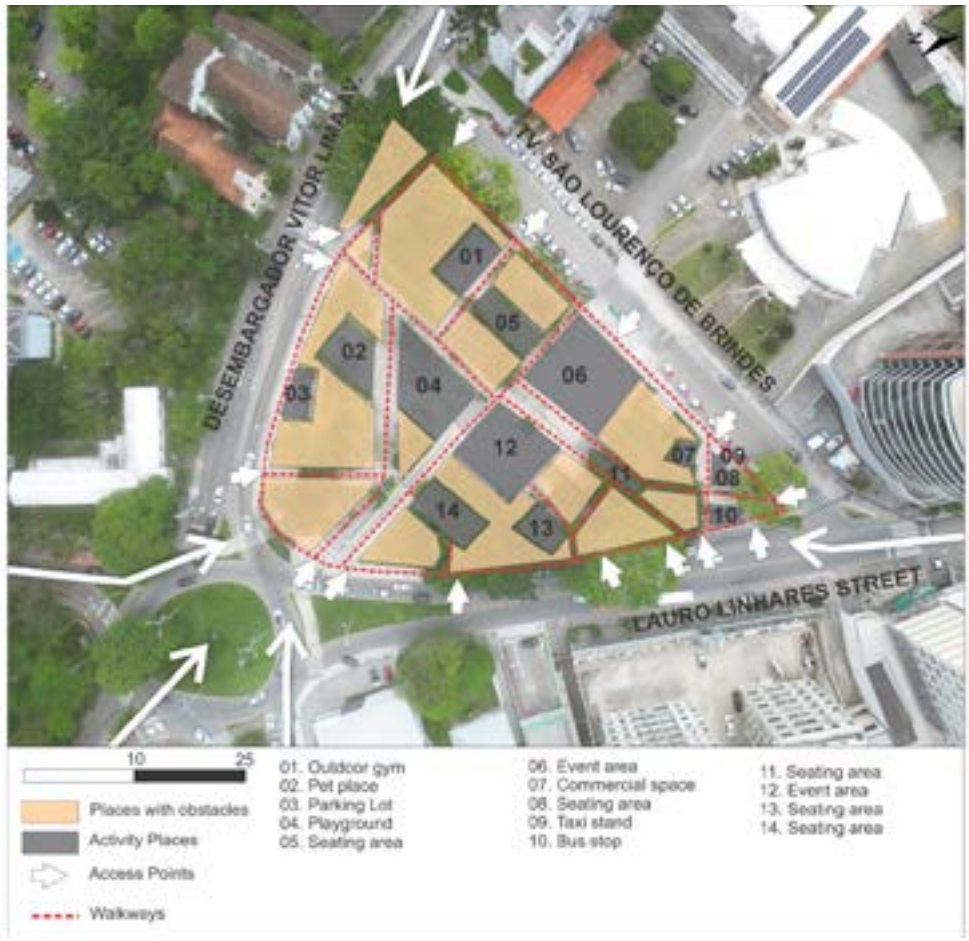

Figure 6: Design Aspects of Praça Santos Dumont.
Source: Prepared by the authors.

6. THE TREE DISTRIBUTION IN PRAÇA SANTOS DUMONT

The analysis of the tree distribution in Praça Santos Dumont is illustrated in Figure 7. In this figure, in addition to the location of the trees, the access points to the square are identified, which occur due to significant elevation changes along its perimeter, making it inaccessible at certain points. The internal paths and vegetation distribution are also highlighted. Areas designated for activities and flowerbeds are distinguished separately, as the spaces with lawns and flowerbeds, where trees are predominantly found, are also subject to physical barriers such as low walls and curbs.

Praça Santos Dumont features a substantial amount of shaded areas created by vegetation, resulting from interventions at different historical moments. It incorporates a mix of native and exotic tree species, shaped by various landscaping projects from the early days when the square served as the center of the Freguesia da Trindade (18th century) to more recent years, during which the neighborhood underwent significant transformations, and the square became the subject of several redesign projects.

Today, there is an efficient distribution of trees in the lateral spaces designated for activities, strategically positioned near seating areas, particularly in the locations shown in photos 01, 04, and 05 (Figure 7), which benefit from more effective shading. However, there are gaps in tree presence in areas such as the two large spaces for events, where some equipment is installed, and various events are held, making them more exposed to sunlight due to the lack of tree coverage.

The absence of trees in these spaces may be intentional, allowing for a large central area in the square for outdoor events with direct sun exposure. Additionally, although trees are distributed along the sidewalks near seating areas, they often act as visual barriers to the space, causing a sense of insecurity and hesitation for those entering the square.

Regarding tree species, there is a predominance of deciduous trees, which lose some of their leaves in winter to allow sunlight in and grow fuller in summer to provide shading. The space is characterized by a mix of native and exotic trees of small, medium, and large sizes. The main species include:

Fig Trees (Ficus Carica), distributed in different parts of the space. Guarapuvu (Schizolobium parahyba), considered the symbol of Florianópolis, a large tree that can reach up to 30 meters in height. Jatobá (Hymenaea courbaril). Indian Almond Tree (Terminalia catappa). Loquat (Eriobotrya japonica). Chinese Banyan (Ficus microcarpa), among others. These elements collectively define the square's character and influence user appropriation and the overall dynamics of the space.

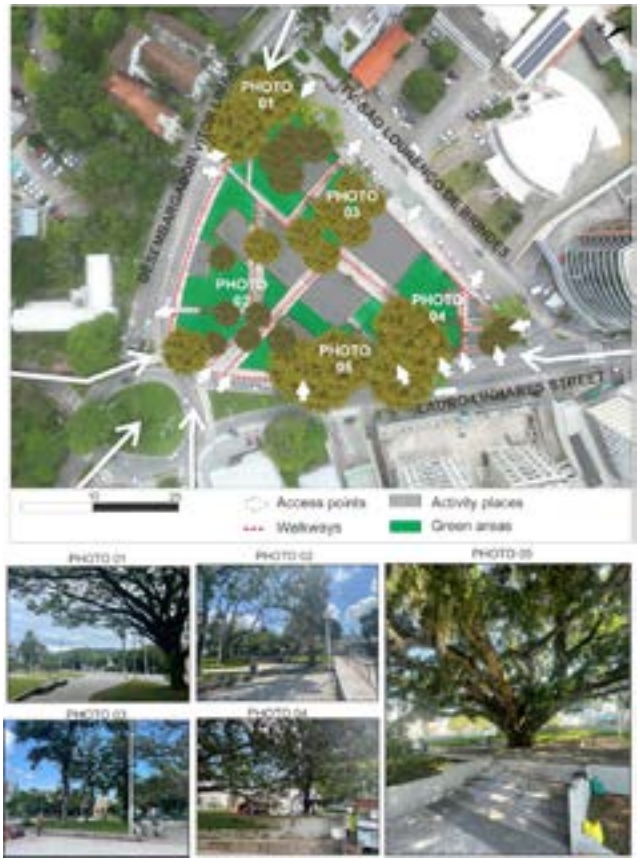

Figure 7: Distribution of Trees in Praça Santos Dumont.
Source: Prepared by the authors.

7. USER PERCEPTION OF THE ARBORIZATION IN PRAÇA SANTOS DUMONT

The questionnaires revealed that the presence of trees in Praça Santos Dumont was perceived both positively and negatively by respondents. While participants expressed satisfaction with the existing trees, they also pointed out dissatisfaction due to the lack of trees in certain areas, especially near some seating spaces. The online questionnaires, conducted via Google Forms and shared with groups from the Trindade neighborhood and the Universidade Federal de Santa Catarina (UFSC), gathered a total of 35 responses. Seven questions were formulated, combining open-ended questions and graded evaluations (on a scale of 0 to 5). The responses were compiled and are presented below:

01. Do you often visit Praça Santos Dumont? How frequently and during what times of the day?

Out of the 35 responses, only two participants indicated they "do not" visit the square or do so "rarely." The majority reported regular visits, with most passing through the square on weekdays during business hours. Only nine participants mentioned occasional visits. Notably, many participants revealed from the first question that they mainly use the square as a passageway on their way to work, university, or the market. This highlights that the square serves primarily as a thoroughfare, with its appropriation mostly by people moving towards other destinations.

02. How satisfied are you with the presence of trees in Praça Santos Dumont?

50% of participants rated their satisfaction as "2" on the scale, indicating low satisfaction with the tree distribution. The reasons for this dissatisfaction were further explored in subsequent responses.

03. What positive aspects do you observe in the distribution of trees in this square?

The predominant responses highlighted the importance of shade and the ability to stay in the area during hot days due to the presence of trees. For example, one response noted: "The few remaining trees provide shade and allow for longer stays on hot days." Participants also pointed out the presence of furniture in shaded areas as a positive aspect.

Additionally, the distribution of trees was considered adequate for not interfering with pedestrian circulation. Positive comments also emerged regarding tree species, such as: "I'm glad there are large trees in the square."

04. What negative aspects do you observe in the distribution of trees in this square?

The most frequently mentioned issue, present in more than half of the responses, pertains to the center of the square, which was entirely covered in concrete following a 2021 revitalization, leaving a large area devoid of trees. Users highlighted the difficulty of staying in the area on hot summer days due to the lack of shade and the concrete flooring, as expressed in comments like: "There's little shade in a space with a lot of concrete. On hot days, the square is not usable," and "the 'core' of the square is huge, totally devoid of trees, and has a concrete floor. This needs to be reconsidered because it's unbearably hot." Additionally, some users pointed out other tree-deficient areas, such as the perimeter of the square near sidewalks, which are also concreted and lack trees. Other negative points mentioned include the dense presence of trees along the boundaries of the space, creating a visual barrier and discouraging entry into the square, a lack of lighting in some densely wooded areas, which can create a sense of insecurity, and the placement of seating furniture near areas without trees.

05. Do you think the tree distribution meets the needs of the space throughout all seasons?

Responses predominantly leaned toward lower ratings, between 1 and 3, highlighting dissatisfaction with the tree species and their distribution. This resulted in the space being considered uncomfortable for year-round use.

06. Does the presence of trees make you want to stay in the square?

For this question, 100% of the responses were "yes," indicating that the presence of trees is a significant factor that enhances the appropriation of the local space.

07. Do you have any suggestions for improving the arborization of the space? What are they?

Once again, the predominant responses to this question were related to the central area of the square, which is paved with concrete and lacks trees, as shown in Figure 8. While the design reasons for keeping this area "empty" to allow for events are understood, this creates significant discomfort for users, limiting its use on sunny days. One user expressed this concern, stating: "The seating areas without trees are good for sitting in winter. However, in summer, more shaded areas are needed. The paved area below the stairs and next to the playground (more central area) is underused, with little occupation. The vegetation generally needs more frequent care." Another comment suggests a review of the design, highlighting the need for specialists to consider alternatives to make the space more usable, taking into account both frequent events and the community's daily needs. Users also requested more flowers to soften the predominance of concrete, as well as more resting furniture near trees and better maintenance of the trees themselves.

These perceptions provide a comprehensive understanding of the public's perception of the square's arborization and its impact on user experience and space appropriation. The feedback suggests a demand for a balanced approach to maintaining areas for events while increasing shaded spaces to enhance comfort and usability throughout the year.

Figure 8: Tree Planting in the Central Area of the Square.
Source: Photo by the authors.

8. FINAL CONSIDERATIONS

The article aimed to analyze the opinions of visitors to Praça Santos Dumont regarding its tree coverage and how this influences their willingness to use or stay in the space. To achieve this, a questionnaire was administered to users to identify their preferences. It is important to note that the study has a limitation concerning the sample size, as only 35 people were interviewed, which may not fully represent all perspectives of the square's users.

The results reveal that tree coverage is a fundamental element for attracting people to public spaces, especially leisure spaces such as squares and parks. In the analysis of Praça Santos Dumont, it is observed that users frequent the space regularly in their daily routines, but they also point out some negative aspects related to the tree coverage, which sometimes demotivate them from using it.

There is a clear need for adjustments in design aspects, such as the excessive amount of concrete used in the paving of the space, which may lead to increased temperatures, along with the absence of trees in some areas, potentially making the space uncomfortable during the hotter seasons of the year. Users particularly report discomfort in the central area, which lacks trees to provide shade for events such as the weekly vegetable markets, handicraft fairs, and other occasional community events. Additionally, they request more furniture near the shaded areas and more trees around the high-traffic areas.

It is worth noting that, in addition to tree coverage, the appropriation of urban public spaces can be influenced by various other factors not addressed here, such as urban insertion and other morphological and social elements.

Despite being a specific case study, this research contributes to the understanding of how architects and urban planners can carefully consider the landscape aspects of public leisure spaces, promoting the creation of more humanized environments that meet the needs and comfort of users.

REFERENCES

APPLETON, Jay. **The Experience of Landscape**. Londres: John Wiley & Sons LTD, 1975. 316 p.

BRASIL, Conselho Nacional de Saúde. **Resolução Nº 466, de 12 de dezembro de 2012. Brasília, 2012**. Available: http://www.conselho.saude.gov.br/web_comissoes/conep/index.html

BRASIL, Nações Unidas. **Objetivo 11. Tornar as cidades e os assentamentos humanos inclusivos, seguros, resilientes e sustentáveis**. Available: https://brasil.un.org/pt-br/sdgs/11

CAVALCANTE, Sylvia; ELIAS, Terezinha Façanha. Apropriação. In: CAVALCANTE, Sylvia; ELALI, Gleice A. **Temas Básicos em Psicologia Ambiental**. 1st edition. Rio de Janeiro: Vozes, 2011. cap. 5, p. 63-69.

CLIMATE-DATA. **Clima de Florianópolis (Brasil)**. Available: https://pt.climate-data.org/america-do-sul/brasil/santa-catarina/florianopolis-1235/.

JACOBS, Jane. **Morte e Vida de Grandes Cidades**. 3ª edição. São Paulo: WMF Martins Fontes, 2011. 510 p.

KAPLAN, Stephen; KAPLAN, Rachel. **Humanscape**: Environments for people. Michigan: Michigan Publishing, 2017. 496 p

KOHLSDORF, Maria Elaine. **A apreensão da forma da cidade**. Brasília, DF: Unb Publisher, 1996. 253 p.

MASCARÓ, Lucia; MASCARO, Juan. **Vegetação Urbana**. 4. ed. [S. l.]: Masquatro, 2002.

NASAR, Jack L. **Environmental Aesthetics:** Theory, Research, and Application. Cambridge: Cambridge University Press, 1992. ISBN 9780521429160.

OLIVEIRA, Lucimara Albieri.; MASCARÓ, Juan José. Análise da Qualidade de Vida Urbana Sob a Ótica dos Espaços Públicos de Lazer. **Ambiente Construído**, Porto Alegre, v. 7, n. 2, p. 59-69, abr./jun. 2007.

TENÓRIO, Gabriela de Souza. **Ao desocupado em cima da ponte:** Brasília, arquitetura e vida pública. 2012. 391 f., il. Dissertation (Ph.D. in Architecture and Urbanism) — Universidade de Brasília, Brasília, 2012.

TUAN, Yi-Fu. **Topofilia:** Um estudo da percepção, atitudes e valores do meio ambiente. 1. ed. Londrina: Eduel, 2012. 342 p.

ULRICH, Roger S. Human Responses to Vegetation and Landscapes. **Landscape and Urban Planning**, Amsterdam, v. 13, p. 29-44, 1986.

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METHODOLOGY FOR SUSTAINABLE COMMUNITY ACTIONS – PRACTICES OF INTEGRATION OF THE FIVE HELIX MODEL IN A BRAZILIAN COMMUNITY GARDEN

METODOLOGIA PARA AÇÕES COMUNITÁRIAS SUSTENTÁVEIS – PRÁTICAS DE INTEGRAÇÃO DO MODELO DAS CINCO HÉLICES EM UMA HORTA COMUNITÁRIA BRASILEIRA

METODOLOGÍA PARA ACCIONES COMUNITARIAS SOSTENIBLES – PRÁCTICAS DE INTEGRACIÓN DEL MODELO DE LAS CINCO HÉLICES EN UN HUERTO COMUNITARIO BRASILEÑO

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ABSTRACT
This article presents the development of a methodology applicable to community actions, that was developed based on the foundations of Participatory Action Research and the values of Systemic Design, Agroecology, Food Sovereignty and Solidarity Economy, which lead to environmentally, socially and economically sustainable initiatives. Its goal is to synthesize good practices experienced in seven years of activities with low-income communities in a methodological framework that allows the inclusion of integral sustainability values in this context, contributing to their quality of life, social cohesion and protagonism. We demonstrate, through the narrative of our working experience in one of the communities, the importance of the integrated work of the elements of the five-fold helix (society, government, industry, academia and environment). We analyze the path, indicating the progress already achieved and the challenges that still arise, based on what we can foresee as next steps. We conclude by inviting other groups to use the proposed methodology and to evolve together towards the dissemination of fully sustainable actions.

KEYWORDS
Community Garden; Integral Sustainability; Systemic Design; Participatory-research action; Five Helix Model.

RESUMO
Este artigo apresenta o desenvolvimento de uma metodologia aplicável a ações comunitárias, desenvolvida a partir de fundamentos da Pesquisa-ação Participativa e dos valores do Design Sistêmico, Agroecologia, Soberania Alimentar e Economia Solidária, que conduzem a iniciativas ambiental, social e economicamente sustentáveis. Seu objetivo é sintetizar boas práticas vivenciadas em sete anos de atividades com comunidades de baixa renda em um framework metodológico que permita a inclusão de valores integrais de sustentabilidade neste contexto, contribuindo para a sua qualidade de vida, coesão social e protagonismo. Demonstramos, por meio da narrativa da nossa experiência de trabalho em uma das comunidades, a importância do trabalho integrado dos elementos da hélice quíntupla (sociedade, governo, indústria, academia e meio-ambiente). Analisamos o percurso indicando as evoluções já alcançadas e os desafios que ainda se apresentam, a partir

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do que conseguimos visualizar como próximos passos. Concluímos convidando outros grupos a utilizarem a metodologia proposta e a evoluir conjuntamente para a disseminação de atuações integralmente sustentáveis.

PALAVRAS-CHAVE
Hortas comunitárias; Sustentabilidade integral; Design Sistêmico; Pesquisa-ação participativa; Modelo da Quíntupla Hélice.

RESUMEN
Este artículo presenta el desarrollo de una metodología aplicable a acciones comunitarias, desarrollada a partir de los fundamentos de la investigación-acción participativa y los valores del Diseño Sistémico, Agroecología, Soberanía Alimentaria y Economía Solidaria, que conducen a iniciativas ambiental, social y económicamente sostenibles. Su objetivo es sintetizar buenas prácticas experimentadas en siete años de actividades con comunidades de bajos ingresos en un marco metodológico que permita la inclusión de valores integrales de sostenibilidad en este contexto, contribuyendo a su calidad de vida, cohesión social y protagonismo. Demostramos, a través de la narrativa de nuestra experiencia de trabajo en una de las comunidades, la importancia del trabajo integrado de los elementos de la hélice quíntuple (sociedad, gobierno, industria, academia y medio ambiente). Analizamos el recorrido indicando las evoluciones ya alcanzadas y los desafíos que aún se presentan, a partir de lo cual logramos visualizar los próximos pasos. Concluimos invitando a otros grupos a utilizar la metodología propuesta y a evolucionar conjuntamente hacia la difusión de actuaciones completamente sostenibles.

PALABRAS CLAVE
Huertos comunitarios; Sostenibilidad integral; Diseño Sistémico; Investigación-acción participativa; Modelo de la Hélice Quíntuple.

1. INTRODUCTION

This article presents an ongoing research-intervention project started at the beginning of 2017 in a low-income community, the Santa Lúcia Agglomerate, in Belo Horizonte, State of Minas Gerais, Brazil. Its goals are to contribute to the resident's quality of life, including integral sustainability values in this context, by means of the formalization of their collective identity and improvement of their protagonism. In order to achieve these purposes, the Community Gardening Program (CGP) is being developed fostering dialog and collective learning, while building the Esperança (Hope) Community Garden, as well as other similar initiatives in Belo Horizonte. In doing so, another important desired result is the improvement of their health conditions through good nutrition and food security and sovereignty.

In this territory, knowledge regarding urban agriculture practices involve a very relevant heritage of rural experiences. Cultivating, then, is part of their culture. Nowadays, there are also a number of online courses and a diversity of related media available as sources that disseminate this type of information (1) (p. 9). Therefore, it has been identified by the group itself, with the facilitation of our academic team, that the creation of a community garden would be a suitable approach for the existing problem that was being posed: the need for a collective action to transform a vacant area in the community, source of many problems, into a productive one that could improve their welfare in many aspects.

In order to achieve this purpose, some methodologies and tools have been combined creating a methods for sustainable community actions. The Systemic Design methodology is used as a reference for sustainable principles, related to the optimization of resources (considering circularity and other strategies), valorization of local culture and resources, respect to all living forms, inclusion, accessibility, recognition of the importance of positive win-win relationships and autonomy that, in the agricultural context, coincides with the values of agroecology (2–4). The conduction of the project was structured as a Participation Action Research, involving conversation meetings, workshops and mutirões (meetings where inhabitants work together for achieving a goal), supporting the local group in its initiatives around its community garden such as the improvement and preparation of the area, planting, harvesting and distribution of their production, aiming at increasing the local quality of life.

A network involving the propelling elements of the five helix model (society/ community; government/ public administration; industry/ local businesses; academy/ universities; the environment) (5) was then formed and maintained in dialog to take forward and develop the initiative, as described next.

2. THEORETICAL FOUNDATIONS

As theoretical foundations the project is based on "Integral Sustainability", "Systemic approaches" and "Agroecology, Food Sovereignty and Solidarity Economy".

2.1 Integral Sustainability

Since the 1970s, when it was published the book "The Limits to Growth" (6) sustainability has been increasingly recognized as an essential value to our societies. At this moment, the focus was on the environment calling for the "attention on depletion of nonrenewable resources and resulting increases in commodity prices" (7) (p. 576). In 1972, in the Stockholm Conference the first assessment of the global human impact on the environment took place, and environmental issues were placed as a priority of international concern involving both industrialized and developing countries. In 1992, The Earth Summit (Rio 92) represented an even more significant moment, since it was acknowledged then the need of a joint effort of all countries in building, improving and reconciling the three pillars of the sustainable development environmental, economic and social emphasizing above all the respect among human beings and between them and the environment. From that moment on, the world has been creating periodic meetings to discuss this theme. Moreover, the political debate, since the Millennium Summit (2000) and the Johannesburg World Summit (2002) shifted emphasis to poverty alleviation (7).

Nowadays, many societies are considering in their everyday life the Sustainable Development Goals (SDG), also known as the Global Goals, launched by the UN in 2015, throughout the proposal of Agenda 2030, with 17 goals that encompass those three pillars (8).

Therefore, the concept of "development" is being put together with "sustainability" and is acquiring different meanings according to the social-economic contexts of each period. In fact, it has constantly been criticized mainly due to the overvaluation given to economic

development, letting aside fundamental necessities of the society, in disagreement with the purpose of a broader evolution. The meaning of development is being thus reevaluated, including other instances of power, incorporating in the contemporary world "the debate on the legitimate purposes of the appropriation of the material world" (9) (p.24). Many authors (10–13) consider that the development is based not only on the economic dimension, but must also embody social justice, equity, quality of life, including the receptivity to the citizen participation at public life, that is, the democratization of the decision process.

From this paradigm, the term "integral sustainability" is proposed here to call attention to the need of a holistic approach, involving economic, environmental and social aspects in order to achieve the balance required for humanity's well-being.

In this complex context, the Esperança Community Garden Project (ECGP) is being developed with the poorest populations who have little participation in public life, usually having no prominence around the decisions concerning their social realities regarding housing, food, education and health. The guideline of the Project is to observe and act on different aspects of this reality. Social, environmental, economic and cultural aspects are approached simultaneously, by stimulating collaboration, identifying local resources and their economic value and taking care of their living environment which includes the vegetable garden itself.

2.2 Systemic Approaches

For a long time, our society is failing at fixing problems that threaten human quality of life such as inequality, hunger, diseases, crimes, lack of education and housing. Moreover, efforts that focus only on one aspect of reality and do not try to balance others are far from being effective. In order to achieve integral sustainability, it should be considered all possible elements that interfere in the context that is being developed or studied, embracing complexity wich is inherent to these problems which have many interrelated variables and uncertainties.

Systemic thinking is a way of reasoning that considers the complexity of the whole. It is a cognitive process that leads to the capacity of perceiving, modeling and evaluating the consequences of actions in an expanded way in terms of time and space (14).

The Systemic Design methodology puts into relation activities from different areas, in order to balance the system and try to reach zero waste using five principles: output/input, relationships, autopoiesis, act locally, life at the center of the project (2). It is a methodology that makes qualitative and quantitative analysis of the current process with its outputs and inputs; identifies its problems; and presents a "Systemic Model" proposing changes that optimize resources (matter and energy), improve equitable relations, foster networks, value local culture and give priority to quality of life over product generation. "Integral Endeavors" refers to productive activities that gather partners, collaborators, customers, suppliers in a network for mutual benefit, having the Systemic Design and integral sustainability as the basis of their processes and strategies (4,15,16).

The Esperança Community Garden Project uses as guidelines the Systemic Design principles and aims at fostering the development of Integral Endeavours within the community for the quality of life of all individuals and productive activities involved. The following sections will present examples of this implementation. It is important to stress that the implementation of the garden also observes the recommendations and principles of agroecology and solidarity economy, searching to contribute to food sovereignty, as explained next.

2.3 Agroecology, Food Sovereignty and Solidarity Economy

Agroecology values correspond to the Systemic Design ones, applied specifically to the area of agriculture. It is an agricultural practice adapted to the productive needs of the land, comprising multiple solutions of ecological farming in harmony with the territorial, cultural and social-economic conditions of each agrosystem. Its principles consider the local features, in order to preserve biodiversity, natural resources and ways of life, building an ethos of integral sustainability (17). It is considered a science, a practice and a movement. It is a science, as it uses principles from ecology, as well as transdisciplinary and action-oriented research, applied to agricultural and food systems. It is a practice, as it combines the local culture with its traditional and resilient ancestral knowledge, especially in smallholder farming systems, to optimize resources and produce healthy food with no pesticides. It supplies food for the families involved in the production and for the local market, shortening or even eliminating

the middlemen. It is also a movement as it acts against the imbalance of food availability, empowering the stakeholders in keeping food sovereignty. It defends the right of the countries to their autonomy to deal with their politics and strategies of production, distribution and consumption of food, protecting the small and medium agriculture (17–20).

Aligned with agroecology, in the 1970s, gained prominence in Brazil the social and solidarity economy, which have opposite patterns to hegemonic capitalism (21–23). Their main principles are: the option for cooperation and solidarity; the social appreciation of the worker's production; the prioritization of economic production and technology efforts for the purpose of fully satisfying everyone's needs; the perception of the relevance of female participation for the implementation of solidarity practices; and the preservation of the environment (24).

3. METHODS

The Community Gardening Program (CGP) is composed by a series of projects and initiatives that give support to the constitution and maintenance of community gardens developed to foster dialogue and learning related to nutrition and food security, disseminating integral sustainability values and systemic thinking. It is the result of the confluence of needs, interests and resources materialized as urban gardens.

The methodology of the CGP described in this article involves continuous bibliographic studies and the application of the Systemic Design and Solidarity Economy principles, practicing agroecology through the Participatory Reseach Action (25), which allows the creation of a continuously reflexive and pedagogical process within the community.

The Participatory Reseach Action methodology was chosen because its values lead to the direction of our objectives. Since its origins, it rescued values considered indispensable for the achievement of sustainable development, namely: the construction of democratic relations; the deliberative participation of the subjects; the recognition of individual, cultural and ethnic rights of minorities; tolerance for differing opinions; and the consideration that subjects change more easily when driven by group decisions (26). Besides, it intends to introduce to the community a process committed to the "cognitive construction of experience", based on the "collective critical reflection" for the "emancipation of the subjects from the conditions that the collective considers oppressive" (26) (p.485).

This framework assumes the important feature of unpredictability, as it values the power of the community where the participants are recognized as a "frailty receiver with potentialities" and each researcher assumes the ethical posture of putting himself/ herself as an "enhancer subject with frailties" (27) (p.491).

The development of the CGP was an organic process grounded in the values and principles of the group. It all began with two projects that ran initially in parallel. The first one is the LEIA (*Laboratório Ecossistêmico Interdisciplinar de Aprendizagem* – Ecosystemic Interdisciplinary Laboratory of Learning) that had an experimental garden at UNA University rooftop, where workshops on sustainable relations used to take place. This initiative was closely related to the university's master degree in Social Management, Education and Local Development, and also to the Gastronomy and Architecture and Urbanism graduation courses. Its approach involves a participatory, collaborative and collective process, prioritizing social management, associated with solidarity economy, in addition to urban environmental and socioeconomic sustainability (28) (p.136). The second one is the Extension (Outreach) Courses on Urban Gardens from the Design School of the State University of Minas Gerais (ED-UEMG), used as a didactic resource and a means to communicate and practice the values of Systemic Design, as a methodological basis for design projects.

The initiative of the first project started within the community itself. After a request from a member of the Santa Lúcia Community to one of the LEIA´s coordinators, to help them finding a solution to a vacant lot located in front of her home, that presented as a threat for their security and health (an area of geological risk, that was used as garbage dump and therefore attracted pests and illegal activities), the group structured an outreach project to work with the community, the first one from the Community Gardens Program.

This outreach project was then materialized (on mid-2016) within the principles of Solidarity Economy and Systemic Design, involving the initial university groups (UNA and ED-UEMG) and also incorporating an invited researcher from another university (UFMG), formalizing the multidisciplinarity of the project thats includes: economy and social sciences, social psychology, gastronomy, architecture and urbanism, design.

At the very beginning of the project, the first actions encompassed the development of a research to understand the local resources and demands to

collectively define the use of that piece of land. The result showed that the community would like to use that space to build a fruit and vegetable garden. This decision had the influence of the origin of many of them, who came from rural areas, where they used to grow plants, their own food. Therefore, this inheritance constituted an important asset for the initiative, as the knowledge embedded in their culture, memories, traditions and identities.

From these initial participatory steps, the actions for the implementation of the community garden are always intended to involve dialogue, cooperation, exchanges and the attraction of more and more participants to the network that would transform relations and the environment.

4. THE NETWORK

The initial actors were some members of the **community,** especially the ones living near the area of intervention and the **academic group**, composed by three university teams (UNA, UFMG and ED-UEMG). Before any actual intervention the representatives from the municipality responsible for the area, URBEL/ PBH (*Companhia Urbanizadora e de Habitação de Belo Horizonte*) were called to dialogue and since then are taking part of the network (29). One year later we invited SUSAN/ PBH (*Subsecretaria de Segurança Alimentar e Nutricional/ Secretaria Municipal de Assistência Social Segurança Alimentar e Cidadania*) to support the development of the vegetable garden (30), also representing the **local administration.**

Another important member of the network is the nursery school located in front of the garden (*Creche Educacional Nascer da Esperança*), **a local organization** of the community itself. The name of the community garden was chosen by means of an activity that the teachers developed with the children and the selected one was Esperança (Hope), establishing the name Esperança Community Garden (ECG). Besides, they have an important role in the community garden of hosting meetings of the local group and mobilizing other members of the community thanks to their close relations with the children´s parents. Two special moments of their participation were the initial mutirão in 2017, a joint effort to clean the space and plant the first seedlings; and the first meeting of Belo Horizonte´s Community Gardens and Agroecology, in 2019, that gathered gardeners from many similar initiatives to exchange experiences, including participants of other initiatives of the CGP (31).

A representative of the **industry**, a local real estate construction company was called to give support to the 2017´s *mutirão*, which participated donating three "ipês" seedlings and with its employees taking part in the action, which is consistent with its **environmental** responsibility policy.

5. MAIN ACTIONS

The Esperança Community Garden is composed by two contiguous pieces of land, that we call "Top Garden" and "Bottom Garden" (Figure 1). The project´s first action was a mutirão, during which the "Bottom Garden" area was cleaned and some seedlings that were brought by the participants were planted. After that, the main routine involves the cycle of continuous cleaning and preparation of the soil and space increasing the area for planting (both in the bottom and in the top garden), maintenance of the plants (watering, combating harmful elements), harvesting, planting new seedlings. Although they always bring seedlings from their own personal circle of relationships, the new production relies mainly on the donations from SUSAN (through a project that promotes the implementation and maintenance of production units in Belo Horizonte, including the donation of supplies), especially of seedlings and manure (32). URBEL provides some equipment, basic infrastructure and also some technical engineering assistance.

The academic group gives continuous support to the local community. Having a WhatsApp group as an open communication channel, it dialogues and provides support to the local group for the demands that arise, be them related to relationship, supplies or infrastructure issues. For instance, it helps to mediate conflicts that arise in their daily routine and takes the local demands to other groups involved, such as URBEL and SUSAN. It also organizes periodic local meetings, always practicing the participatory research-action principles: giving protagonism to their voices and ideas, fostering social cohesion, respecting their previous knowledge of planting, using integral sustainability values and practices.

It is also important to highlight two impacting milestones of the Project. The first one was the COVID19 pandemic, within three aspects: a) the ECG was maintained and bravely resisted to this complex period; b) our relationship, even physically apart for a long time, was strong enough to resist and strengthen; an WhatsApp group was created (despite the initial difficulty of some members with this technology) and became this constant means of contact so useful for our nowadays

Figure 1: a) Condition of the area in 2016 (top left); b) areal view of the two parts that compose the Esperança Community Garden (Bottom Garden and Top Garden with nowadays usable area delimited in green) (bottom left); c) the workable top Garden in 2024 (top right); d) the bottom Garden in 2024 (bottom right).

activities, giving voice to each and every member; c) our connection with the community allowed us to contribute with the dissemination of information about the measures of protection against the virus regarding the use of fabric masks, by the distribution of an instructional booklet, a coloring leaflet and a jigsaw puzzle for the schools of the community (33). The second milestone were the meetings that gathered gardeners from all over Belo Horizonte in the Community Gardens and Agroecology events, where the groups, many of them fostered by SUSAN, could meet to communicate their achievements, discuss and find solutions to common problems.

The academic group also intermediates the exchange of knowledge bringing to the community technical workshops, such as "how to identify contour lines to build the planting beds", "how to use materials available to help irrigation", "how to produce fertilizer using the organic waste from their household". Regarding the acquisition of knowledge from the academy, students from a number of courses are being received in the Esperança Community Garden to make research for their academic works and are encouraged to bring back results (for instance, different composting methods).

Nowadays, the regular participants are about six families, who live very close to the community garden, together with teachers, employees and children from the nursery school. At this moment, a younger generation is approaching, after the contact with the academic group in a local event for women empowerment, promoted by the Belo Horizonte local administration. The Esperança Community Garden has then leaders that are resilient and actively involved from the very beginning, and count also on the participation of other members in cycles of expansion and contraction.

In this last one year and a half, the group is trying to build a containment wall on the steepest parts of the "Top Garden" (that currently is not effectively being used) to reduce the danger of landslide that would affect neighboring houses, and would also increase the usable area of the garden. The initial plan was to build it by using the social technology of tire walls, both considering its land containment function and also as a strategy to give a proper destination (upcycling) to wasted tires. Nevertheless, its building is very strainful and physically demanding, making it a challenging task, since the group is mainly composed by older women. Besides, during a recent visit with representatives of SUSAN they have demobilized this plan, by considering more adequate that the city hall´s construction department would build a concrete containment wall, a solution whose viability is still undefined.

The participation of the academy based on the

Systemic Design methodology is being of support, exchange, sharing of sustainable values and principles, but up to now was not being used as a planning tool to formally prepare a specific project to be executed. Nevertheless, considering the difficulty in tackling the earth containment problem, we have decided to develop a conceptual plan to help inspire viable, economic terrain containment solutions and optimization of the use of the space (Figure 2).

Figure 2: Planning for intervention in the Top Garden - a) plan (left); b) section along the terrain (top right); c) façade and plan of the social area (middle right); d) perspective views of the Garden and detail of the stairs and flowerbeds (bottom right). Author: Rosângela Mendonça/ ArquiCAD.

Respecting the local features, the typology conceived for the "Top Garden" was the terracing. The flowerbeds, that allow access by both sides, have the width of one meter since, considering ergonomic principles, the average person arm span is about 50 cm. Many of them have, from one side, hight of 80 cm in order to allow working on the soil in upright position, without bending, that is a more comfortable position for everyone, and specially for the elderly. In the middle, it was conceived a plateau with a structure with shade cover, making a greenhouse to grow seedlings or even to build an aquaponic structure (where fish farming can be interrelated to growing hydroponic plants, in a way that the fish droppings supply nutrients for plants and they, in turn purify the water). Also, a small social area was conceived where daily meetings could take place as well as being a space to clean and prepare production before leaving the garden premises, cleaning and storing tools and supplies in general. The roof dimensions were maximized in order to have a bigger area to collect rainwater that will be stored to water the plants.

6. RESULTS

All this initiative, that begun with academic internal projects and found opportunity to be extended to the society from one voluntary personal point of contact, have promoted significant changes for those involved regarding aspects of integral sustainability – changes in the environment, in relationships, and even in economic aspects, as resources are being used to produce quality food at a low cost, contributing to the mental and physical health of the ones involved.

Along the process, the methodology itself has been consolidated, having their principles validated, creating a new framework (Figure 3). Consistent with the participatory research-action methodology, the actions are happening in

participatory cycles of four moments (collective planning, implementation, monitoring, evaluation of the results and sharing of lessons learned) (25,26) including elements of the Systemic Design process (having its five principles as a guide for good practices), that are being registered through images, recordings, notes and reports.

7. DISCUSSION

Urban community gardens are becoming an alternative to the large market chains, to give access to quality food, especially to the low-income population. Participants in the integrated system see also community gardens as a space of nature and peace within the chaotic urban center.

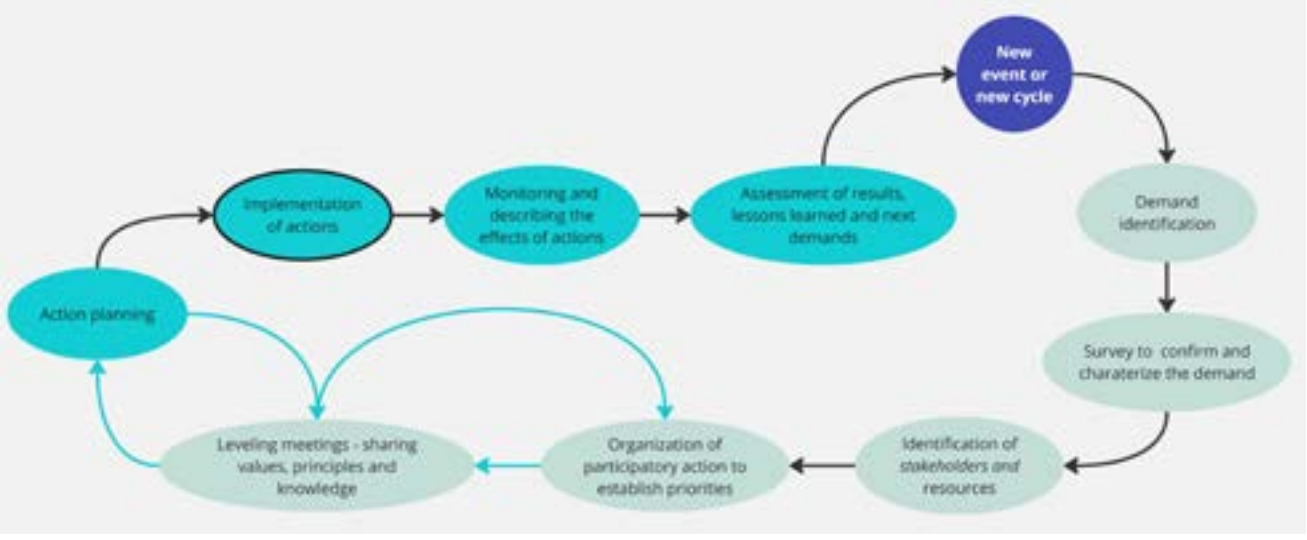

Figure 3: Framework of the methodology for sustainable community actions. Source: Own authors.

Up to now, questionnaires, interviews, observant participation, meetings, focus groups, collective actions (mutirões), welcome coffees and workshops have been developed. These initiatives are being used to get to know each person involved and encourage them to participate, to try and understand their wishes and needs, individually and as a community, to deal with relationship issues that eventually emerge, to share knowledge, to integrate and harmonize the group.

In relation to the environment, the area was effectively cleaned, some terrain level adjustments have been made and planting beds created and, more than just tackling the problems of a vacant lot in the community, a green productive spot was created.

The Participatory Reseach Action and Systemic Design principles contribute to reinforce that exchanges between academic institutions, local authorities and community should evolve naturally, without a notion of superiority, as long as everyone participates effectively in the movement and learns from each other.

Considering the spreading of similar initiatives in the community itself, it is noteworthy that the ECG is growing as a reference.

With the development of community-based, collaborative and shared work, community gardens are a way of resisting gentrification and a context for practicing partnership involving the community with their internal "specialized" groups, the private sector, the local administration, higher education institutions.

The experiences in the ECG show some typical features, as stated during their internal meetings and with other groups. Even if the communitarian, collective quality of the initiatives is reinforced, some members still have attitudes of dominance and control of the space as if it were almost private, willing to exercise and represent power as managers of the space and its production. Disputes about what to plant; where and how to plant; how to distribute production are frequent challenges. Whenever this takes a dimension that it starts to be perceived as a problem to the operation of the group, mainly because this kind of attitude creates conflicts, meetings should be organized to discuss how the individual can be expressed within the collective purpose of the garden.

Community gardens have then grown and strengthened areas of previous vulnerability, creating a healthy green leisure space, giving access to quality

food, exercising dialog. The kind of conflicts that arise in the context of the community gardens have a "treatable dimension" and, more than being problems, can be seen as opportunities to learn to solve conflicts through dialog a member expressing what has offended, bothered or been felt as lack of respect to his/ her right; the other processing the consequences of his/ her attitude; and both elaborating a solution to avoid the repetition of the conflict.

It can be perceived how low-income communities have resilience as their strength. If operational disagreements arise, also solidarity is present among their members, sharing personal resources in critical situations of their everyday life regarding, for instance, moments of illness and difficulty of communication.

Community Gardens are then a space of sharing resources, knowledge, learning to solve disputes and conflicts, organizing to plan and implement actions. Communication is being practiced involving every stakeholder.

For the Academy, it is being an opportunity of sharing knowledge, practicing solidarity, putting theories into practice. The Systemic Design methodology, associated with the principles of Solidarity Economy, is being an important guide to inspire propositions. Its principles are being transmitted and practiced as essential elements for building sustainability, for instance, 1) output-input: caring for the quality of the production, using natural control for harming elements, without the use of pesticides; production of composts; knowledge being exchanged between the academy and the community; 2) relationships: use of distribution of the gardening production to strengthen relationships; meetings to make collective decisions and share knowledge; fostering relationships among community/ society, universities/ academy; businesses/ industry; public administration; 3) autopoiesis: fostering the protagonism and conscious agent of every participant; initiatives to acquire autonomy; learning from each other and from previous actions; 4) valorization of local resources: knowledge, space, culture; 5) valorization of life: actions of inclusion, respect for the timing of nature; use of the space to provide wellbeing, more than the urge to produce to generate financial resources.

8. CONCLUSIONS

The Community Garden Program (CGP), especially in the Esperança Community Garden (ECG), has become an important social and academic practice, bringing new knowledge to all participants – researches, students, members of the community and of the public institutions – and contributing to the development of the society by using some effective methods, tools and actions. It is an opportunity for practicing diversity, exchanging empiric and academic knowledge, bringing together three pillars of the society: community, academy and public administration, trying also to increase the involvement of the "industry" to transform the environment.

Theories are being verified in practice. The systemic approach is proving to be very important for the broader goal of creating a context of change, in order to try and solve chronic problems of our society by means of the protagonism of the community itself, which is also one of the bases of the solidarity economy.

After seven years of exchange between the participants of this network, changes have been materialized by the transformation of the area of geological risk into a productive community garden. It can be observed that the continuous cycles of the research-action methodology has been proven coherent with what happens in real life within a community, as an ongoing process of thinking, acting and trying to learn from it. The intensification of meetings and dialogs are contributions of the academic approach. Nevertheless, there is yet work to be done to make the cyclic production a reality, to establish a more harmonious relationship within the group directly involved and to broaden the participating group, for them to achieve self-management and formalize it also as a possible economically sustainable activity. It is also an enduring process making the community understand the possibility and the significant value of being autonomous. It requires behavior, social and emotional changes which, in its turn, requires time, strong connections and a greater development of the local cohesion.

Regarding the academic research, the CGP seems to be getting near to maturity, making possible to try and approach the actual elaboration of formal Systemic Design plans, with the deepening on the theoretical understanding of social cohesion and its relation to sustainability. The compilation of the identified best practices for spreading actions for integral sustainability as a means of improving the quality of life gathered in this seven-year experience, allowed us to propose a model of action that could be replicated, in order to disseminate the benefits of this kind of initiative to other territories.

As future developments, we hope that other groups will apply and provide feedback on this proposed model, expanding our network, the learnings and the benefits of pursuing integral sustainability.

REFERENCES

Costa HS de M, Almeida DAO de. **Agricultura Urbana: possibilidades de uma praxis espacial**? Cad Estud Cult [Internet]. 2012;4(8):1–21. Available from: https://periodicos.ufms.br/index.php/cadec/article/view/3528

Bistagnino L. **Systemic Design** [Internet]. 2nd ed. Bra (Cn): Slow Food Editore srl; 2011. 272 p. Available from: https://www.unilibro.it/ebook/luigi-bistagnino/systemic-design-e-book-formato-pdf/29750742

Mendonça RMLO. **Systemic Network Innovation and Its Application in the Brazilian Context of the "Estrada Real"** [Internet]. Politecnico di Torino; 2014. Available from: https://iris.polito.it/handle/11583/2534088#.XDYjJVz0mMp

Monteiro R, Mendonça RM, Pessoa B. Briefing: ferramenta estratégica para o Design Sustentável. **Rev Transverso** [Internet]. 2024;1(14):13–31. Available from: https://revista.uemg.br/index.php/transverso/article/view/8359

Quaresma F, Córdula L, Pontes-Silva A, Schott E, Santos LL dos, Júnior FGRP. **Modelos de hélices tripla, quádrupla e quíntupla:** o papel das universidades. Scielo Prepr. 2024;

Meadows DH, Meadows DL, Randers J, III WWB. **Limits to Growth** [Internet]. 2o. Meadows DL, editor. New York: Universe Books; 1972 [cited 2024 Jan 15]. 205 p. Available from: https://collections.dartmouth.edu/content/deliver/inline/meadows/pdf/meadows_ltg-001.pdf

Paul BD. **A history of the concept of Sustainable Development:** Literature Review. Ann Univ Oradea, Econ Sci Ser [Internet]. 2008;17(2):581. Available from: https://www.academia.edu/29604734/A_history_of_the_concept_of_sustainable_development_literature_review

United Nations Development Program (UNDP). **What are the Sustainable Development Goals?** [Internet]. 2024 [cited 2024 Jan 10]. Available from: https://www.undp.org/sustainable-development-goals

Acselrad H, Leroy J-P. **Novas premissas da sustentabilidade democrática**. UFRJ, editor. Rio de Janeiro; 1999.

Naredo JM. **Raíces económicas del deterioro ecológico y social más allá de los dogmas.** Madrid: Editorial Siglo XXI; 2006.

Ribeiro MA. **Tesouros da Índia:** para a civilização sustentável. Belo Horizonte: Editora Rona; 2003.

Alves JI. **Desenvolvimento e desenvolvimento sustentável: uma revisão contemporânea para pensar políticas públicas num ambiente de complexidade.** Rev Jurídica [Internet]. 2018;01(50):484–513. Available from: https://revista.unicuritiba.edu.br/index.php/RevJur/article/view/2561/1525

Pott CM, Estrela CC. Histórico ambiental: Desastres ambientais e o despertar de um novo pensamento. **Estud Avancados**. 2017;31(89):271–83.

Andrade AL. **O Curso do Pensamento Sistêmico.** 1a ed. São Paulo: Digital Publish & Print Editora; 2014. 230 p.

Mendonça RMLO, Martins V. A academia na rede sistêmica de empreendimentos integrais em agroecologia. In: Mendonça RMLO, Figueiredo MCB de, editors. **Economia Criativa:** Práticas para Inovação e Desenvolvimento [Internet]. Belo Horizonte: Editora UEMG; 2019. p. 74–98. Available from: https://editora.uemg.br/component/k2/item/176-economia-criativa-praticas-para-inovacao-e-desenvolvimento?highlight=WyJlY29ub21pYSIsImNyaWF0aXZhliwiZWNvbm9taWEgY3JpYXRpdmEiXQ==

Mendonça RMLO, de Figueiredo MCB. EILAB, **Design e Sustentabilidade:** uma parceria empreendedora. An do 22o Semin Pesqui e Extensão [Internet]. 2020;46–80. Available from: https://uemg.br/seminariospe-publicacoes/artigos?download=7172:22-p-e-caderno-de-artigos-de-extensao-2020

EMBRAPA. Marco Referencial em Agroecologia [Internet]. Brasília, DF: Embrapa Informação Tecnológica; 2006 [cited 2024 Dec 10]. 70 p. Available from: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/66727/1/Marco-referencial.pdf

Carlile R, Garnett T. What is agroecology? [Internet]. TABLE Expl. University of Oxford, **Swedish University of Agricultural Sciences and Wageningen University & Research**; 2021. 70 p. Available from: https://tabledebates.org/sites/default/files/2021-06/What is agroecology_0.pdf

Santiago JL, Fraxe T de JP, Castro AP de, Campos JF. Agroecologia em rede e o fortalecimento da agricultura familiar. Rev Amaz Ensino Ciências [Internet]. 2017;10(21):12–22. Available from: http://repositorioinstitucional.uea.edu.br/bitstream/riuea/2807/1/Agroecologia em rede e o fortalecimento da agricultura familiar.pdf

Burity V, Franceschini T, Valente F, Recine E, Leão M, Carvalho M de F. **Direito Humano à Alimentação Adequada no Contexto da Segurança Alimentar e Nutricional** [Internet]. ABRANDH; 2010. 204 p. Available from: https://www.redsan-cplp.org/uploads/5/6/8/7/5687387/dhaa_no_contexto_da_san.pdf

Ciodaro AD de A, Mello EMR de. **Um arranjo formativo em economia solidária para alunos do fundamental**. PEPSIC [Internet]. 2018;13(4). Available from: http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S1809-89082018000400014#:~:text=Uma formação em economia solidária,uma vida saudável e digna

Singer P. **Economia solidária versus economia capitalista.** Soc e Estado [Internet]. 2001;16(1–2). Available from: https://www.scielo.br/j/se/a/Xy7BmyrV8tHfwKNVhmSXFyw/?lang=pt

Singer P. Relaciones entre sociedad y Estado en la economía solidaria. **Iconos** – Rev Ciencias Soc. 2009;(33):51–65.

Fórum Brasileiro de Economia Solidária (FBES). Carta de princípios da Economia Solidária [Internet]. 2003 [cited 2024 Jan 10]. Available from: https://fbes.org.br/2005/05/02/carta-de-principios-da-economia-solidaria/

Tripp D. **Pesquisa-ação: uma introdução metodológica.** Educ e Pesqui [Internet]. 2005;31(3):443–66. Available from: https://www.scielo.br/j/ep/a/3DkbXnqBQqyq5bV4TCL9NSH/?format=pdf&lang=pt

Franco MAS. **Pedagogia da pesquisa-ação.** Educ e Pesqui [Internet]. 2005 Dec;31(3):483–502. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1517=97022005000300011-&lng=pt&tlng=pt

Perdigão AC. A ética do cuidado na intervenção comunitária e social: Os pressupostos filosóficos. **Análise Psicológica** [Internet]. 2003;4(XXI):485–97. Available from: http://publicacoes.ispa.pt/index.php/ap/article/view/8/pdf

Mello EMR de, Nery S de O, Almeida DER, Costa JD. Economia solidária e segurança alimentar: pesquisa intervenção em hortas comunitárias. In: Manaus, editor. VI Conferência Internacional de Pesquisa sobre Economia Social e Solidária - CIRIEC "**Economia Social e Solidária, Sustentabilidade e Inovação:** enfrentando os velhos e os novos problemas sociais" [Internet]. UFAM; 2018. Available from: https://even3.blob.core.windows.net/processos/641c78eea4e04d419014.pdf

Prefeitura de Belo Horizonte (PBH). Companhia Urbanizadora e de Habitação de Belo Horizonte [Internet]. [cited 2024 Feb 5]. Available from: https://prefeitura.pbh.gov.br/urbel

Prefeitura de Belo Horizonte. Educação Alimentar e Nutricional [Internet]. 2019 [cited 2024 Jan 9]. Available from: https://prefeitura.pbh.gov.br/smasac/seguranca-alimentar-e-nutricional/informacoes/educacao-alimentar-e-nutricional

ED-UEMG. I Encontro Itinerante das Hortas Comunitárias de Belo Horizonte e Agroecologia [Internet]. 2019 [cited 2024 Feb 5]. Available from: https://ed.uemg.br/i-encontro-itinerante-das-hortas-comunitarias-de-belo-horizonte-e-agroecologia/

Secretaria de Assistência Social SA e C. Unidades Produtivas Coletivas e Comunitárias [Internet]. PBH. 2023 [cited 2023 Aug 15]. Available from: https://prefeitura.pbh.gov.br/smasac/susan/fomento/sistemas-de-producao/coletivas-e-comunitarias

Mendonça RMLO, Rodrigues CS. **Como utilizar máscaras de tecido** – Nova versão detalhando o descarte seguro [Internet]. 2020 [cited 2020 Oct 1]. Available

from: http://ed.uemg.br/como-utilizar-mascaras-de-tecido-nova-versao-detalhando-o-descarte-seguro/

Iida I. Ergonomia: **Projeto e Produção.** 2a. São Paulo: Editora Edgard Blücher; 2005. 614 p.

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CRediT Taxonomy (http://credit.niso.org/)

RMLOM: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, validation, visualization, writing - original draft and writing - revision and editing.

SON: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, validation, visualization, writing - original draft and writing - revision and editing.

EMRM: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, validation, visualization, writing - original draft and writing - revision and editing.

Conflict declaration: nothing has been declared.

DESIGN ELEMENTS THAT QUALIFY HOUSING FOR SOCIAL INTEREST: CASE STUDY IN THE MUNICIPALITY OF CURIONÓPOLIS-PA

ELEMENTOS DE PROJETO QUE QUALIFICAM A HABITAÇÃO DE INTERESSE SOCIAL: UM ESTUDO DE CASO NO MUNICÍPIO DE CURIONÓPOLIS-PA

ELEMENTOS DE DISEÑO QUE CALIFICAN LA VIVIENDA DE INTERÉS SOCIAL: UN ESTUDIO DE CASO EN EL MUNICIPIO DE CURIONÓPOLIS-PA.

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ABSTRACT
This article presents a study about the design limitations regarding Social Housing, observing approaches of flexibility, functionality, and adaptability included in the context of project aspects for family residences. These project elements can expand the perspectives for proposals of adapting the residences according to real families' demands and needs. This way, this research aims to carry out an approach about the main project elements to potentialize the quality of social housing from a bibliographical review, which grounded analyses in case studies carried out in Curionópolis-PA. The results comprise a synthesis of the fundamental concepts for the proposition of an alternative that comprehends the performance of these residences directed to the low-income public.

KEYWORDS
Social Housing; Flexibility; Functionality; Adaptability.

RESUMO
Este artigo apresenta um estudo sobre as limitações projetuais no que se refere a Habitação de Interesse Social (HIS), observando as abordagens de flexibilidade, funcionalidade e adaptabilidade, inclusas no contexto dos aspectos projetuais para residências resilientes. Esses elementos projetuais podem ampliar as perspectivas para as propostas de adaptação das residências de acordo com as demandas e necessidades reais das famílias. Dessa maneira, a pesquisa tem como objetivo realizar uma abordagem sobre os principais elementos projetuais para potencializar a qualidade em habitações sociais, a partir de uma revisão bibliográfica, que fundamentou análises em estudos de caso realizado no município de Curionópolis-PA. Os resultados comportam uma síntese de conceitos fundamentais para proposição alternativa que contemplem o desempenho dessas residências direcionadas ao público de baixa renda.

PALAVRAS-CHAVE
Habitação de Interesse Social; Flexibilidade; Funcionalidade; Adaptabilidade.

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RESUMEN

Este artículo presenta un estudio sobre las limitaciones de diseño en lo que respecta a la Vivienda de Interés Social (VIS), observando los enfoques de flexibilidad, funcionalidad y adaptabilidad, incluidos en el contexto de los aspectos de diseño para viviendas resilientes. Estos elementos de diseño pueden ampliar las perspectivas para las propuestas de adaptación de las viviendas de acuerdo con las demandas y necesidades reales de las familias. De esta manera, la investigación tiene como objetivo abordar los principales elementos de diseño para mejorar la calidad de las viviendas sociales, a partir de una revisión bibliográfica que fundamentó los análisis en estudios de caso realizados en el municipio de Curionópolis-PA. Los resultados contienen una síntesis de conceptos fundamentales para la propuesta de alternativas que contemplen el rendimiento de estas viviendas dirigidas a la población de bajos ingresos.

PALABRAS CLAVE

Vivienda de Interés Social; Flexibilidad; Funcionalidad; Adaptabilidad.

1. INTRODUCTION

Housing is an essential right of the citizen, considering that it is indispensable for their human development. This development comprises the feeling of sheltering, security, and well-being, with a conscious approach regarding the design elements of flexibility and architectural functionality.

Neglecting the needs and particularities of the residents in order to obtain a higher percentage of housing units at a more affordable price, intended for groups mostly belonging to the economically underprivileged social class, makes inadequacies and the rigidity of the construction system, without the attribute of flexibility, which is determinant for the low performance of the building.

The Brazilian Association of Technical Standards (ABNT – Associação Brasileira de Normas Técnias) defines the necessary requirements for habitability, so it is important to mention the performance of the building provided for in ABNT NBR 15.575:2013. Durability refers to the ability of the building or its systems to perform their specific functions. Habitability includes functionality as a requirement restricted to its users to perform tasks and activities in their daily lives.

The residential unit, sometimes neglected, becomes synonymous with quantitative, being restricted to the meaning related to housing projects, in the macro sense, restricted to public policies, leaving the design quality in the background. ABNT NBR 9050:2020 is another standard with precarious service in projects aimed at the general mass, which deals with accessibility in buildings, furniture, spaces, and urban equipment.

In this sense, this article presents the main elements that contemplate the quality of a flexible residential project based on analyses of families' effective use of housing. This usability of the executed project allowed us to observe the application of the concepts of accessibility and performance of the building, according to the cataloging of the recurrent modifications that users make to meet their demands. The analysis also considered the essential concepts of habitability as strategies to evaluate performance so that the houses more efficiently contemplate the families' needs.

The state's function in its different spheres of government in producing houses aimed at the low-income population needs to respond to the growing construction demands to minimize the housing deficit. The time of this response still presents challenges, so the approach to Social Interest Housing (HIS) broadens the discussions, going from the strictly political sphere to the academic and social sphere.

2. DESIGN ASPECTS FOR RESILIENT HOMES

In a context of continuous change, the search for resilient homes emerges as an imminent need. The concept of a resilient social housing project goes beyond construction. It encompasses strategic investments in infrastructure and social programs. From this perspective, for Villa and Oliveira (2021), resilient social housing not only ensures a physical shelter, the house, but stands out for offering a safe, flexible, and healthy refuge for its occupants, a home.

2.1 Flexibility

Flexibility is a characteristic of spatial excellence that makes it possible to modify the physical space of the house according to the changes, requirements, and desires of its residents. For Logsdon et al. (2019), offering flexible residential units aims to meet the needs of a population with lower purchasing power, which often does not have access to appropriate and personalized residences, in addition to reducing expenses and the environmental effects of the building.

According to Costa, Logsdon, and Fabrício (2021), flexibility in social housing can be achieved through a critical analysis of existing projects and by proposing more flexible solutions that are compatible with users' actual needs.

For Celluci and Di Sivo (2015), the architectural concept of flexibility can also be characterized as a solution to obsolescence, ensuring the system's durability over time.

Costa, Logsdon, and Fabrício (2021) state that the mass production of popular or social housing can be used as a strategy to reduce the housing deficit in Brazil. In this scenario, the discussion about implementing criteria that improve housing plans puts architectural flexibility on the agenda, characterized by meeting the specific demands of its occupants, considering their different family nuclei and their specificities of conformation for the project's design.

Till and Schneider (2020), in turn, explored concepts of flexibility, highlighting the relevance of creating housing spaces that can grow with needs, that is, with elements or systems that residents can modify. This concern with the feasibility of flexible practices should be possible from the project's design phase to combat extra

expenses and difficulties of medium or high complexity of the constructive intervention. The maintenance and readaptation of the different types of future uses of houses should seek to make them more resilient and capable of supporting a more significant number of possible family configurations at different times throughout the life cycle.

2.2 Functionality

According to Marroquim and Barbirato (2023), the analysis of functionality must consider not only the technical aspects but also the users' needs and expectations, promoting an efficient and welcoming environment. Thus, integrating technological solutions with a user-centered design can result in more functional spaces that are adaptable to the various demands of everyday life.

Vasconcelos (2017) states that the idea of functionality goes beyond the sectorization of environments themselves, as the dynamics of using space or furniture can have more than one function, which comprises multifunctionality. This articulation of assuming different functions during family dynamics or domestic daily life can occur in a sequenced, simultaneous, or seasonal way. This attribute can favor residents' well-being, observing accessibility and environmental impact requirements.

Logsdon et al. (2019) emphasize the importance of functionality and flexibility in HIS design to ensure the satisfaction of current and future user needs. The authors indicate a set of design guidelines that can simplify and optimize the adaptation of the house throughout its life cycle. Figure 1 shows the three guidelines that contribute to the development of functional projects.

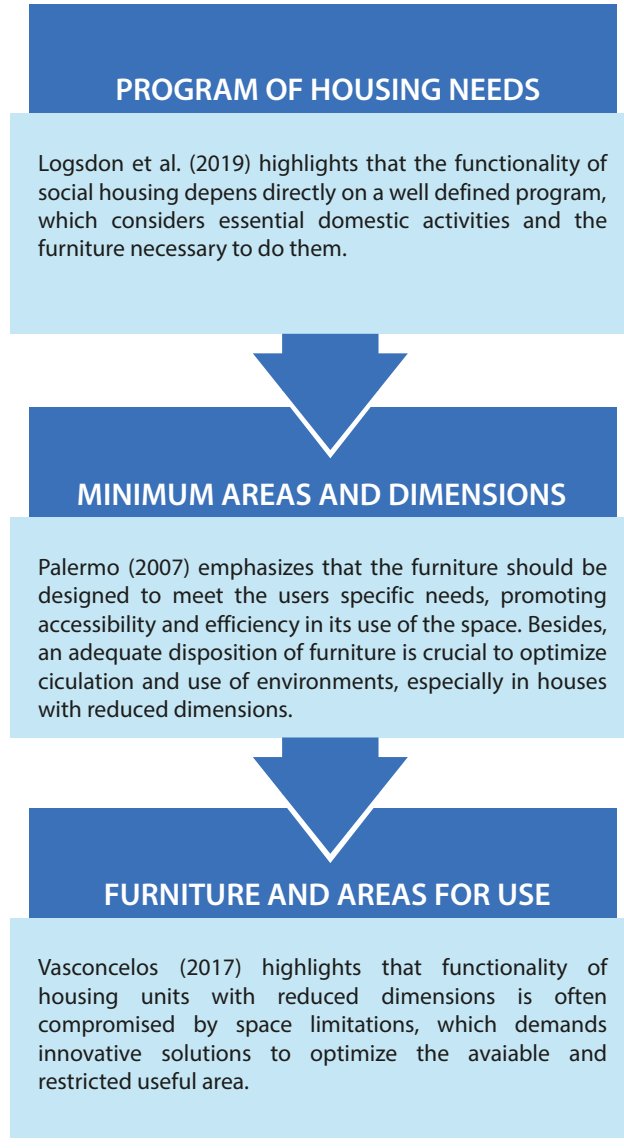

Figure 1 : Guidance of the project.
Source: Authors.

According to Palermo et al. (2007), HIS's dwelling is not merely a refuge but an environment that includes multifunctions, such as a space for rituals and lifestyles that go beyond the simplification of dwelling. Besides, the house must be considered in terms of durability, structure, space, functionality, and symbolism, particularly when intended for the low-income population, a category that earns from 0 to 5 minimum wages.

2.3 Adaptability

Larcher and Santos (2008) discuss the concepts of flexibility and adaptability as essential for the growth of HIS projects. These authors propose a data collection and analysis tool to define design guidelines that enable the

simplified and balanced adaptation of housing throughout its life cycle.

According to Fischer (2017), social housing in Brazil was designed and built in a standardized way, which makes it challenging to adapt it to changes in residents' spatial demands during the family life cycle. Thus, it is suggested that implementing adaptable social home projects can promote and prolong the functional durability of materials, optimizing use and reducing energy consumption throughout their useful life.

Adaptability includes a design element that is available both in terms of flexibility of use and multifunctionality. These concepts comprise factors that contradict the rigidity of the form itself and the projected usability since only the specificity of the family nucleus can attribute the actual use to it according to its effective needs and cultural baggage, not simply focused on theoretical generalities.

Brandão (2011) suggests a set of design guidelines that enable the simplified and balanced adaptation of the house throughout its life cycle. Adaptability can encompass the flexibility of spatial use, materials, and components to favor and facilitate possible changes, expansions, spatial junctions, subtractions, or replacements of the residential unit's environments, elements, or components, without harming structural safety, as shown in Table 1.

Principles	Description
1. Independence	Feature that allows removal and addition without affecting the efficiency of interconnected systems.
2. Upgradability (upgrade capacity)	Systems and components that allow additions, expansions, and upgrades for their own improvement and increase of efficiency.
3. Lifecycle compatibility	Prediction of systems and components with similar lifetimes, especially interconnected ones.
4. Information	Records of designs, specifications, and limitations of the projects in order to assist future cost analysis of adaptations and expansions.
5. Durability	Duration of materials, elements, and components concerning repairs, maintenance, and replacement. It also includes durable spaces.
6. Versatility	Form or arrangement of space that allows alternative uses.
7. Easy access to systems, components, and elements	Recessed technical ceilings, raised floors, shafts, and other solutions that allow easy access to pipes, ducts, wiring, and equipment.
8. Redundancy	Structures designed to receive larger loads, facilities sized for expansion, and additional elements (overprovision).
9. Simplicity	Absence of system complexity, rationalized designs, modular structures and components, and conventional materials.

Table 1 : Principles that facilitate adaptability.
Source: Canada Mortgage Housing Corporation (CMHC) and Canada Clean and Renewable Energy Research Centre (CANMET); Russell and Moffatt.

3. METHODOLOGICAL PROCEDURES

The research used the following methods: literature review, document review, and case study. The theoretical foundation was composed of analyses of current standards, ABNT NBR 9050:2020 and ABNT NBR 15.575:2013, as well as specialized literature, such as Palermo et al. (2007), Villa and Oliveira (2021), Logsdon et al. (2019), Costa, Logsdon and Fabrício (2021), Vasconcelos (2017), Larcher and Santos (2008), Fischer (2017).

The case study is in Curionópolis-PA. In this stage, we sought to evaluate the characteristic design elements of HIS in order to identify inconsistencies and modifications and suggest alternatives to enhance the quality of usability.

To develop the work, the following steps were adopted: (I) identification of the problem; (II) literature review on HIS and concepts of design aspects for resilient residences, such as flexibility, functionality, and adaptability; (III) field activity for data collection, interviews and survey of 10 residences in the housing complex (measurement both in the residence and in the lot), to evaluate the main changes; and (IV) analyses of the case study, from the evaluation of design instabilities in one of the houses to the changes made by the residents.

The field activity allowed the compilation of information and comparative analysis, showing the most recurrent changes and making it possible to understand the reality faced by the population benefiting from HIS. This synthesis of the study made it possible to technically

propose alternatives that enhance the housing quality in this social context.

4. GEOGRAPHICAL AND SOCIAL CONTEXT

Curionópolis-PA originated as a municipality from the unfolding of the municipality of Marabá, located in the southeast of Pará. The constitution of the city was triggered by a cluster of people who were attracted to the region with the expectation of work, caused, above all, by the implementation of the Carajás Iron Project, construction of the Carajás - Ponta Madeira railroad, and by the search for gold in the numerous mines that spread in the region.

According to the Brazilian Institute of Geography and Statistics (IBGE), in its last Census (2022), Curionópolis had a resident population of 19,950 inhabitants, with a demographic density of 8.42 inhabitants/km^2. Figure 2 shows the region, the object of study used to develop this work, and the outline of the Casa Nova Vida housing complex.

According to the IBGE, the heyday of gold in Serra Pelada occurred in the early 80s, and Curionópolis consolidated itself as a support center for mining activity and as a place of residence for the families of miners who, at the time, were prevented from entering the mining area. This village was developed as an area to support the demands of family members, with shops and service sectors such as pensions, bars, and snack bars. However, only on May 10, 1988, it was elevated to municipality status through State Law No. 5,444 (1988), even after mining activities dropped.

4.1 HIS in the Brazilian context

Article 6º of the Brazilian Federal Constitution guarantees the right to housing, which emphasizes the social rights to education, health, food, work, housing, leisure, security, social security, protection of maternity and childhood, and assistance to the destitute. However, despite being provided for by law, with the problem of housing deficit in Brazil, a significant number of people still face situations of housing vulnerability, either living on the streets or in inadequate housing.

In this context, the HIS programs aim to make it viable for the low-income population to access housing. According to CAIXA (2021), the housing unit must be adequate and planned and an instrument that reduces social disparity and inconsistencies in the housing deficit.

According to data from the João Pinheiro Foundation (FJP) on the housing deficit in Brazil (2022) an average of 6.2 million homes were estimated, representing 8.3% of the total occupied housing in the country. In absolute numbers, the indicator that seeks to estimate the absence of housing and/or the presence of housing in unstable conditions pointed to an increase in this impasse of 4.2% compared to 2019.

Analogous to this, it is important to mention the unbridled, intense urbanization process and real estate speculation linked to the context of the low-income population. Fully contemplating housing policies for this public still presents some weaknesses, either due to the lack of broad applicability of essential rights to citizens or due to the dominance that the socially underprivileged class still exercises over the urban scenario.

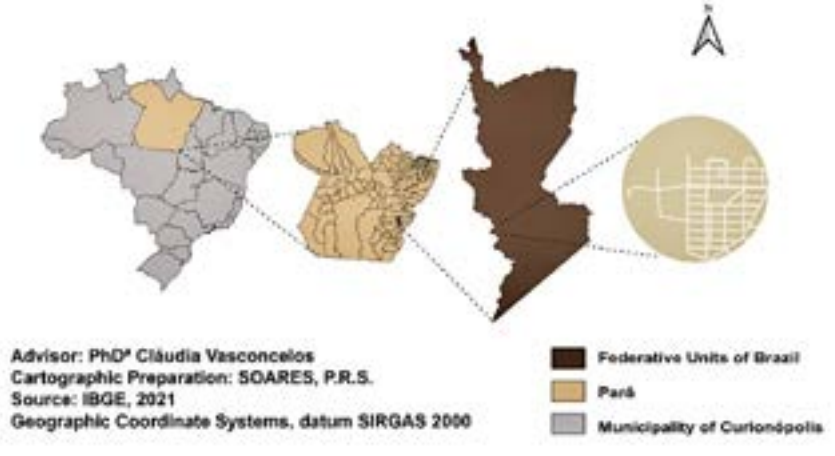

Figure 2 : Location map of the case study: Curionópolis-PA, Brazil.
Source: Authors.

Thus, despite the numerous impasses regarding the integral contemplation of housing guarantees, different social programs were implemented in Brazil, with the purpose of enabling the population to acquire their first property. That is the case of Curionópolis - Pará, through the Casa Nova, Vida Nova Project, whose purpose was to solve the problems of lack of housing, granting residences essentially to the people with disabilities (PwD) population and the low-income public.

4.2 Case studies: good practices in HIS projects

The Quinta Monroy Housing Complex, located in Iquique, Chile, is an example of innovation in HIS, designed by Alejandro Aravena and his team at ELEMENTAL. The project was designed to relocate 100 families who were illegally occupying a plot of land in the center of the city. According to Aravena et al. (2003), the project's main innovation was creating a basic structure that allowed residents to expand their houses according to their needs and as their financial resources increased. This flexible approach was essential to ensure that homes could evolve over time, meeting the changing life cycle of households, as shown in Figure 3.

Figure 3 : Quinta Monroy housing complex, Chile.
Source: Archdaily (2019). Available at:
<https://www.archdaily.com/10775/quinta-monroy-elemental> Access on: Sept. 01. 2024.

Sustainability and the efficient use of space were crucial aspects of the Quinta Monroy project. For Millones Segovia (2017), the use of local materials and efficient construction techniques has not only reduced costs but also minimized environmental impact. In addition, the design allowed for efficient natural ventilation, reducing the need for HVAC systems and, consequently, for operating costs for residents. This sustainable approach created a healthy and economically viable living environment.

Another important aspect of the project was community participation in the design process. As described by Aravena et al. (2003), the inclusion of future residents in design decisions ensured that the houses met the families' actual needs. This active participation fostered a sense of belonging and responsibility among residents, which was crucial to the project's long-term success. Figure 4 shows how collaboration between architects and residents resulted in more appropriate and personalized design solutions.

Figure 4 : Internal view of one of the residences in the housing complex.
Source: Archdaily (2019).Available at:
<https://www.archdaily.com/10775/quinta-monroy-elemental> Access on: Sept. 01. 2024.

For Millones Segovia (2017), innovative solutions, such as using local materials and efficient construction techniques, have been implemented to keep costs low without compromising quality. This approach allowed Quinta Monroy to become a model of HIS, inspiring other initiatives in different parts of the world. It shows that it is possible to produce decent and sustainable housing even with limited resources.

According to Figure 5, the Jardim Edith Housing Complex, designed by MMBB Arquitetos and H+F Arquitetos in São Paulo, is an example of another innovative and effective approach to HIS, overcoming several design limitations. For Franco et al. (2013), integrating the

project with the local community is crucial to promoting social inclusion and improving residents' quality of life.

Figure 5: Jardim Edith housing complex, São Paulo.
Source: Archdaily (2019)]. Available at:
<https://www.archdaily.com.br/br/01-134091/conjunto-habitacional-do-jardim-edite-slash-mmbb-arquitetos-plus-h-plus-f-arquitetos> Access on: Sept. 1. 2024.

As pointed out by Moreira et al. (2013), the emphasis on architectural quality and durability of materials ensured that the dwellings were robust and required little maintenance. This choice was essential to ensure the longevity of the housing units, reducing maintenance costs for both residents and the public administration.

Besides, the organization of the housing units, described by Vada (2019), was planned to maximize the efficiency of the space and provide privacy to the residents, as shown in Figure 6.

Optimizing ventilation and natural lighting not only improved the comfort of the residents but also contributed to the sustainability of the housing complex by reducing the need for artificial lighting and air conditioning systems.

In short, the Jardim Edith Housing Complex demonstrates how successful planning and execution can transform an HIS project into a model of inclusion, durability, and Sustainability.

Figure 6: External view of the housing complex.
Source: Archdaily (2019). Available at:
<https://www.archdaily.com.br/br/01-134091/conjunto-habitacional-do-jardim-edite-slash-mmbb-arquitetos-plus-h-plus-f-arquitetos>. Access on: Sept. 1. 2024.

5. ANALYSIS OF THE CASA NOVA, VIDA NOVA PROJECT – CURIONÓPOLIS/PA

The Casa Nova, Vida Nova project, in Curionópolis-PA, in the country's northern region, was implemented in 2013 by the municipal executive power based on an amendment approved by the legislative power. The residential development was developed with the city's own resources.

The program provided for a minimum of 10% of houses for low-income people with disabilities (PwD), as provided for in Bill 4775/2012. The other houses were intended for the population that proved to earn a minimum income of less than three minimum wages and who did not own any property. This proof occurred through a registration carried out by the Social Assistance Reference Center (CRAS) in Curionópolis-PA.

The project description was based on a current analysis carried out in loco in one of the residential units. Figure 7 shows the project of this isolated single-family unit on the lot, with dimensions of 47.36 m^2, in masonry,

implanted in a lot of 200 m². The floor plan is characterized by the distribution of the following environments: two bedrooms of 8.85 m² (each), bathroom of 2.50 m², circulation of 2.65 m², kitchen of 10.85 m² and living room of 13.66 m², which includes the functions of living and dining. Gables, wooden structures, and ceramic tile characterize the residence's roof.

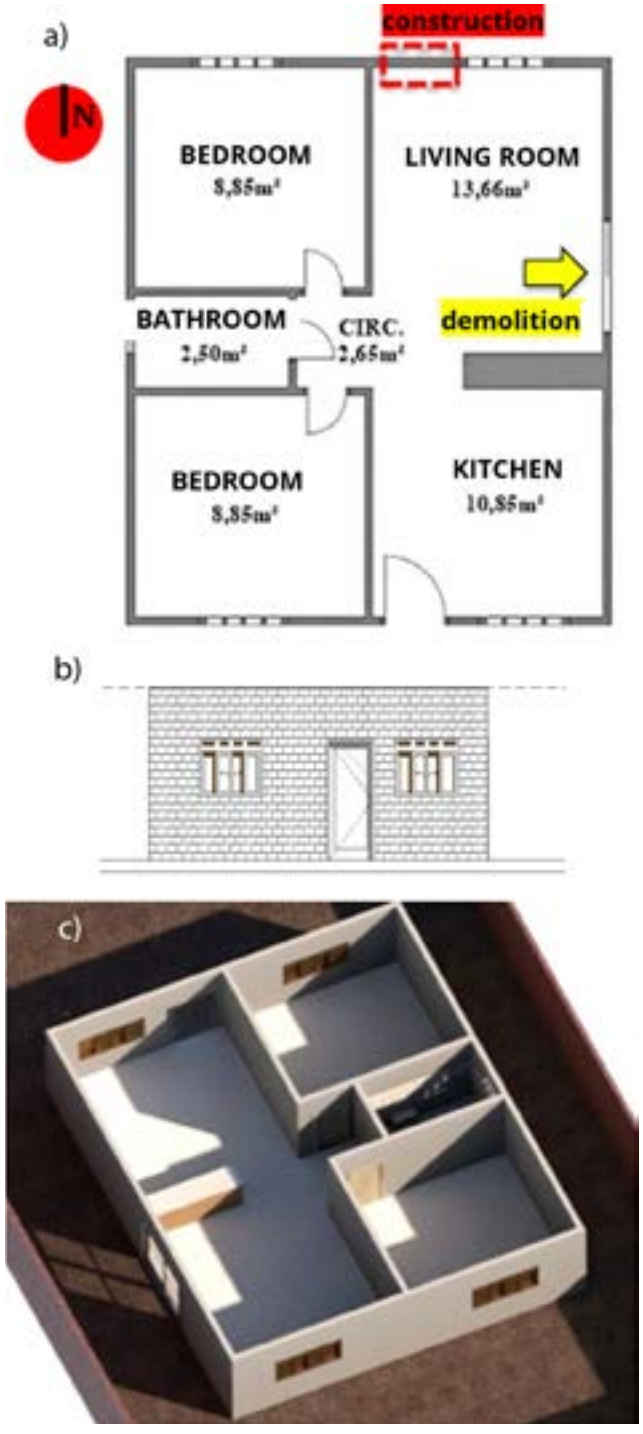

Figure 7: Housing project: (a) Floor plan adapted according to the modifications of new openings made by the resident. In the original plan, the main access was 0.60 m, as delimited with a dashed red marking, being replaced by larger spans, highlighted with a yellow arrow; (b) Elevation; (c) Interior top view.
Source: Authors.

The standard project served 400 families who faced the daily problem of homelessness. In practice, this offer had some characteristics that diverged from the condition of full scope, considering the security and restrictive form of reduced spaces common in HIS projects.

The dimensional constraints of the environments limit use, which is strictly necessary, and sometimes do not include the basic functions and minimum furniture for essential activities and tasks in the family's daily life. In this way, concepts of flexibility and functionality are necessary to understand the effective habitability and well-being of residents and how they could be practically implemented in more efficient projects.

The standard of the houses in this housing complex has narrow openings of only 0.60 m in the bedrooms and bathroom, making it difficult for PwD or people with reduced mobility to walk freely so that it does not meet the fundamental requirements of ABNT NBR 9050:20. It was also observed the recurrent modification of the house main access, as throughout the residents routine, they feel the need to expand the opening and change circulation, to make the social sector more flexible, to improve the habitat's performance.

Replacing the original access allowed the provision of a free span of greater capacity in the new opening. The original span was restrictive and located on the north façade. Modifying the new access from the north façade to the east one increased the free span of this frame, but it caused infrastructure interferences, especially in hydraulic maintenance and sewage.

The renovations proposed by the residents made it possible to adapt the requirements for the sizing of the openings, according to ABNT NBR 9050:2020 and ABNT NBR 15.575:2013. These two norms provide for the building capacity or its systems to adequately perform their functions autonomously to its users. Figure 8 shows that the openings of the bathroom and bedroom doors have spans of 0.60 m, which does not meet accessibility requirements, since ABNT NBR 9050:2020 recommends that the free spans of the doors be at least 0.80 m.

The original main access to the building was modified to facilitate families' daily use. However, some residents did this renovation without proper technical assistance, as shown in Figure 9. The ABNT NBR 15575:2013 standard, which deals with the building's durability, establishes that both the building and its systems must be able to perform their functions in the long term. Furthermore, the standard reinforces the importance of adequately guiding residents through a manual, specifying the

correct conditions of use and maintenance to ensure the structure's longevity, performance of the building, and useful life.

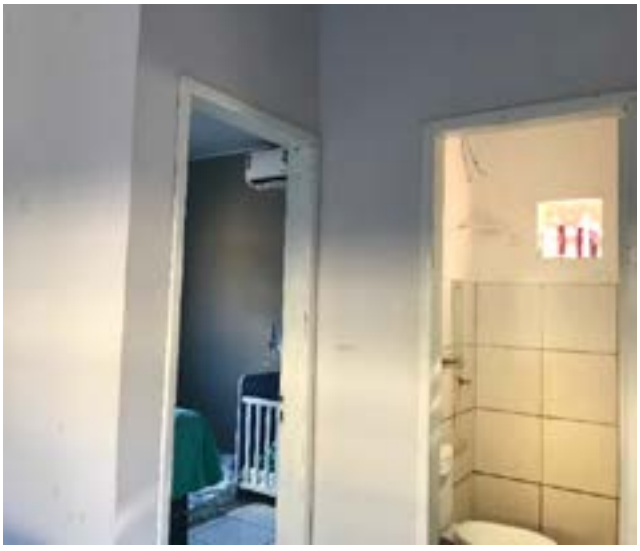

Figure 8: Recurring changes in the use of residences.
Source: Authors.

Figure 9: Recurring changes in the use of residences.
Source: Authors.

Figure 10 shows this new main access, which was arranged by the resident in order to improve circulation in the environment and expand the opening size to more efficiently meet the needs of use. The adjustment guaranteed a more adequate frame dimension, promoting greater comfort and accessibility to residents. Expanding the opening of the free passage allowed to fulfill accessibility requirements, facilitating the transit of people, including those with reduced mobility, according to the ABNT NBR 9050:2020 standard. This norm recommends that doors with free spans be equal to or greater than 0.80 meters—emphasizing that this resolution caused incompatibility with the house's hydraulic and sewage system.

Figure 10: Recurring changes in the use of residences.
Source: Authors.

During the field activity, interventions carried out by residents in 10 residences without technical assistance were identified. These small and medium-sized renovations include expanding environments, adapting door openings, and providing the main access to the house, among other adjustments made to meet the residents' needs.

The adjustments in the design or execution of the work reflect a collective effort to improve the houses' functionality and comfort based on the families' specificities of use. The construction of sidewalks and ramps was the most recurrent modification among the ten houses analyzed, aiming to improve access. Figure 11 shows the most recurrent renovations, modifications, and expansions in the analyzed housing complex, which were carried out by the residents themselves to adapt the spaces to the effective needs of the family nucleus.

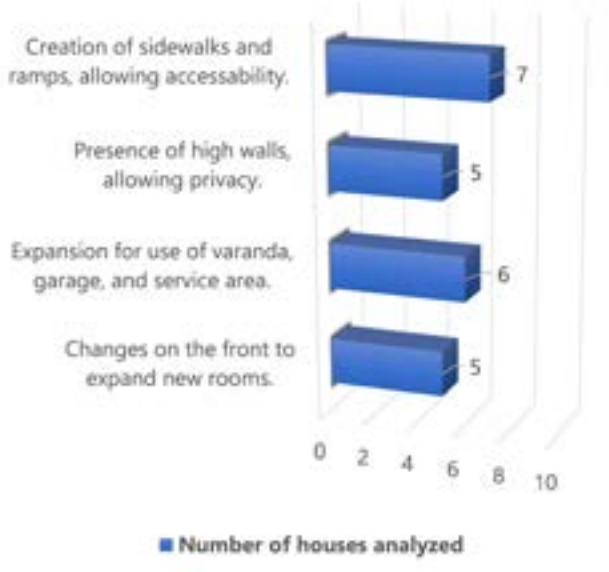

Figure 11: Survey of HIS in the Casa Nova complex, Vila Nova in Curionópolis-PA.
Source: Authors.

The result of the study found that the use of domestic spaces in restrictive areas is directly correlated with the low performance of the environments, considering their respective sectors, functions, activities, and tasks of the house's daily life as a function of the profile of the family nucleus. Thus, it is considered that the perceptions of housing occupation, the identity of the place, and the privacy and territoriality of the environments can accommodate different sociocultural contexts. This appropriation of the housing unit will always be a particular process with specificities specific to the residents.

Architectural strategies for project design must consider the flexible attributes of the building, observing the fulfillment of planned categories that support the predictability of the user's appropriation and the particularities of his family nucleus. In other words, the flexibility parameter must be in accordance with the program of needs, which meets the demands of the effective residents, allowing the construction of a housing unit with a resilient aspect and in accordance with current standards. This concern of those who design to meet the real need must have, from the design phase, the following premises: habitability, functionality, durability, and accessibility, as provided for in the Brazilian standards ABNT NBR 15.575:2013 and ABNT NBR 9050:2020.

6. CONCLUSION

This research sought to analyze scientific productions and apply this knowledge as a basis for the data collection protocol and evaluation of the case study directed to the HIS enterprise. This database enabled a systematization and planning of the field activity to characterize the changes in the project to meet the residents' actual needs.

The case study consisted only of single-family residential units isolated on the lot, with a high rate of standardization and repetition. Characterizing the development with dimensional restriction of the environments compromised the house's performance regarding the use and maintenance of its components by its residents.

The recurrent failure of the enterprises built en masse persists in the generalization of the family nucleus or the standard user. That is, in the recurrent standardization of the housing unit, with a high repetition rate of the composition of the form, which does not contribute to housing performance. This duality of physical space and actual demand generates a consequence regarding need in the short term, or immediately after the property is delivered, due to renovation to adapt it to the tasks and activities of the routine and the family profile.

The results of the research showed that the interventions that residents themselves carried out in the houses, without technical assistance, managed to mitigate the immediate need of the specific family context, but sometimes in an unpretentious attempt to adapt some requirements of the current standards, both performance, ABNT NBR 15.575:2013, and accessibility, ABNT NBR 9050:2020. In terms of performance, the aim was to improve the requirements of habitability, flexibility, and functionality. As for accessibility, the aim was to meet the residents' actual needs, with their specificities and particular profiles, observing the construction of ramps, and intervention in the access to housing, either without obstruction or by widening doors.

REFERENCES

ARAVENA, Alejandro; IACOBUCCI, Andrés. **Elemental**: manual de vivienda incremental y diseño participativo. Berlin: Hatje Cantz, 2012.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **ABNT NBR 15.575:** Edificações habitacionais

– Desempenho. Rio de Janeiro, 2013.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **ABNT NBR 9050**: Acessibilidade a edificações, mobiliário, espaços e equipamentos urbanos. Rio de Janeiro, 2020.

BRANDÃO, D. Q. Disposições técnicas e diretrizes para projeto de habitações sociais evolutivas. **Ambiente Construído**. Porto Alegre, v. 11, n. 2, p. 7-22, abr./jun. 2011. Disponível em: https://www.scielo.br/j/ac/a/djNCy8P5q9FvKQp8Rb3PXdD/. Acesso em: 17 jan. 2024.

BRASIL. **Constituição da República Federativa do Brasil de 1988**. Brasília, DF: Presidência da República. Disponível: https://www.planalto.gov.br/ccivil_03/Constituicao/Constituicao.html. Acesso em: 22. ago. 2024

CAIXA. **Habitação de Interesse Social**. Disponível em: https://www.caixa.gov.br/poder publico/infraestrutura-saneamento-mobilidade/habitacao/interessesocial/Paginas/default.aspx. Acesso em: 22 ago. 2024.

CANADA Mortgage Housing Corporation; CANADA'S Clean and Renewable Energy Research Centre. **Building Adaptability**: a survey of systems and components, Ottawa, maiy 1997.

CELLUCCI, C.; DI SIVO, M.. **A Habitação Flexível**: Critérios e Estratégias para Implementação da Flexibilidade. 2015. Disponível em: https://shorturl.at/mpwFR. Acesso em: 11 jan. 2024.

Conjunto Habitacional do Jardim Edite / MMBB Arquitetos + H+F Arquitetos. **ArchDaily Brasil**, 2019. Disponível em: https://www.archdaily.com.br/br/01-134091/conjunto-habitacional-do-jardim-edite-slash-mmbb-arquitetos-plus-h-plus-f-arquitetos. Acesso em: 1 set. 2024.

COSTA, H. A.; LOGSDON, L.; FABRICIO, M. M. **Flexibilidade em projetos de arquitetura: contribuições a partir de uma revisão sistemática da literatura**. PARC Pesquisa em Arquitetura e Construção, Campinas, SP, v. 8, n. 3, p. 144–160, 2017. Disponível em: https://periodicos.sbu.unicamp.br/ojs/index.php/parc/article/view/8650206. Acesso em: 11 jan. 2024.

Curionópolis (PA) | Cidades e Estados | IBGE. Disponível em: <https://www.ibge.gov.br/cidades-e-estados/pa/curionopolis.html>. Acesso em 12. jan. 2024.

Fundação João Pinheiro. FJP. **Déficit Habitacional no Brasil**. Disponível em: <https://fjp.mg.gov.br/deficit-habitacional-no-brasil/>. Acesso em 22. ago. 2024.

FISCHER, Rafael Santos. **Estratégias de adaptabilidade na habitação social**: implicações no ciclo de vida energético do edifício. 2017. 202 f. Tese (Doutorado em Arquitetura e Urbanismo) - Universidade Federal do Paraná, Curitiba, 2017. Disponível em: https://acervo-digital.ufpr.br/ handle/1884/48001. Acesso em: 17 jan. 2024.

FRANCO, F. M.; MOREIRA, M.; BRAGA, M.; FERRONI, E. R.; HEREÑÚ, P. E. R.. **Todas as escalas:** conjunto habitacional Jardim Edite. Summa+, n. 134, p. 68-77, 2014.

LARCHER, J. V. M.; SANTOS, A. dos. **Flexibilidade e adaptabilidade:** princípios para expansão em projetos de habitações de interesse social. Ambiente Construído, Porto Alegre, v. 8, n. 4, p. 63-77, out./dez. 2008. Disponível em: https://shorturl.at/nCDLQ. Acesso em: 11 jan. 2024.

LOGSDON, L.; FABRICIO, M.; SOUSA, D.; PADILHA, Y. **Funcionalidade e Mobiliário da Habitação:** contribuições para o projeto de moradias sociais. In: Arquitetura Revista, vol. 15, n. 2, pp. 212-237, 2019, Unisinos. Disponível em: https://shorturl.at/diCGU. Acesso em: 11 jan. 2024.

LOGSDON, L.; PEREIRA, L. M.; FRANCO, J.; FABRICIO, M. M.. **Flexibilidade na habitação social: a prática e a teoria em busca da qualidade espacial**. 2018. Disponível em: https://shorturl.at/lpzW9. Acesso em: 15 jan. de 2024.

MARROQUIM, F. M. G.; BARBIRATO, G. M.. ANÁLISE DA FUNCIONALIDADE DE PROJETOS DE HIS NA CIDADE DE MACEIÓ-AL DE 1964 A 2014. In: **SIMPÓSIO BRASILEIRO DE QUALIDADE DE PROJETO DO AMBIENTE CONSTRUÍDO**, 6., 2019. Anais [...]. [S. l.], 2019. p. 906–917. Disponível em: https://eventos.antac. org.br/index.php/sbqp/article/view/3195. Acesso em: 28 ago. 2024.

MILLONES SEGOVIA, Yessenia. La otra mitad de la Quinta Monroy. **Revista de Arquitectura**, v. 22, n. 32, 2017. Disponível em: https://dearquitectura.uchile.cl/index.php/RA/article/view/46147. Acesso em: 1 set. 2024.

MOREIRA, M.; FRANCO, F. M.; BRAGA, M.; FERRONI, E. R.; HEREÑÚ, P. E. R.. **Cidade negociada**: Habitação de interesse social, São Paulo - MMBB Arquitetos e H+F Arquitetos. Projeto: revista mensal de arquitetura, n. 401, p. 56-63, 2013.

PALERMO, C. et al. Habitação Social: Uma visão projetual. In: **Colóquio de Pesquisas em Habitação**, 4, 2007. Disponível em: http://www.mom.arq.ufmg.br/coloquiomom/comunicacoes/palermo.pdf. Acesso em: 03 jan. de 2024.

PARÁ. Assembleia Legislativa Do Estado Do Pará. **Lei N° 5.444 de 10 de maio de 1988**. http://bancodeleis.alepa.pa.gov.br:8080/lei5444_1988_68352.pdf. Acesso em: 22. ago. 2024.

PL 4775/2012. Portal da Câmara dos Deputados. Disponível em: https://www.camara.leg.br/propostas-legislativas/561542. Acesso em: 08 jan. 2024.

RUSSEL, P.; MOFFATT, S. **Assessing the Adaptability of Buildings**. In: ENERGYRELATED ENVIRONMENTAL IMPACT OF BUILDINGS, 31., 2001. Proceedings… 2001.

TILL, J.; SCHNEIDER, T. **Flexible Housing Revisited**. 2020.

VADA, Pedro. Durabilidade e qualidade arquitetônica no Conjunto Habitacional Jardim Edith. **ArchDaily**, 2019. Disponível em: https://www.archdaily.com.br/br/author/pedro-vada. Acesso em: 1 set. 2024.

VASCONCELOS, Cláudia Queiroz de. **Avaliação da compacidade, funcionalidade e flexibilidade em habitações de dimensões reduzidas**: estudos de caso em edifícios de Florianópolis-SC. 2017. 345 p. Tese (Doutorado em Arquitetura e Urbanismo) - Universidade Federal de Santa Catarina, Florianópolis, 2017. Disponível em: https://tede.ufsc.br/teses/PARQ0287-T.pdf. Acesso em: 08 jan. 2024.

VILLA, S. B; OLIVEIRA, N. F. G. Métodos de Avaliação da Resiliência no Ambiente Construído em Habitação de Interesse Social: Uma Abordagem Teórica no Contexto da Cidade de Uberlândia-MG. **9° Congresso Luso-Brasileiro para o Planejamento, Regional, Integrado e Sustentável** (PLURIS 2021 Digital) Pequenas cidades, grandes desafios, múltiplas oportunidades. 07, 08 e 09 de abril de 2021.

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POLYMERS AND SUSTAINABILITY: OVERVIEW OF THE USE OF CONVENCIONAL AND BIODEGRADABLE POLYMERS

POLÍMEROS E SUSTENTABILIDADE: VISÃO GERAL DO USO DE POLÍMEROS CONVENCIONAIS E BIODEGRADÁVEIS

EPOLÍMEROS Y SOSTENIBILIDAD: VISIÓN GENERAL DEL USO DE POLÍMEROS CONVENCIONALES Y BIODEGRADABLES

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ABSTRACT
This article aims to provide an overview of important moments in the consolidation of the use of conventional and biodegradable polymers throughout history. It begins by discussing the definition of conventional and biodegradable plastics, followed by a historical contextualization of petroleum-derived plastics, referred to here as conventional plastics, highlighting significant events in their evolution. The article then emphasizes the development and growth of biodegradable polymer applications. To this end, a literature review was conducted, supported by data collection from publications discussing polymer technologies. The studies highlight the environmental advantages of biodegradable polymers, despite their still higher production costs. Although biodegradable polymers are a viable alternative to petroleum-derived polymers, there are cases in which their use is not yet feasible, depending on the context of application, economic conditions, and consumer experience.

KEYWORDS
Biodegradable Polymer; Synthetic Polymer; Sustainable Development of Products, Design and Technology.

RESUMO
Este artigo tem como objetivo fornecer uma visão geral dos momentos importantes na consolidação do uso de polímeros convencionais e biodegradáveis ao longo da história. Ele começa discutindo a definição de plásticos convencionais e biodegradáveis, seguido por uma contextualização histórica dos plásticos derivados do petróleo, referidos aqui como plásticos convencionais, destacando eventos significativos em sua evolução. O artigo então enfatiza o desenvolvimento e crescimento das aplicações de polímeros biodegradáveis. Para isso, foi realizada uma revisão da literatura, apoiada pela coleta de dados de publicações que discutem tecnologias de polímeros. Os estudos destacam as vantagens ambientais dos polímeros biodegradáveis, apesar de seus custos de produção ainda serem mais altos. Embora os polímeros biodegradáveis sejam uma alternativa viável aos polímeros derivados do petróleo, há casos em que seu uso ainda não é viável, dependendo do contexto de aplicação, das condições econômicas e da experiência do consumidor.

PALAVRAS-CHAVE
Polímero Biodegradável; Polímero Sintético; Desenvolvimento Sustentável de Produtos, Design e Tecnologia.

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RESUMEN

Este artículo tiene como objetivo proporcionar una visión general de los momentos importantes en la consolidación del uso de polímeros convencionales y biodegradables a lo largo de la historia. Comienza discutiendo la definición de plásticos convencionales y biodegradables, seguido de una contextualización histórica de los plásticos derivados del petróleo, referidos aquí como plásticos convencionales, destacando eventos significativos en su evolución. El artículo luego enfatiza el desarrollo y crecimiento de las aplicaciones de polímeros biodegradables. Para ello, se realizó una revisión de la literatura, respaldada por la recopilación de datos de publicaciones que discuten tecnologías de polímeros. Los estudios destacan las ventajas ambientales de los polímeros biodegradables, a pesar de que sus costos de producción aún sean más altos. Aunque los polímeros biodegradables son una alternativa viable a los polímeros derivados del petróleo, hay casos en los que su uso aún no es factible, dependiendo del contexto de aplicación, las condiciones económicas y la experiencia del consumidor.

PALABRAS CLAVE

Polímero Biodegradable; Polímero Sintético; Desarrollo Sostenible de Productos, Diseño y Tecnología.

1. INTRODUCTION

Conventional synthetic polymers emerged as catalysts for innovation and the development of various products in the 20th century. However, the variety and widespread use of these materials led to environmental damage, for which we sought solutions at the beginning of the 21st century, such as improper disposal and the landfills' overcrowding and other environments designed for waste deposition. According to Allison et al. [1], the accumulation of plastic waste is a growing threat, endangering health and sustainability on a global scale. On the other hand, public awareness of the solid waste problem is increasing, and plastics, due to their extensive use in packaging, have become a significant part of this issue [2].

Nascimento et al. [3] point out that the increase in plastic waste may be linked to the development of smaller packaging, changes in consumption habits, and the reduction in household sizes. Poor management of plastic waste poses serious environmental challenges, including the clogging of sewage systems and health risks [4]. According to Brito et al. [5], many problems arise from the disposal of this material due to its high resistance to degradation, as it takes many years to decompose. Additionally, the degradation of very small portions of some plastics, which are not visible, accumulates in ecosystems in large quantities.

In this context, it is important to understand that conventional synthetic polymers are produced to take advantage of their properties during the usage phase and can be derived from fossil or biological sources [6]. However, considering the end of the life cycle, we observe the need for polymers that meet biodegradability conditions and biocompatibility with low-toxicity degradation as alternatives to existing conventional synthetic polymers [7].

According to Mukherjee et al. [4], polymers can be classified into natural biodegradable polymers (polysaccharides and proteins), synthetic biodegradable polymers (esters, amides, ethers, urethanes), and synthetic biopolymers (or hybrid systems). Figure 1 presents the classification of polymers.

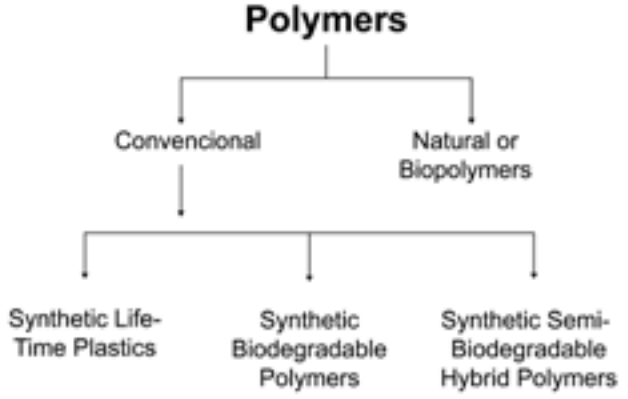

Figure 1: Polymer Classifications. Source: Adapted from Mukherjee et al. [8]

It is important to note that biodegradable plastics are not strictly linked to renewable resources, as biodegradation is related to the chemical structure of the compound rather than its origin [9]. Decomposition criteria in the environment need to be established and communicated to ensure that users and end consumers are aware of the biodegradation capabilities of these bioproducts [10]. Soil burial is widely used to test degradation, but reproducing results is challenging due to the lack of control over climate and microorganisms at the test site [11]. The decomposition period depends on the chemical structure, but for practical purposes, if degradation takes many years under such conditions, the polymer is not considered biodegradable [12]. Therefore, to achieve significant results with biodegradable polymers, it is important to implement industrial-scale composting, just as we plan reverse logistics, sorting centers, and recycling processes. This issue can guide the feasibility of bioplastic implementation.

In a competitive market, it is crucial to offer products that not only meet customer needs but are also produced with reduced costs, lower material and energy consumption, and minimized environmental impacts [13, 14]. Simultaneously, companies with a more advanced strategic vision focus on sustainability, considering not only eco-efficiency, which encompasses economic and environmental impacts, but also social impacts and ethical aspects of their operations [15]. Contemporary design, in response to societal and market demands, is increasingly aligned with the concepts of sustainable development, innovation, and social well-being [16]. Thus, in the development of products with biodegradable polymers, several phases up to their final disposal should be considered, and the goal of implementing this technology is precisely to ensure that the end of the product lifecycle is positive and does not harm the environment. Another important characteristic is that many biodegradable

polymers come from renewable sources; however, it is crucial to understand that some biodegradable plastics come from non-renewable sources. This article focuses on biodegradable plastics also considered bioplastics, i.e., derived from renewable sources.

Significant advances have been made in the production of biodegradable plastics from renewable resources, aiming to achieve materials with performance comparable to petroleum-based polymers [17]. Some environmental and socioeconomic factors related to the growing interest in biopolymers include: (a) significant environmental impacts, (b) extraction processes for petroleum-derived polymers, and (c) oil scarcity and price increases [5]. Therefore, the use of raw materials such as corn, cassava, algae, among others, could reduce the reliance on oil for polymer production, representing a transition from non-renewable to renewable sources.

These attributes contribute to the rise of biopolymers. The increased interest in these materials, combined with growing environmental concerns, has led to a significant rise in research into their use [18]. The relevance of biodegradable polymers has also increased in the industrial market over the past decades, particularly with the growing focus on sustainability and environmental impacts since the 1990s. According to Araújo et al. [19], global biopolymer production reached approximately 2.05 million tons in 2017 and 2.18 million tons in 2023, with projections to increase to 7.43 million tons by 2028 [20]. However, several limitations hinder the expansion of these materials, such as cost, applicability, purpose, and disposal adequacy.

To contribute to a state-of-the-art scenario, this article employs a literature review methodology, providing insights into key moments in the consolidation of conventional and biodegradable polymer use. The research aims to be systematic and comprehensive [21]. The study addresses two main topics: (1) the historical context of the emergence and evolution of conventional synthetic plastics, and (2) the concept of sustainability and the emergence and development of biodegradable plastics. Data were collected from academic publications, books, and journals, recognized as both classic and contemporary materials, from national and international sources, covering the publication period from 1990 to 2023. It is important to note that this work did not follow a linear path, allowing for some flexibility in theoretical development.

The focus will be on biodegradable polymers, but a historical context regarding petroleum-derived plastics will be presented, highlighting events that marked the evolution of this technology. Subsequently, the characteristics of biodegradable plastic use will be mapped, including the origin of the technology, its usage segments, limitations, and opportunities.

2. HISTORICAL CONTEXT OF THE EMERGENCE AND EVOLUTION OF CONVENTIONAL SYNTHETIC PLASTICS

There are several contextual axes that depict the beginning of the discovery of conventional polymers. The first plastic material technology was based on nitrocellulose and was developed by Parkes in 1862 and Hyatt in 1866 [22]. Around 1860, John Wesley Hyatt developed a cellulose derivative [17]. He combined camphor with cellulose nitrate, obtained by dissolving cotton fibers in an alcohol solution, to create celluloid [23]. Celluloid was first marketed as an imitation ivory, used to make a surprisingly wide range of objects, especially small personal items [24]. After cellulose nitrate, formaldehyde was the next creation to evolve in plastic technology [17]. By mid-1887, casein (milk protein mixed with formaldehyde) was used to develop non-flammable whiteboards [25].

According to Crespy, Bozonnet, and Meier [26], Bakelite was the first synthetic thermosetting plastic and significantly contributed to the onset of the "plastic age." Bakelite was discovered in 1907 by Baekeland through the polycondensation of phenol with formaldehyde [22]. It was widely used in the manufacture of telephones, saucepan handles, pipe stems, radio cabinets, and other products in the electrical and automotive industries [23]. As Crespy, Bozonnet, and Meier [26] report, despite Bakelite's qualities, it declined after World War II due to its strong residual odor being associated with wartime desperation and memories, as well as the poor quality of resins synthesized at that time.

Murder and Knot [27] cite the year 1912 as the time when polyvinyl chloride (PVC) was discovered, showing flexibility and resembling rubber or leather when heated in the presence of a liquid with a high boiling point [22]. PVC is widely recognized as the trivial name for polyvinyl chloride and, in terms of global production, is one of the three most relevant polymers, alongside polyethylene and polystyrene [11].

Polyethylene (PE) was discovered by Reginald Gibson and Eric Fawcett in 1933, two chemists working for ICI (Imperial Chemical Industries). It was first synthesized as a low-density resin (LDPE) in 1935 [28]. This polymer, originally called high-pressure polyethylene (HDPE),

resulted from Nobel Laureate Robert Robinson's interest in ultra-high-pressure reactions as an ICI consultant [29]. Besides PVC and PE, polystyrene (PS) is also one of the most important polymers in use [11]. Its practical use was considered in 1902 by Kronstein and Matthews in 1911 [22]. Matthews filed a patent describing the polymerization processes of the styrene monomer to produce a substance for manufacturing items previously made of wood, hard rubber, celluloid, and glass [30]. Commercial production of PS began in the 1930s by the German company BASF and was introduced to the United States in 1937 [28]. The production of PS since 1946 was due to the spread of knowledge and the availability of high-purity styrene monomer in factories during World War II as part of the synthetic rubber program [30]. The polymer is relatively resistant and is primarily used as protective packaging material, especially for electrical equipment, or as sintered sheets to replace paper or cardboard [31].

All these polymers, which have been and continue to be widely used, come from non-renewable sources and are not biodegradable. Therefore, the historical context of conventional synthetic plastic technologies has had a significant impact on society throughout the 20th century. According to Geyer [32], the invention of modern consumer society and sustained economic growth in the post-war period created a perfect environment for these new materials. Feldman [22] adds that polymers were previously seen as a chemical specialty, but from then on, they became associated with plastics, fibers, and elastomers, as well as with engineering through the products´ design and manufacturing .

From the last decade of the 20th century, the growing focus on sustainability in various sectors has driven the development of new alternatives to conventional polymer sources. Biodegradable plastics have been present in the market for several years and are used in a variety of sectors, particularly those derived from renewable sources, i.e., bioplastics.

Material selection is a fundamental part of product design, examining the overall context of this polymer category is essential to understanding the interactions of these technologies throughout products´ development.

2.1 The Concept of Sustainability, Emergence and Development of Biodegradable Plastics, and the Biological Cycle of the Circular Economy

Biodegradable plastic is intrinsically linked to the concept of sustainability, playing a significant role in the sustainable development of products across various sectors. By the end of the 20th century, climate change and restrictions on fossil resources were already driving the development of plants for producing materials needed by humans from renewable sources [17]. According to Horn et al. [33], in 1987, the concept of sustainability was defined by the United Nations Commission led by Gro Brundtland. This concept emerged with considerable challenges, such as economic crises, social inequality, drug trafficking, political instability, and particularly characterized by the notion of scarcity [34]. Sustainable development faced significant limitations at its inception, related to market growth and its needs. In Brazil, sustainable development became popular in the 1990s, with Rio-92 presenting negotiation processes on the Climate Change Convention, the Biodiversity Convention, the Forest Protocol, the Earth Charter, and Agenda 21 [35].

As Campos [36] notes, the concept of sustainability implies limits that are not absolute but are imposed by technology, social organization, natural resources, and the capacity to absorb waste at a given historical moment. Concern for sustainable development drove the advancement of studies on integrating environmental challenges into design from the early 2000s. Researchers like Bahmed, Boukhalfa, and Djebabra [37] highlighted the need for a methodological approach to incorporate environmental challenges into product development due to the high complexity and uncertainties of that period. An additional challenge was that few companies openly shared their design processes that included environmental or social aspects of sustainability or adopted a systemic view of sustainability [38].

However, by the 1990s, there was evidence that design could help designers evaluate the quality and cost of a project in the initial phase, with more than 70% of the product cost determined at this stage [39]. Bahmed, Boukhalfa, and Djebabra [37] reinforced that to incorporate environmental parameters effectively, it was crucial to act from the development phase, when 80% of the product impacts are defined. This understanding aligns with the more contemporary view of McAloone and Pigosso [40], which emphasizes that the more advanced the project, the more difficult and even impossible it becomes to

make necessary changes, as materials, technologies, and product lifespan are decided in the initial phase.

The disposal of plastic packaging reflects behaviors within an industrial context shaped by various factors, including the actions of consumers, producers, and large industries [1]. Consumers play an essential role in the packaging lifecycle, and it is crucial that they understand the importance of environmentally appropriate disposal [41]. At the same time, packaging design needs to be improved not only in terms of functionality but also to avoid the increase of poorly classified packaging and plastic waste that does not return to the productive cycle [42].

According to Idumah and Nwuzor [43], the management of plastics recovered from municipal solid waste (MSW) is a particularly sensitive industry due to the continuous growth in the plastics´ amount, their low biodegradability, and their environmental impact. Huang et al. [44] observe that plastic waste degrades slowly, persisting in the environment for hundreds of years, characterizing it as non-biodegradable waste.

Although various companies and systems are involved from concept to end-of-life (EoL) and in recycling products, a joint effort is needed to implement sustainability throughout the entire lifecycle [45]. Silva and Palsson [46] emphasize that the environmental impact at EoL is not limited to the negative effects of waste treatment but also includes the potential savings this process can generate. Nyström et al. [47] add that while companies may invest in more durable products to reduce future costs, they face the risk of not recovering these investments due to premature obsolescence and future uncertainties.

Geyer, Jambeck, and Law [48] state that the only way to permanently eliminate plastic waste is through destructive thermal treatment, such as incineration and pyrolysis. However, these processes can release gases that contribute to air pollution and the greenhouse effect [42, 49]. Alassali et al. [50] point out that the global amount of plastic waste incinerated and recycled is still low compared to the amount deposited in landfills.

An additional concern is the fate of these wastes in rivers and oceans. Ritchie and Roser [51] report that the world generates 350 million tons of plastic waste annually, with almost a quarter, about 82 million tons, being poorly managed. Of this amount, approximately 19 million tons are released into the environment, with 13 million tons affecting terrestrial environments and 6 million tons polluting rivers, coasts, and oceans. Chamas et al. [52] highlight that this pollution is strongly linked to the lack of efficient waste management infrastructure.

The end-of-life scenarios outlined above underscore the importance of considering design and questioning the cyclical flow. As McDonough and Braungart [53] argue, in 2002, in their book Cradle to Cradle, products should be designed so that at the end of their useful life, they can either be reused or recycled without losing their quality as technical nutrients or can safely return to the environment decomposed as biological nutrients. Based on this concept, returning to the productive cycle through recycling or reuse is the most employed approach for conventional polymers.

At the beginning of the 21st century, also in 2002, Manzini and Vezzoli [54] indicated that the view on sustainability needed to be broad and systemic. The authors presented a refined view of sustainable development listing some general requirements: (I) fundamentally relying on renewable resources to ensure renewal; (II) optimizing the use of non-renewable resources (understood as air, water, and land); (III) not accumulating waste that the ecosystem cannot renaturalize (i.e., return to its original mineral substances and, importantly, to their original concentrations). These requirements relate to goals in plastic development, material choice in product design, and consumer purchasing decisions.

Adopting a systemic view can impact the three dimensions of sustainability: economy, environment, and society [55]. Chiu and Chu [13] highlight that this concept is widely known as the Triple Bottom Line (TBL), where profit, environment, and society are assessed integratively. Rachuri, Sriram, and Sarkar [56] reinforce this perspective, emphasizing that measuring product impacts on sustainability should consider these three indicators jointly within the TBL framework.

According to Luckachan and Pillai [7], one of the first studies on polymer degradation was Wolfram Schnabel's classic work in 1981, which discussed three modes of degradation through (i) thermal, (ii) mechanical, and (iii) photoelectric processes. Later, Narayan in 1993 [57] published a study addressing the use of biodegradable plastics in industry, marketing, design, and engineering. The author mentions that in that context, in response to environmentally conscious plastic disposal, two new industries emerged: recyclable plastics and biodegradable plastics.

The growing adoption of biodegradable plastics has paved the way for new application possibilities. Petersen et al. [58] examined the potential of biodegradable plastics, focusing particularly on packaging, especially for food. This study evaluated the feasibility of using bioplastics in food packaging for animal products, fruits, vegetables,

and frozen foods. While the studies were underway, the future perspective of polymer technology for packaging was based on renewable resources. However, limitations associated with these materials could vary in terms of performance, processing, and cost [58, 59]. On the other hand, Gross and Kalra [60] conducted research on the opportunities offered by biodegradable polymers for the environment. They highlighted that one of the main benefits of renewable raw materials, compared to petroleum, is the reduction in CO2 emissions from fossil fuels. The emergence of new biodegradable polymer technologies that meet degradability, environmental compatibility, and low-toxicity degradation product requirements is the definitive solution to these types of problems [7].

The Circular Economy (CE) concept, established in 2015, also grounded in the defense of cyclical flow, can influence and promote the reduction of environmental impacts through one of its fundamental cycles: the biological cycle. According to Oliveira, Silva, and Moreira [61], the term "circular" is attributed to the concept due to the existence of two main cycles that sustain the model: the biogeochemical or biological cycle and the technical cycle. In the biological cycle, components are, at a minimum, non-toxic and potentially beneficial, allowing them to be safely returned to the biosphere [62]. On the other hand, the technical cycle encompasses durable goods, such as engines and computers, composed of technical materials unsuitable for the biosphere, such as metals and most plastics [63]. Below, Figure 2 illustrates the simplified structure of the biological cycle.

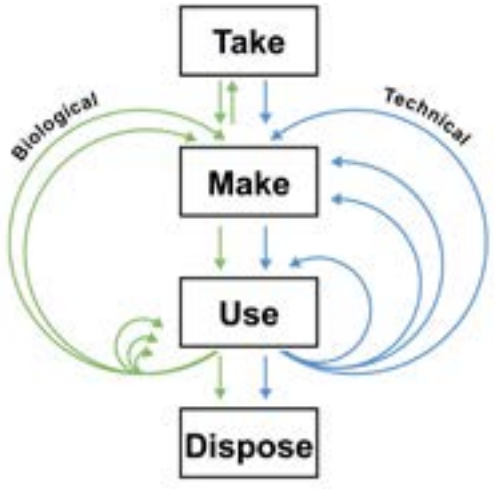

Figure 2: Simplified butterfly diagram. Source: Velenturf et al. [64]

Various academic contributions have sought strategies to promote the circularity of plastics, such as banning the recycling of problematic plastics that may harm terrestrial and aquatic environments, standardizing plastic formulations, extending product lifespans, and developing guidelines for circularity [65]. Jürgens and Endres [66] also discuss the use of bio-based plastics and mechanical recycling to recover plastic materials at the end of their life cycle. In addition to these strategies, other studies investigate the challenges organizations face in implementing Circular Economy (CE) and sustainability strategies, such as investing in new technologies and infrastructure, changing user behavior [67], lack of education on the topic, and accountability for the end-of-life of products [68].

Turkcu and Tura [69] suggest that companies can adopt strategies such as creating ecosystems for waste management, forming strategic partnerships, innovating business models, and using communication approaches to effectively integrate sustainability. Feldman et al. [68] emphasize that CE requires a complete transformation of the supply chain, with active participation from governments, businesses, researchers, and consumers. For CE to succeed, it is crucial that consumers are willing to buy recycled products and adopt practices such as repair and reuse [67]. The growing consumer interest in sustainable practices is a positive indicator for achieving these goals [68]. Thus, understanding and overcoming barriers related to low consumer engagement can help companies develop strategies that better inform the public and encourage the adoption of circular products and services [70].

Considering only the end of life, there are three classes of biodegradable polymers presented by Chandra and Rustgi [71], which are: (a) First class are synthetic polymers with vulnerable groups susceptible to hydrolysis attacks by microbes; (b) Second class are natural bacterial polymers, such as polyhydroxybutyrate (PHB) and polyhydroxyvalerate (PHV), which are highly biodegradable and susceptible to bacterial action; (c) Third class are mixtures of polymers and additives that are easily consumed by microorganisms, such as mixtures of starch with polyethylene (PE).

According to Mukherjee et al. [8], "the basic characteristics of natural biodegradable polymers are their availability and derivation from natural and relatively inexpensive sources, such as polysaccharides, lignin, chitosan, starch, cellulose, guar gum, collagen, and albumin." Van Beilen and Poirier [72] note that although the focus is on using plants for biofuels, such as

bioethanol and biodiesel, plants are a potential source of a much wider range of useful chemicals and biomaterials. Plastics composed of renewable resources (corn, tapioca, potatoes, sugar and algae) and that are totally or partially bio-derived, biodegradable, or compostable are referred to as bioplastics.

According to Pathak and Sneha [17], biological materials have potential advantages for balancing greenhouse gases and environmental impacts throughout life cycles and with the use of renewable resources, in contrast to finite resources. On the other hand, Van Beilen and Poirier [72] comment that biomaterials often lack performance quality, affecting characteristics such as durability and strength, and do not have the cost competitiveness required for their use in low-value, large-scale consumer products. Lambert and Wagner [73] emphasize that bio-based polymers, even if not biodegradable, can potentially be used in a wider variety of applications where biodegradability is not a desired atribute.

Biodegradable polymers require adequate resistance for applications such as construction materials, hygiene products, and packaging, reducing disposal issues, such as reduced resistance to microbial degradation when they are in the environment [8]. In the technological advancement of biodegradable polymers, there are studies on the development and improvement of materials, such as the production of polyhydroxyalkanoates (PHA), bacterial cellulose, silk, xanthan, and polyesters from fermentation, also called white biotechnology, or by chemical methods [72].

Corn sugar in the U.S. and sugarcane in Brazil have been the preferred renewable feedstock for fermentation-based biofuels (ethanol) and for producing bio-based products, including polylactic acid (PLA) [74]. According to Mores et al. [75], in Brazil, bioplastic production from sugarcane is feasible due to the country's climatic advantages and the extent of available land for this crop. Demmer [76] mentions alternatives such as algae and sugarcane for the plastic industry in the U.S., but highlights that corn and soybeans are significant and economically attractive commercial crops for the country. Some authors describe high-cell-density systems with low-cost starch, rice bran, or wheat bran as the primary carbon source for producing PHA in semicontinuous culture [77]. Thus, there is a search for natural sources for various applications, which aligns with Herman Daly's statement, cited by Meadows et al. [78], arguing that the sustainable use of non-renewable resources occurs when it happens at the same rate of replacement by renewable sources. However, it is still not evident that this is being done at the necessary time and quantity.

For practical use, biodegradable materials are currently most important in medical sciences, where they can be used as implants to replace bones or other body parts, and in surgeries as sutures [12]. The main applications in Brazil are in food packaging, bags, agricultural films, and consumer products, using biopolymers, biodegradable polymers, and green polymers [5].

Thus, it can be asserted that biodegradable polymers can play a significant role in material recovery, reducing landfill waste volume, and utilizing renewable resources [79]. According to Lambert and Wagner [73], the main application areas for the development of biodegradable polymers include packaging, disposable food utensils, and agricultural films.

3. CONCLUSION

With the purpose of examining the historical panorama of the use of conventional and biodegradable plastics, this study presented two periods of polymer technology evolution throughout the history of materials. One of these periods dates to the early stages of research, development, and refinement of technology, while the other emerged at a time of increasing interest in sustainability across various sectors, which has driven the search for new alternatives to conventional polymer sources.

Biodegradable polymers hold significant importance in the industrial market due to their varied applications. Unlike conventional synthetic polymers derived from petroleum, biodegradable polymers degrade more quickly. Biodegradation is a highly promising solution as it is less harmful to the environment and completes the carbon and nitrogen cycles.

It is evident from the literature reviewed and presented in the article that the use of biodegradable polymers influences and benefits causes that implement sustainability as a strategic pillar. The interest in exploring biodegradable polymers, combined with heightened environmental concern, has led to a significant increase in research into their use, as indicated by the consulted literature.

Biodegradable polymers follow a biological cycle in which, upon safe degradation, they transform into nutrients for the soil. In this context, the biological cycle structured in the circular economy plays an important role by encouraging the use of biodegradable materials that can be integrated into the product life cycle based on circularity.

The role of consumers is crucial in the proper disposal of biodegradable and non-biodegradable polymers, given the growing involvement and concern with sustainability. Understanding and overcoming challenges related to consumer disengagement should be a targeted strategy for companies to develop approaches that encourage the use of sustainable products, identifying opportunities to engage and sensitize consumers to adopt these practices.

The technology of biomaterials is on the rise, driving the demand for sustainable products that have a lower environmental impact. In developing products with biodegradable polymers, designers should adopt strategies that consider the entire product life cycle, especially its end phase, aiming to minimize environmental harm. Therefore, despite the commercial and physical constraints of biodegradable polymers, they offer a notable opportunity to advance products and ventures that do not harm the environment. On the contrary, solutions that incorporate biopolymers have the potential to positively impact environmental sustainability.

It is concluded that the pursuit of achieving structural performance like conventional synthetic polymers is driven by socioeconomic and environmental challenges, such as oil scarcity and rising extraction costs.

Thus, there is a broad field of opportunities to conduct further studies on various biodegradable polymers. As future applications or adaptations of this article, it is suggested that deeper research be conducted on the implementation of biodegradable plastics in the industry, understanding the limitations and opportunities for companies using such materials in product development. Due to the complexity of accessing internal company information, it would be beneficial for future research to seek such data to understand the use of biopolymers as corporate strategies. Integrating design within the context of this work, another possibility would be to deepen the study to understand the role of design in the end-of-life phase of products incorporating biodegradable polymers in their composition. These approaches can significantly contribute to advancing environmental sustainability and developing innovative solutions to contemporary challenges.

REFERENCES

ALLISON, Ayşe Lisa et al. Barriers and enablers to buying biodegradable and compostable plastic packaging. **Sustainability**, v. 13, n. 3, p. 1463, 2021.

BOHLMANN, Gregory M. Biodegradable packaging life-cycle assessment. **Environmental Progress**, v. 23, n. 4, p. 342-346, 2004.

NASCIMENTO, Tauana et al. Interação entre usuários e embalagens: percepções dos usuários no reuso de embalagens. In: **Engenharia de materiais e meio ambiente: reciclagem, sustentabilidade, novos processos e desafios.** Ponta Grossa: Aya, p. 90-104, 2022.

IDUMAH, Christopher Igwe; NWUZOR, Iheoma C. Novel trends in plastic waste management. **SN Applied Sciences**, v. 1, p. 1-14, 2019.

BRITO, G. F; AGRAWAL, P; ARAÚJO, E. M; MÉLO, T. J. A. Biopolímeros, Polímeros Biodegradáveis e Polímeros Verdes. **Revista Eletrônica de Materiais e Processos (REMAP)**, v.6.2, p. 127-139, 2011.

HAHN, Stefan; HENNECKE, Dieter. Final Report WP4 - **Comparison between natural and synthetic polymers**. 2022.

LUCKACHAN, Gisha E.; PILLAI, C. K. S. Biodegradable polymers-a review on recent trends and emerging perspectives. **Journal of Polymers and the Environment**, v. 19, p. 637-676, 2011.

MUKHERJEE, Chandrapaul et al. Recent advances in biodegradable polymers–Properties, applications and future prospects. **European Polymer Journal**, p. 112068, 2023.

ASGHER, Muhammad et al. Bio-based active food packaging materials: Sustainable alternative to conventional petrochemical-based packaging materials. **Food Research International**, v. 137, p. 109625, 2020.

AMARAL, Murilo Alves do; BORSCHIVER, Suzana; MORGADO, Cláudia do Rosário Vaz. Análise do segmento de bioplásticos: prospecção tecnológica em "plásticos verdes", PHA e PLA. **Engevista**, v. 21, n. 2, p. 228-241, 2019.

NICHOLSON, John. The chemistry of polymers. 3. ed. **The Royal Society of Chemistry**, p. 1-191, 2006.

PAVLATH, Attila E. Biodegradable polymers: Why, what, how. **Physical Sciences Reviews**, 2020.

CHIU, Ming-Chuan; CHU, Chih-Hsing. Review of sustainable product design from life cycle perspectives. **International Journal of Precision Engineering and Manufacturing**, v. 13, p. 1259-1272, 2012.

PENG, Qingjin et al. Tools for Sustainable Product Design: Review and Expectation. In: International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. **American Society of Mechanical Engineers**, 2013. p. V004T05A044.

HAUSCHILD, Michael; JESWIET, Jack; ALTING, Leo. From life cycle assessment to sustainable production: status and perspectives. **CIRP annals**, v. 54, n. 2, p. 1-21, 2005.

CAVALCANTE, Ana Luisa Boavista Lustosa et al. Design para a Sustentabilidade: um conceito Interdisciplinar em construção. **Projetica**, v. 3, n. 1, p. 252-263, 2012.

PATHAK, Swati; SNEHA, C. L. R.; MATHEW, Blessy Baby. **Bioplastics: its timeline based scenario & challenges**. J. Polym. Biopolym. Phys. Chem, v. 2, n. 4, p. 84-90, 2014.

FALCONE, Daniele M. B.; AGNELLI, José Augusto M.; FARIA, Leandro I. L. de. Panorama Setorial e Perspectivas na Área de Polímeros Biodegradáveis. Polímeros: **Ciência e Tecnologia**,vol. 17, n. 1, p. 5-9, 2007.

ARAÚJO, Bruna Aline; et al. A aplicação de polímeros biodegradáveis como uma alternativa sustentável. **Research, Society and Development,** v. 10, n. 9, p. e49010918248-e49010918248, 2021.

EUROPEAN BIOPLASTICS. **Bioplastics market development update 2023**. European Bioplastic, Berlin, Germany, 2023. Disponível em: <https://www.european-bioplastics.org/bioplastics-market-development-update-2023-2/>. Acesso em: 11/03/2024.

AZEVEDO, D. **Revisão de Literatura, Referencial Teórico, Fundamentação Teórica e Framework Conceitual em Pesquisa – diferenças e propósitos**. Working paper, 2016. Disponível em: < https://shre.ink/8PnN > Acesso em 09 set.2023.

FELDMAN, Dorel. Polymer history. **Designed monomers and polymers**, v. 11, n. 1, p. 1-15, 2008.

ANDERSON, Kevin J. Bakelite: 80 Years Since the First Synthetic Resin. **MRS Bulletin**, v. 14, n. 7, p. 69-69, 1989.

REILLY, Julie A. Celluloid objects: their chemistry and preservation. J**ournal of the American Institute for Conservation**, v. 30, n. 2, p. 145-162, 1991.

KRÄTZ, Otto. Aufstieg und Niedergang des Galaliths. **Chemie in unserer Zeit**, v. 38, n. 2, p. 133-137, 2004.

CRESPY, Daniel; BOZONNET, Marianne; MEIER, Martin. 100 Years of Bakelite, the Material of a 1000 Uses. **Angewandte Chemie International Edition**, v. 47, n. 18, p. 3322-3328, 2008.

MURDER, Karel; KNOT, Marjolijn. PVC plastic: a history of systems development and entrenchment. **Technology in Society**, v. 23, n. 2, p. 265-286, 2001.

ANDRADY, Anthony L.; NEAL, Mike A. Applications and societal benefits of plastics. **Philosophical Transactions of the Royal Society B: Biological Sciences**, v. 364, n. 1526, p. 1977-1984, 2009.

SEYMOUR, Raymond Benedict; CHENG, T. C. (Ed.). Advances in polyolefins: The world's most widely used polymers. **Springer Science & Business Media**, 1987.

TEACH, William Charles; KIESSLING, George Curt. Polystyrene. Reinhold, New York, NY, 1960.

SCOTT, Gerald. **Polymers and the Environment**. Cambridge: Royal Society of Chemistry, p. 1-148, 1999.

GEYER, Roland. **Production, use, and fate of synthetic polymers. In: Plastic waste and recycling**. Academic Press, 2020. p. 13-32.

HORN, Bibiana Silveira; et al. **O uso do triple bottom line como uma ferramenta alternativa de sustentabilidade empresarial na sociedade de risco.** Caminhos para a Sustentabilidade através do Design. In: Caminhos para a sustentabilidade através

do Design. Porto Alegre: Ed. UniRitter, 2014. p. 119-132.

AMORIM, Ricardo. **A tecnologia e o meio ambiente. Programa de Apoio à formação profissional.** Gazeta Mercantil. 1993.

CAPOBIANCO, João Paulo. **O que podemos esperar da Rio 92**. São Paulo em Perspectiva, São Paulo, v. 6, n. 1-2, p. 13-17, 1992.

CAMPOS, Carlos Silva. Relatório Brundtland – a versão original. Disponível em: <https://ambiente.wordpress.com/2011/03/22/relatrio-brundtland-a-verso-original/>. Acesso em: 03 out. 2023.

BAHMED, Lylia; BOUKHALFA, Ali; DJEBABRA, Mebarek. Eco-conception in the industrial firms: methodological proposition. **Management of Environmental Quality: An International Journal**, v. 16, n. 5, p. 530-547, 2005.

WAAGE, S. A. Re-considering product design: a practical "road-map" for integration of sustainability issues. **Journal of Cleaner Production**, Oxford, v. 15, n. 7, p. 638-649, 2007.

NATIONAL RESEARCH COUNCIL et al. **Improving engineering design: Designing for competitive advantage**. National Academies Press, 1991.

MCALOONE, Tim C.; PIGOSSO, Daniela CA. Ecodesign implementation and LCA. Life Cycle **Assessment: Theory and Practice**, p. 545-576, 2018.

OTTONI, Breno Luiz et al. Communication and biodegradable packaging relationship: a paradigm for final disposal. **Journal of Applied Packaging Research**, v. 10, n. 1, p. 2, 2018.

NEMAT, Babak et al. Design affordance of plastic food packaging for consumer sorting behavior. **Resources, Conservation and Recycling**, v. 177, p. 105949, 2022.

IDUMAH, Christopher Igwe; NWUZOR, Iheoma C. **Novel trends in plastic waste management.** SN Applied Sciences, v. 1, p. 1-14, 2019.

HUANG, Saimin et al. Plastic waste management strategies and their environmental aspects: A scientometric analysis and comprehensive review. **International Journal of Environmental Research and Public Health**, v. 19, n. 8, p. 4556, 2022.

RAMANI, Karthik et al. **Integrated sustainable life cycle design: a review.** 2010.

SILVA, Nathalie; PÅLSSON, Henrik. Industrial packaging and its impact on sustainability and circular economy: A systematic literature review. **Journal of Cleaner Production**, v. 333, p. 130165, 2022.

NYSTRÖM, Thomas et al. Managing circular business model uncertainties with future adaptive design. **Sustainability**, v. 13, n. 18, p. 10361, 2021.

GEYER, Roland; JAMBECK, Jenna R.; LAW, Kara Lavender. Production, use, and fate of all plastics ever made. **Science advances**, v. 3, n. 7, p. e1700782, 2017.

EVODE, Niyitanga et al. **Plastic waste and its management strategies for environmental sustainability.** Case Studies in Chemical and Environmental Engineering, v. 4, p. 100142, 2021.

ALASSALI, Ayah et al. Towards higher quality of recycled plastics: Limitations from the material's perspective. **Sustainability**, v. 13, n. 23, p. 13266, 2021.

RITCHIE, Hannah; ROSER, Max. **How much plastic waste ends up in the ocean?**. Our World in Data, 2023.

CHAMAS, Ali et al. Degradation rates of plastics in the environment. ACS **Sustainable Chemistry & Engineering**, v. 8, n. 9, p. 3494-3511, 2020.

MCDONOUGH, William; BRAUNGART, Michael. **Cradle to Cradle: Remaking the way we make things**. New York: North Point Press, 2002.

MANZINI, Ezio; VEZZOLI, Carlo. **O desenvolvimento de produtos sustentáveis: Os requisitos ambientais dos produtos industriais.** Editora da Universidade de São Paulo, p. 25-25, 2002.

TARNE, P.; TRAVERSO, M.; FINKBEINER, M. Review of life cycle sustainability assessment and potential for its adoption at an automotive company. **Sustainability**,

Basel, v. 9, n. 4, art. 670, 2017. Disponível em: <https://www.mdpi.com/2071-1050/9/4/670>. Acesso em: 20 Fev. 2024.

RACHURI, S.; SRIRAM, R. D.; SARKAR, P. **Metrics, standards and industry best practices for sustainable manufacturing systems.** In: IEEE INTERNATIONAL CONFERENCE ON AUTOMATION SCIENCE AND ENGINEERING, 2009, Bangalore, India. Proceedings [...]. New York: IEEE, 2009. p. 472-477.

NARAYAN, Ramani. Biodegradable plastics. **Opportunities for innovation: biotechnology**, NIST GCR, p. 93-633, 1993.

PETERSEN, Karina et al. Potential of biobased materials for food packaging. **Trends in food science & technology**, v. 10, n. 2, p. 52-68, 1999.

DEMMER, Brian. **Comparison and analysis of biobased/biodegradable and petrochemical cutlery flexibility**. 2011.

GROSS, Richard A.; KALRA, Bhanu. Biodegradable polymers for the environment. **Science**, v. 297, n. 5582, p. 803-807, 2002.

OLIVEIRA, Adna Caroline Vale; SILVA, Aline de Souza; MOREIRA, Ícaro Thiago Andrade. Economia Circular: Conceitos e Contribuições na Gestão de Resíduos Urbanos. **RDE-Revista de Desenvolvimento Econômico**, v. 3, n. 44, 2020.

MACARTHUR, Ellen et al. Towards the circular economy: Accelerating the scale-up across global supply chains. **Journal of Industrial Ecology**, v. 3, n. 1, p. 23-44, 2014.

MACARTHUR, Ellen et al. Towards the circular economy: Opportunities for the consumer goods sector. **Journal of Industrial Ecology**, v. 2, n. 1, p. 23-44, 2013.

VELENTURF, A. P. M. et al. **A new perspective on a global circular economy**. 2019.

LISIECKI, M. et al. Circular economy initiatives are no guarantee for increased plastic circularity: A framework for the systematic comparison of initiatives. **Resources, Conservation and Recycling**, v. 197, p. 107072, 2023.

JÜRGENS, Meret; ENDRES, Hans-Josef. Environmental impacts of circular economy practices for plastic products in Europe: Learnings from life cycle assessment studies. **Procedia CIRP**, v. 122, p. 312-317, 2024.

CHENAVAZ, Régis Y.; DIMITROV, Stanko. From waste to wealth: Policies to promote the circular economy. **Journal of Cleaner Production**, p. 141086, 2024.

FELDMAN, Jessica et al. **Circular economy barriers in Australia: How to translate theory into practice?**. Sustainable Production and Consumption, 2024.

TURKCU, Deniz; TURA, Nina. **The dark side of sustainable packaging: Battling with sustainability tensions.** Sustainable Production and Consumption, v. 40, p. 412-421, 2023.

RAINATTO, Graziela Maira et al. How can companies better engage consumers in the transition towards circularity? Case studies on the role of the marketing mix and nudges. **Journal of Cleaner Production**, v. 434, p. 139779, 2024.

CHANDRA, R.; RUSTGI, Renu. **Biodegradation of maleated linear low-density polyethylene and starch blends.** Polymer Degradation and Stability, v. 56, n. 2, p. 185-202, 1997.

VAN BEILEN, Jan B.; POIRIER, Yves. Production of renewable polymers from crop plants. **The Plant Journal,** v. 54, n. 4, p. 684-701, 2008.

LAMBERT, Scott; WAGNER, Martin. Environmental performance of bio-based and biodegradable plastics: the road ahead. **Chemical Society Reviews**, v. 46, n. 22, p. 6855-6871, 2017.

SNELL, Kristi D.; PEOPLES, Oliver P. PHA bioplastic: A value-added coproduct for biomass biorefineries. **Biofuels, Bioproducts and Biorefining:** Innovation for a sustainable economy, v. 3, n. 4, p. 456-467, 2009.

MORES, Giana de Vargas; FINOCCHIO, Caroline Pauletto Spanhol; BARICHELLO, Rodrigo; PEDROZO, Eugenio Avila. Sustainability and innovation in the Brazilian supply chain of green plastic. J**ournal of**

cleaner production, v. 177, p. 12-18, 2018.

DEMMER, Brian. **Comparison and analysis of bio-based/biodegradable and petrochemical cutlery flexibility**. 2011.

HUANG, Ting-Yen; DUAN, Kon-Jen; HUANG; Shih-Yow; CHEN, C. Will. Production of polyhydroxyalkanoates from inexpensive extruded rice bran and starch by Haloferax mediterranei. **Journal of Industrial Microbiology and Biotechnology**, v. 33, n. 8, p. 701-706, 2006.

MEADOWS, D. H., J. Randers, et al. **The limits to growth: the 30- year update. White River Junction**, Vt: Chelsea Green Publishing Company. 2004. xxii, 338 p.

DAVIS, Georgina; SONG, J. H. **Biodegradable packaging based on raw materials from crops and their impact on waste management.** Industrial crops and products, v. 23, n. 2, p. 147-161, 2006.

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CULTURAL HERITAGE AND THE CLIMATE CRISIS: A LITERATURE REVIEW

PATRIMÔNIO CULTURAL E CRISE CLIMÁTICA: REVISÃO DA LITERATURA

PATRIMONIO CULTURAL Y CRISIS CLIMÁTICA: REVISIÓN DE LA LITERATURA

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ABSTRACT
Extreme weather events have been increasing over time. In this way, climate change represents obstacles to society, imposing challenges on cities. Among them is the preservation of their cultural and natural heritage. Urban complexes with a preservation interest face greater vulnerability due to natural, cultural and social factors. In this context, the aim of this article is to present the state of the art on research into the impacts of climatic events on sites of preservation interest. The methodological procedures comprised four stages: defining the topic and research question; searching academic databases; establishing inclusion and exclusion criteria; and analyzing the materials. The research found shows a consensus on the need to pay attention to the impacts of climate change on cultural and natural heritage. As limitations, most of the research with case studies focuses on the Global North. In terms of gaps, the research highlights the need for an integrative approach to the preservation of cultural heritage in the face of the impacts of climate change.

KEYWORDS
climate change; cultural heritage; sustainability.

RESUMO
Os eventos climáticos extremos vêm aumentando com o passar do tempo. Dessa forma, as mudanças climáticas representam obstáculos à sociedade, impondo inúmeros diversos desafios às cidades. Dentre eles, está a preservação de seu patrimônio cultural e natural. Os conjuntos urbanos com interesse de preservação enfrentam maior vulnerabilidade, devido a fatores naturais, culturais e sociais. Nesse contexto, este artigo possui como objetivo apresentar o estado da arte sobre as pesquisas dos impactos dos eventos climáticos nos sítios com interesse de preservação. Os procedimentos metodológicos compreenderam quatro etapas: delimitação do tema e pergunta de pesquisa; busca em bases de dados acadêmicas; estabelecimento de critérios de inclusão e exclusão; e análise dos materiais. As pesquisas encontradas mostram um consenso quanto à necessidade de atenção aos impactos das mudanças climáticas ao patrimônio cultural e natural. Como limitações, a maioria das pesquisas com estudos de caso concentra-se no Norte Global. Sobre as lacunas, as pesquisas evidenciam a necessidade de uma abordagem integrativa na preservação do patrimônio cultural, diante dos impactos das mudanças climáticas.

PALAVRAS-CHAVE
mudanças climáticas; patrimônio cultural; sustentabilidade.

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RESUMEN

Los eventos climáticos extremos han ido aumentando con el tiempo. De esta manera, el cambio climático representa obstáculos para la sociedad, imponiendo numerosos desafíos a las ciudades. Entre ellos se encuentra la preservación de su patrimonio cultural y natural. Los conjuntos urbanos con interés de preservación enfrentan una mayor vulnerabilidad debido a factores naturales, culturales y sociales. En este contexto, el objetivo de este artículo es presentar el estado del arte sobre las investigaciones de los impactos de los eventos climáticos en los sitios con interés de preservación. Los procedimientos metodológicos comprendieron cuatro etapas: delimitación del tema y la pregunta de investigación; búsqueda en bases de datos académicas; establecimiento de criterios de inclusión y exclusión; y análisis de los materiales. Las investigaciones encontradas muestran un consenso sobre la necesidad de prestar atención a los impactos del cambio climático en el patrimonio cultural y natural. Como limitaciones, la mayoría de las investigaciones con estudios de caso se concentran en el Norte Global. En cuanto a las brechas, las investigaciones evidencian la necesidad de un enfoque integrador en la preservación del patrimonio cultural, ante los impactos del cambio climático.

PALABRAS CLAVE

cambio climático; patrimonio cultural; sostenibilidad.

1. INTRODUCTION

Climate change has become a major challenge for society, imposing obstacles to the preservation of heritage. Among them is the need to guarantee a sustainable environment for future generations, since meeting current needs is already severely compromised. Extreme climatic events have been seriously increasing over time (Roaf; Crichton; Nicol, 2023). These include the rise in global temperatures and the intensification of phenomena such as El Niño and La Niña, with changes in ocean temperatures and a high incidence of cyclones, storms and thunderstorms. This leads to major droughts, floods and torrents that affect cities and cause damage to material and immaterial heritage. Forests go up in flames, causing changes to biomes, while rivers dry up, causing climate inversions.

The IPCC Climate Change Report (2023) indicates that human activities are the main drivers of global warming. In urban areas, this phenomenon causes adverse effects on human health, livelihoods, and food security. Furthermore, these changes impact cities and their inhabitants due to factors such as rising average temperatures, reduced daily temperature ranges, and an increased frequency of extreme events (IPCC, 2023; Alvez, 2019; NU, 2022). Consequently, these effects exacerbate inequalities, putting the most vulnerable populations at risk and leading to social problems (Iwama, 2016; Peiter, Maluf, Rosa, 2011).

According to the UN (2022), IPCC data show that the current period is critical, as pollutant emissions were the highest in history between 2010-2019. This scenario indicates the need to anticipate measures to mitigate the adverse effects of climate events. As pointed out by the IPCC (2020), the development of actions at all scales helps create adaptation strategies to climate effects, seeking development suited to new climate conditions. According to the latest IPCC report (2023), responsive planning actions can ensure full sustainable development for the future of cities.

Within this context, the challenge arises for heritage preservation, composed of assets susceptible to the effects of climate events. Urban areas of preservation interest face greater vulnerability due to the interactions between natural, cultural, and social aspects. The safeguarding of heritage is a growing concern, as extreme climate events and rising average temperatures can accelerate the degradation of protected assets. Urban centers and their surroundings must be protected against the increasingly frequent effects of climate change (ICOMOS, 2011). Furthermore, when addressing this issue, it is essential to consider not only the physical impact but also the social and cultural implications of interventions (Iwama, 2016; Peiter, Maluf, Rosa, 2011; IPCC, 2020).

Focusing on the urban context, it is known that cities are the main consumers of energy and agents in greenhouse gas emissions (UN, 2022). Consequently, urban areas are sources of anthropogenic climate change due to the concentration of inhabitants, buildings, and infrastructure that, if not addressed responsively, can generate environmental and climatic impacts. Therefore, planning focused on climate change in urban areas must consider the interaction between mitigation and adaptation actions (Grafakos et al., 2020).

Based on these aspects, the general objective of this work is to present a literature review on studies of the impacts of climate events on sites of preservation interest. Additionally, it aims to discuss the main research results, understanding the main knowledge gaps related to the impacts of climate change on cultural heritage.

2. THEORETICAL REFERENCE

When addressing the issue of climate change and its impacts on areas of preservation interest, some concepts and theoretical bases are important. Therefore, the following topics will deal with the main references on climate change, cultural heritage and the impacts of climate change on cultural heritage.

2.1 Climate change

Climate change refers to significant and long-lasting alterations in global and regional climate patterns, primarily driven by human activities such as the burning of fossil fuels and deforestation. Concern about climate change began to gain prominence in the 1980s. At that time, research indicated a decrease in ozone concentration, caused by increased greenhouse gas emissions (Brazil, 2024).

Subsequently, numerous reports started to warn about the problems arising from climate change. This includes the IPCC Report (Intergovernmental Panel on Climate Change), first published in the 1990s. Later, important international agreements, such as the United Nations Framework Convention on Climate Change (1992) and the Kyoto Protocol (1997), solidified global

recognition of the need to mitigate the effects of climate change. Despite this, the implementation of effective policies faces significant challenges.

The latest IPCC reports provide a comprehensive and alarming overview of climate change and its impacts. The most recent data, from the AR6 report (IPCC, 2022), highlight the accelerated increase in global average temperatures, the intensification of extreme climate events such as heat waves, storms, and heavy rainfall, and the rise in sea levels. According to the report, "human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020)" (IPCC, 2022, p.42).

Furthermore, the report states that "Cultural losses, related to tangible and intangible heritage, threaten adaptive capacity and may result in irrevocable losses of sense of belonging, valued cultural practices, identity and home (...)" (IPCC, 2022, p. 51). This highlights the need for adaptation and mitigation actions to prevent losses related to cultural and natural heritage.

The 2030 Agenda for Sustainable Development, established by the UN, created global actions aimed at improving living conditions in the present and for future generations. The action plan, composed of the Sustainable Development Goals (SDGs), sets targets in 17 areas (NU, 2015). Regarding climate change, several goals are relevant, with SDG 11 (Sustainable Cities and Communities) standing out, which includes target 11.4: "strengthen efforts to protect and safeguard the world's cultural and natural heritage" (NU, 2015a); as well as SDG 13 (Climate Action), emphasizing the importance of the issue on the contemporary global agenda (NU, 2015b, 2015c, 2015d).

Therefore, the urgent need to mitigate the effects of climate change and adapt to these new conditions is emphasized, as a way to ensure the resilience of communities and the sustainability of natural resources for future generations. There is an urgent call for decisive actions to mitigate the effects of climate change and adapt infrastructures and public policies to face future challenges, generating a coordinated global response to limit global warming and reduce adverse impacts.

2.2 Effects of climate change on urban areas and the built environment

Climate change causes profound changes in urban structures and the built environment. Furthermore, it can cause or exacerbate economic and social problems (IPCC, 2022). Large-scale disasters and humanitarian emergencies resulting from climate change have become increasingly frequent and severe, triggering a series of crises that deeply affect communities around the world (Weissbecker and Czincz, 2011).

Extreme events, in addition to causing damage to cities and buildings, also lead to forced population displacements, food and water shortages, and public health crises. Humanitarian emergencies require a rapid and coordinated response that includes humanitarian assistance, recovery, and effective adaptation strategies to reduce the impact of future disasters and strengthen the resilience of affected populations.

Among the main impacts of climate change on cities are extreme weather events such as floods, heat waves, droughts, and storms. Rising average temperatures and sea levels increase the risk of flooding in coastal areas, while uncontrolled urbanization worsens the heat island effect, affecting the health and well-being of populations (IPCC, 2022; NU, 2022).

In response to the damage caused by climate change, actions are divided between adaptive and mitigation measures. Mitigation measures "aim to directly address the root cause (the cause) of global warming" (Barbieri and Viana, 2013, p.60). Thus, they are difficult to implement because they require large-scale actions, such as the Kyoto Protocol. In the case of adaptive measures, they seek to mitigate the impacts, generating a quicker and more noticeable response (Barbieri and Viana, 2013).

Given the above, the phenomena caused by climate change require an urgent adaptation of urban infrastructures, planning policies, and mitigation strategies to face the challenges of climate change, while directly affecting economic development, the environment, and the quality of life in urban centers.

2.3 Challenges of preserving cultural heritage in the context of the climate crisis

According to IPHAN (2014), "cultural heritage consists of monuments, groups of buildings, and archaeological sites of fundamental importance for the memory, identity, and creativity of peoples and the richness of cultures." It includes monuments, historical buildings, archaeological sites, traditions, knowledge, practices, languages, and artistic expressions that are passed down through generations. The preservation of cultural

heritage is essential to ensure the continuity of identity and collective memory, as well as to promote respect for cultural diversity.

With climate change, sites of cultural interest face increasing threats. The World Heritage Committee (UNESCO, 2006) points out that climate changes can cause physical, social, and cultural damage to heritage. Thus, both isolated buildings and complexes, environmentally significant areas, and cultural practices are at risk. Additionally, social impacts may occur, which must be considered in analyses and proposals.

According to Colette (2007), heritage and climate are interconnected, and the stability of heritage depends on interactions with the environment. Among the consequences of climate change on heritage are physical damages, such as losses due to erosion, humidity, flooding, and salt weathering. Moreover, social and cultural problems can arise from the perspective that heritage is dynamic and encompasses all relationships within a given community. Additionally, climate change may force migrations, dissolving communities, practices, and memories.

According to the Valletta Principles (ICOMOS, 2011), historic areas are subject to continuous changes that impact all elements that constitute these sites, including natural, human, tangible, and intangible aspects. In general, buildings are more vulnerable, subject to physical and structural changes due to weathering. Therefore, climate issues exacerbate the problem, potentially accelerating degradation through phenomena such as porosity, thermal stress, and corrosion (Pereira; Paes; Pasini, 2023; Ziebell et al., 2023).

Given the above, it becomes essential to understand the potential impacts of climate change on cultural and natural heritage. Adaptation and mitigation strategies must be developed to preserve the environment, culture, and memory of these sites.

3. METHODS

The work sought to establish the state of the art, with the following stages:

Stage 01 - Delimiting the topic and research question: the initial search involves the terms Cultural Heritage and Climate Change. Based on this, the research seeks to answer the following question: what are the main studies dealing with the impacts of climate change on areas with cultural value?

Stage 02 - Search in academic databases: search in various databases: Scielo, Scopus, Periódicos Capes; Catalog of Theses and Dissertations and the Brazilian Digital Library of Theses and Dissertations (BDTD). The strings entered into the platforms were: "climatic changes" OR "climate variations" AND "cultural heritage sites" OR "cultural heritage preservation"; e “patrimônio cultural” AND “mudanças climáticas”.

Stage 03 - Establishment of inclusion or exclusion criteria for the materials found: systematic reviews and empirical studies were considered for analysis. The study site was not delimited. The period of publication considered included the last 10 years (2013 to 2023). Scientific articles published in journals and at scientific events were searched for and evaluated on the Scielo, Scopus and Portal de Periódicos da Capes databases.

As the strings used are wide-ranging, it was necessary to filter the articles found. Initially, the titles were considered for a first filtering. Studies dealing with, for example, biological and agricultural sciences were removed, as were studies that did not correspond to the area of cultural heritage studies. After filtering, 71 articles remained. The abstracts were read in depth to select the articles included in the review, resulting in 4 systematic reviews and 4 empirical studies. In addition, searches with the same strings were carried out on Google Scholar, adding 5 articles to the analysis.

Stage 04 - Analysis of the materials: based on the research and scientific papers found, we identified the research that addresses the effects of climate events and the strategies for mitigating the effects in areas with cultural heritage. In addition, the gaps in knowledge in the area were assessed.

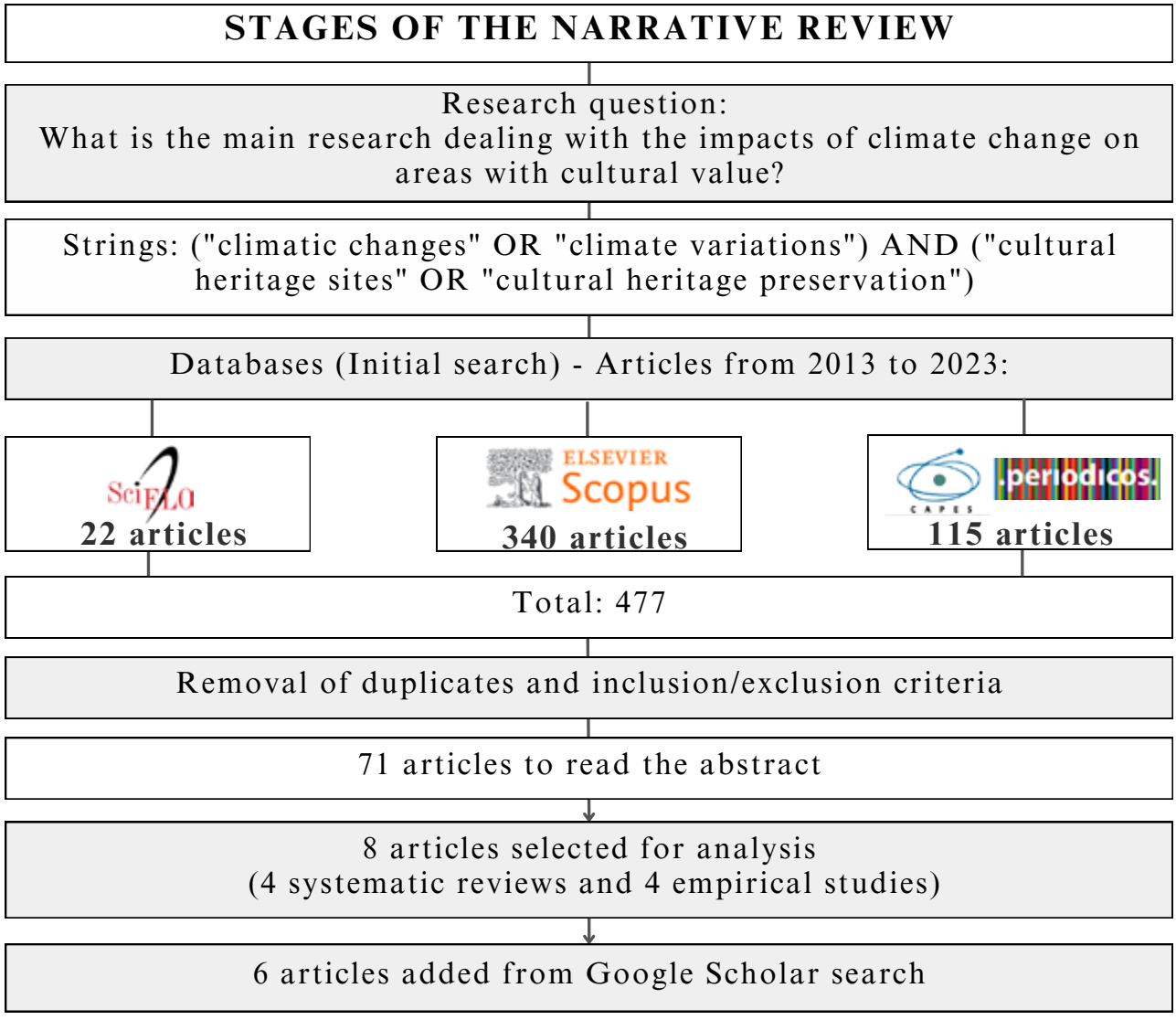

Figure 01 - Summary of the stages of the review.
Source: prepared by the authors.

4. LITERATURE REVIEW

In the current literature, several studies deal with issues of adapting heritage to climate conditions. Among them, four systematic reviews were found, published between 2021 and 2023. The reviews and objectives are shown in the table below.

Title: Climate change impacts on cultural heritage: A literature review	
Authors	**Objectives**
Sesana, et al. (2021)	This review synthesizes the international literature on climate change impacts on tangible cultural heritage by developing hazard-impact diagrams focusing on the impacts of gradual changes in climate on: (1) the cultural heritage exposed to the outside environment, (2) the interiors of historical buildings and their collections, and (3) a third diagram associated with climate change and the impacts due to sudden changes in the natural physical environment. **Keywords:** climate change; impacts; natural hazards; risks; tangible cultural heritage
Title: Climate Change and Cultural Heritage: A Systematic Literature Review (2016–2020)	
Authors	**Objectives**
Orr; Richards; and Fatorić. (2021)	This systematic review reflects on the state of the art by evaluating 165 publications (2016–2020) about cultural heritage and climate change. To capture relevant literature, the authors used five sets of English keywords, using the asterisk wildcard to include permutations of each phrase: i) 'cultural resourc*' AND 'climat* chang*,' ii) 'cultural heritag*' AND 'climat* chang*,' iii) 'historic* heritag*' AND 'climat* chang*,' iv) 'heritag* site*' AND 'climat* chang*,' and v) 'historic* environment*' AND 'climat* chang*.' **Keywords:** cultural resources; historic environment; cultural landscape; heritages sites; climatic change; research meta-characteristics
Title: Do we know how urban heritage is being endangered by climate change? A systematic and critical review	
Authors	**Objectives**
Quesada-Ganuza, et al. (2021)	The main objective of the article is to conduct a systematic review and meta-analysis of risk assessment methodologies for cultural heritage in historic urban areas in the context of climate change, aiming to bring these methodologies closer to urban planners. The research aims to contribute to more efficient climate adaptation policies, highlighting the knowledge gap in methodologies focused on other climate risks beyond flooding, such as heat and cold waves, and proposing a more holistic approach to cultural heritage preservation. Keywords: Historic urban areas; Extreme events; Risk assessment; Vulnerability assessment; Exposure.
Title: Climate Change and UNESCO World Heritage-Listed Cultural Properties: A Systematic Review (2008–2021)	
Authors	**Objectives**
Nguyen and Baker (2023)	The article aims to systematically review 58 peer-reviewed publications from 2008–2021 that examine the relationship between climate change and UNESCO World Heritage-listed cultural properties. It highlights key trends, such as the increase in research since 2008, the regional focus on Europe and North America, and the predominance of studies on natural over cultural sites. The study also identifies critical gaps, including the need for greater representation from the Global South, better interdisciplinary collaboration between STEM and HASS fields, and the importance of considering both tangible and intangible elements in the safeguarding of cultural heritage sites. Keywords: climate change; cultural sites; hazards; UNESCO; World Heritage Properties

Table 01 - Summary of systematic reviews

Source: Authors, 2024.

As for the empirical and theoretical works, four articles were analyzed, published between 2017 and 2023. The papers and objectives are shown in the table below.

Title: Smart Cities and Cultural: Heritage Protecting historicalurban environments from climate change	
Authors	**Objectives**
Marsella and Marzoli (2017)	The paper illustrate the approach of the STORM project that mitigate the impact of climate changes on cultural heritages and the mutual benefits which could derive from an integration of the STORM outcomes with smart cities systems through the use of standard emergency data exchange protocols and an integrated framework aimed at improving existing processes related to the three identified areas: Prevention, Response and Policy. **Keywords:** smart cities, cultural heritage, climate change,safety, interoperability
Title: Climate change challenges to existing cultural heritage policy	
Authors	**Objectives**
Dastgerdi; Sargolini; and Pierantoni (2019)	This study aims to debate the cultural heritage concept as the primary and neglected factor for wise development of climate-resilience policies. It adopted the qualitative meta-synthesis method to analyze the impacts of climate change on world heritage sites, through a systematic review of reports published by the UNESCO. **Keywords:** cultural heritage; climate change; conservation; climate resilience; protection; sustainability; territorial planning
Title: Optimizing preservation for multiple types of historic structures under climate change	
Authors	**Objectives**
Xiao et al. (2021)	The article aims to address the challenge of adapting cultural resources in coastal parks to climate change, focusing on the limitations of current adaptation planning due to insufficient funding. It introduces the Optimal Preservation (OptiPres) Model as a decision support framework to help managers evaluate trade-offs among different types of historic structures—such as wooden buildings and masonry forts—under various budget constraints. The study emphasizes the need to integrate factors like vulnerability, cultural significance, and costs into adaptation decisions and highlights that periodic funding and adaptive use of buildings can optimize preservation efforts across coastal parks. **Keywords:** Climate change; Adaptation planning; Historic preservation; National park; Decision support tool.
Title: Heritage sites, climate change, and urban science	
Authors	**Objectives**
Smith, Ortman and Lobo (2023)	The article proposes a new research perspective on the relationship between climate change and heritage sites, emphasizing that these sites offer valuable empirical records of past urban responses to environmental shocks. By scientifically analyzing archaeological remains, the study seeks to generate hypotheses on factors that influenced resilience and adaptation success. This knowledge can inform contemporary urban climate adaptation strategies. The article highlights that this approach complements existing efforts focused on climate-related damage to heritage and the role of local communities in preserving these sites, adding a new dimension to climate change and heritage research. **Keywords:** Heritage sites; Archaeology; Urban adaptation; Urban sustainability.

Table 02 - Summary of empirical studies

Source: Authors, 2024.

In addition, searches were carried out using the strings in Google Scholar, and 6 articles were added for analysis.

Title: Are cultural heritage and resources threatened by climate change? A systematic literature review	
Authors	**Objectives**
Fatorić and Seekamp (2017)	The article addresses the gap in understanding the impacts of climate change on cultural heritage and resources across different continents and disciplines. Through a systematic literature review, the study identifies and characterizes the current state of knowledge. Based on the analysis of 124 publications, the article highlights the growing academic interest in the topic, though with a limited geographical focus, predominantly on Europe. The study also emphasizes the need for future research to propose sustainable adaptation options and to document whether, and how, the implementation of cultural heritage preservation measures is effectively taking place. The goal is to guide academic research and influence policy formulation for the preservation and adaptation of cultural heritage on a global scale. **Keywords:** Climate change; Geographical Information System; Cultural Heritage; Climate Change Impact; Systematic Literature Review.
Title: An innovative methodology of assessing the climate change impact on cultural heritage	
Authors	**Objectives**
Rajčić, Skender and Damjanović (2017)	The main objective of the article is to present a methodology developed as part of the FP7 project "Climate for Culture," which aims to assess the impact of climate change on cultural heritage collections housed within historic buildings. The key innovation of this study is the combination of high-resolution future climate projections with building simulation tools to predict indoor climate conditions and identify future risks. **Keywords:** accuracy assessment; biological damage; building simulation; climate change; heating; indoor climate; mechanical damage; painted wood; risk assessment;
Title: Review of Potential Risk Factors of Cultural Heritage Sites and Initial Modelling for Adaptation to Climate Change	
Authors	**Objectives**
Carroll and Aarrevaara (2018)	The paper reviews the climatic and meteorological factors that contribute to the degradation of cultural heritage buildings, structures and sites. It focuses on the Nordic countries, where climate change trends such as shorter winters and increased precipitation are accelerating this process. The paper proposes an initial classification of affected materials and structures, together with a numerical scale to assess the urgency of action. The aim is to provide guidance on how best to allocate resources for the preservation of cultural heritage sites in the context of climate change mitigation and adaptation. **Keywords:** cultural heritage; preventative conservation; climate change; mitigation; adaptation; climate modelling.
Title: Economic and Societal Impacts on Cultural Heritage Sites, Resulting from Natural Effects and Climate Change	
Authors	**Objectives**
Alexandrakis, Manasakis and Kampanis (2019)	The research proposes a new approach to cultural heritage, understanding monuments and landscapes as important in creating a sense of history and place. The paper presents a socioeconomic impact model that links the economic benefits of heritage sites, particularly through tourism, to the natural risks caused by climate change. The study highlights the market and non-market benefits that heritage sites provide to society and suggests that this understanding can guide policy interventions aimed at conserving, promoting and protecting cultural heritage from climate-related risks and natural disasters. **Keywords:** Tourism; Cultural heritage; Climate Change; economy; society; natural hazards
Authors	**Objectives**
García (2019)	The paper examines the risks that climate change poses to tangible and intangible cultural heritage around the world. By reviewing examples of heritage threatened by rising sea levels, storms and droughts, the paper aims to explore potential solutions, such as integrating cultural heritage into disaster risk management and leveraging cultural traditions to improve understanding and communication of climate risks. Finally, the paper seeks to highlight the role of cultural heritage in strengthening resilience and promoting recovery within local communities facing climate-related challenges. **Keywords:** Not applicable.

Title: Managing Cultural Heritage In The Face Of Climate Change	
Authors	**Objectives**
Jigyasu (2019)	The article explores how climate change is creating environmental conditions that increase the vulnerability of cultural heritage to damage and risks. Using case examples, the article demonstrates the need for more research, data collection, and modeling to develop future climate scenarios. Additionally, it emphasizes the importance of translating this knowledge into practical and feasible strategies for managing cultural heritage. **Keywords:** Not applicable.

Table 03 -Summary of papers found on Google Scholar
Source: Authors, 2024.

5. CLIMATE CHANGE IN CULTURAL HERITAGE AREAS

Climate change poses significant challenges to the preservation and management of cultural heritage sites worldwide. As environmental conditions change, areas with cultural heritage face increasing risks from phenomena such as rising sea levels, extreme weather events, and temperature fluctuations. These changes not only threaten the physical integrity of historical buildings, landscapes, and artifacts, but also can interfere with the social and cultural practices associated with these sites. This section explores studies on the impacts of climate change on cultural heritage sites, highlighting the need for integrated approaches that reconcile preservation with new environmental realities.

The first study, by Sesana et al. (2021), provides a systematic review of the impacts of climate change on cultural heritage. After systematic searches and specific inclusion and exclusion criteria, 100 articles were analyzed, published in journals, book chapters, and conferences. The study categorized the research into three key themes: exposed cultural heritage (external environment); building interiors and collections; and the impact of extreme events on the physical and natural environment. Regarding impacts on built heritage, three main categories were identified: changes in temperatures, precipitation, and winds. For the interiors of buildings and collections, the main challenges are mechanical, chemical, and biological degradations. Finally, in the category of events affecting the physical environment, the main climate change-related problems are flooding, sea-level rise and coastal impacts, changes in ocean characteristics (temperature, salinity, and acidity), thawing soils, drought, and extreme heat.

Thus, the authors point out that climate change can increase the exposure of cultural heritage to various stressors. Although research predominantly focuses on the European scenario, articles from studies in North America, Australia, and New Zealand were included. As gaps, the authors note that most research does not consider uncertainties when projecting the real impacts of climate change. They recommend using a set of scenarios that can capture uncertainties and identify actual vulnerabilities to adverse climate events. As final considerations, the authors suggest further research in other regions, seeking tools and practices to manage cultural heritage in the current climatic context.

The second study, by Orr, Richards, and Fatorić (2021), conducted a review from 2016 to 2020 on the impact of climate change on cultural heritage. The study, published in 2021, analyzed a total of 165 publications. The authors note the predominance of studies in the European context and few studies focusing on the relationship between climate change and intangible heritage. Additionally, they mention that the field of study is growing and has a diversity of research and methodologies. Nevertheless, studies remain few compared to publications addressing physical impacts on buildings. The authors warn of the need for research that addresses the complexity of the topic, bringing practical strategies for action in mitigating the effects of climate change on cultural heritage sites.

Next, the work of Quesada-Ganuza et al. (2021) on the threats of climate change to urban heritage was analyzed. The study is a systematic and critical literature review from the Web of Science and Scopus databases. After applying search and inclusion and exclusion criteria, 29 articles from journals and conferences published in English between 2015 and 2020 were analyzed. Most of the studies (22 articles) address issues related to flooding and sea-level rise.

The authors point out that the main gap is the lack of an integrated view of the risks to cultural heritage in urban areas, considering, in addition to physical aspects, the impacts on socio-economic, cultural, and governmental systems. They also emphasize the need

to assess other impacts in urban areas beyond flooding. The cited impacts include drastic temperature changes. Moreover, the authors call for more in-depth studies on the impacts of climate change on urban heritage and its cultural values to achieve resilience and sustainability in the environments where they are located. Additionally, they state that cultural heritage is an essential part of the sense of place and belonging, which are crucial to the sustainability of any community with preservation areas. They highlight the need for practical tools for urban planning agents to develop strategies for protecting urban heritage.

The last review found in the search, by Nguyen and Baker (2023), is a systematic literature review from 2008 to 2021 on climate change in UNESCO-listed cultural heritage sites. The study was published in 2023 and analyzed 58 articles available on Scopus and Google Scholar. The study points out an increase in publications on the topic after 2018, mostly corresponding to case studies, followed by conceptual and review studies. Additionally, there is also a predominance of studies on sites of natural preservation interest and few studies focused on areas with cultural heritage. Furthermore, they note the concentration of studies on the topic in northern countries, with a lack of substantial studies in the global south.

Regarding empirical and theoretical studies, four articles were analyzed. The first empirical study analyzed was conducted by Marsella and Marzoli (2017). The study addresses the interface between smart cities and cultural heritage, dealing with the protection of urban historical areas from the effects of climate change. Thus, the study integrates the monitoring of climate sites of cultural interest with the theme of smart cities, in a case study on the STORM project. The project aimed to create information systems for managing damage to cultural heritage. There are three main focus areas: prevention, intervention, and planning policies. Digital and computational technologies, such as IoT, are used to integrate data collected in smart cities to assess and protect urban cultural heritage.

Then, the work of Dastgerdi, Sargolini, and Pierantoni (2019) on the challenges of climate change to current preservation policies was evaluated. The article, published in 2019, discusses the concept of cultural heritage as a neglected factor in developing climate resilience policies. The study analyzed data from UNESCO reports from 2006 to 2019 on the major impacts of climate change. A total of 46 sites considered World Heritage - both cultural and natural - were identified as having threats from climate change.

The study highlights different types of risks and difficulties in preserving these sites, emphasizing the need to rethink current heritage policies. According to the authors, the uncertainties about the effects of climate change require a new perspective on cultural heritage. Thus, a model of heritage appreciation as a dynamic resource is suggested, considering the specificities of each territory. The proposed model would involve different stakeholders, including planners, researchers, and the community.

Subsequently, Xiao et al. (2021) bring a study on optimizing the preservation of various types of historical structures in the face of climate change. The research conducts a case study on coastal parks and recreation areas in the United States, which face challenges from the adverse effects of climate change. The proposed model aims to develop risk management models for preserving historical structures in coastal areas directly affected by climate change. The proposed model seeks to analyze the feasibility of interventions based on funding for periodic maintenance.

Finally, the work of Smith, Ortman, and Lobo (2023) discusses the relationships between sites of preservation interest, climate change, and urban sciences. The research suggests that heritage archaeological analyses can serve as a source of knowledge for urban climate science. The authors propose the need to decolonize research on climate change and heritage and to create a decolonized urban science that seeks climate resilience in traditional knowledge.

Regarding the studies found using the Google Scholar search tool, one systematic review and five empirical works or case studies were identified. The systematic review conducted by Fatorić and Seekamp (2017) aimed to address the gap regarding the impacts of climate change on cultural heritage. A total of 124 publications were included, limited to English-language publications. The authors point to an increase in publications in the field from 2003 to 2015. Most studies are concentrated in Europe (59%). Only 2% of the studies are located in South America (Chile, Colombia, and Peru).

Moreover, of the analyzed publications, 69% correspond to case studies or conceptual articles. Regarding methods, they were varied, with research involving secondary data (36%) and modeling and simulations (25%) standing out. In terms of publication areas, fields such as Architecture & Built Environment (26%), Climate & Natural Hazards (20%), and Archaeology (14%) dominate. The authors note that there are still knowledge gaps in the field that can be explored. Among the gaps are the importance of community engagement in preserving cultural heritage

and resources. Additionally, the authors point out a gap between legislation and preservation plans and their actual implementation to achieve adaptation for preservation (Fatorić and Seekamp, 2017).

The study by Rajčić, Skender, and Damjanović (2017) addresses a methodology for assessing the impact of climate change on cultural heritage. The methodology was developed during the execution of the FP7 Climate for Culture project, from 2009 to 2014. For its execution, it was based on high-resolution models that have building simulation tools to predict future internal climate, identifying possible risks. More than 100 case studies located in Europe and the Mediterranean region were generated.

The representative case study chosen is a wooden chapel in Croatia. The church, built of wood, has numerous internally painted panels that are susceptible to damage from climate changes. The model was validated for accuracy in the context of preventive conservation. The methodology is used to assess possible risks of biological, mechanical, and chemical damage to heritage objects, especially under conditions of intermittent heating. Thus, it provides support for applying this damage assessment method to buildings with active climate control (Rajčić, Skender, and Damjanović, 2017).

For acquiring temperature and humidity data in the building, three sensors were initially attached: two indoors and one outdoors. Later, only one indoor and one outdoor sensor remained since the indoor sensors always presented the same data. Data were collected from October 14, 2011, to June 18, 2014. In the case of high-resolution climate models, simulations were conducted for the recent past (1960 - 1990), near future (2020 - 2050), and distant future (2070 - 2100), using the past as a control period. The model was tested and validated, and statistical assessments of the simulation quality were subsequently performed. The main results indicate that the model was validated and could be useful for computing future data, assessing potential biological, mechanical, and chemical risks to wooden panels. The authors suggest further research in other locations and with other materials susceptible to different types of damage (Rajčić, Skender, and Damjanović, 2017).

The study by Carroll and Aarrevaara (2018) analyzes the potential risks to cultural heritage considering the context of Nordic countries. In these countries, the trends resulting from climate change are shorter winters and increased annual precipitation. The authors classify materials and structures that may be affected, using a numerical scale of intervention urgency. These measures can assist in decision-making regarding heritage management in this region. As a case study, the authors analyze a set of rural residences in Finland. As considerations, the authors highlight the need for more case studies on the impacts of climate change, as the scenarios are uncertain. They also note that natural deterioration is exacerbated by climate change, necessitating further analysis (Carroll and Aarrevaara, 2018).

The research by Alexandrakis, Manasakis, and Kampanis (2019) examines the economic and social impacts on preservation sites from natural effects and climate change. The work is linked to the European HERACLES Project (HEritage Resilience Against CLimate Events on Site). The cities defined as case studies are Gubbio (Italy) and Heraklion (Greece). For the analysis, categories were defined for classification based on economic theories, resulting in data for analysis. Thus, the risks are analyzed along with the economic aspect to support decision-making for cultural heritage management. Another important factor considered by the study is the social and economic impact of tourism on communities.

The results indicate that areas with cultural heritage offer non-market benefits to society, providing an opportunity for conservation and protection interventions against the impacts of climate change and natural disasters. The authors highlight preventive maintenance as essential in all cases, as well as measures to ensure safety during potential natural events and climate change impacts (Alexandrakis, Manasakis, and Kampanis, 2019).

In her article, García (2019) discusses the impact of climate change on cultural heritage and the need for resilient strategies to protect tangible and intangible cultural assets. The author notes that assessing the impact of climate change on cultural assets faces challenges. In the case of historical environments, they naturally suffer greater damage from climatic instability, such as changes in rainfall and temperature patterns.

Another important point raised by the research is the difference between adaptation and mitigation. The term adaptation is used to describe the process of adjusting to the climate (actual or expected) to reduce damage. Mitigation, on the other hand, refers to any human intervention that has the potential to reduce greenhouse gas emissions. Thus, in the field of cultural heritage, most research refers to adaptation. Additionally, the research field is still emerging and faces challenges. The article also

addresses risk management and resilient recovery in the context of climate change (García, 2019).

Among the possible solutions to the problems highlighted in the article, the author points to the need for integrating cultural heritage into the field of disaster risk management; the importance of culture and traditions, including providing solutions; and communication of risks and necessary actions as a way to strengthen the resilience of local communities (García, 2019).

Finally, Jigyasu (2019) addresses the importance of considering climate change in disaster risk analyses in the context of cultural heritage. The study outlines the main types of risks to cultural heritage, whether tangible or intangible. According to the author, climate change exacerbates disasters by increasing the number and intensity of climate-related events that cause damage to heritage. Additionally, factors such as the unpredictability of most climatic phenomena make heritage management challenging.

Strategies to improve management include adopting preventive conservation techniques, enhanced monitoring systems, and adaptation practices. Furthermore, it is essential to revisit traditional knowledge for effective responses to climate change challenges. The author also points to the need for a shift in approach to heritage conservation and management, promoting pre-disaster actions, mitigation, and adaptation. This includes developing risk scenarios based on predictive models and databases on damage to cultural heritage from climatic disasters (Jigyasu, 2019).

Regarding the location of the studies, when case studies are involved, there is a predominance of works in European countries. For the United States, Xiao et al. (2021) presents the issue of climate change in protecting coastal parks considered natural heritage. Systematic review works were not included in the map. Additionally, the work of Dastgerdi, Sargolini, and Pierantoni (2019) identifies UNESCO-protected sites and their main damages, including natural and cultural heritage. There is greater geographical diversity, including natural parks in locations such as Peru, South Africa, Indonesia, India, and Australia. For cultural heritage, countries such as Peru, Russia, Canada, Mali, Lebanon, and other European countries are cited. Since these are informational data, they were not included on the map.

Regarding the most frequent keywords, "climate change" and "cultural heritage" appear in almost all keyword sets. Other frequently related keywords include "conservation," "adaptation," and "risk assessment," showing a focus on adaptive planning. Among the less frequent words are "smart cities," "mechanical damage," "painted wood," and "building simulation," highlighting more specific and technical aspects of the interactions between climate and cultural heritage.

Overall, the articles show a consensus on the need to address the impacts of climate change on cultural and natural heritage. The review highlights methodological gaps and the need to integrate preventive and adaptive policies in the management of cultural heritage in the face of climate change. The main goal should be adaptation, seeking resilience in the conservation of cultural heritage.

4. FINAL CONSIDERATIONS

With climate change, cultural heritage sites face increasing threats. It is essential to understand the potential impacts and develop mitigation strategies for extreme events to preserve both memory and the environment. Regarding adaptation strategies, in-depth studies on local climate patterns are necessary. Consequently, tailored climate simulation models can assist in developing strategies that preserve the environment and enhance its long-term environmental resilience.

Although it is widely acknowledged that climate change affects heritage, there are gaps in understanding the damage to both built and natural cultural heritage. Many areas of heritage interest have yet to receive substantive assessments, lacking detailed studies on their exposure to extreme weather events. Additionally, there is a growing need to develop and implement innovative technologies and tools capable of improving the monitoring, assessment, and preservation of heritage in the face of the current climate crisis.

Based on the analyzed articles, it is clear that this field of study is broad and requires a multidisciplinary approach that accounts for the complexity of the issue. The systematic reviews highlight the need to address various identified gaps, ranging from the predominance of studies in certain geographic regions to the lack of a holistic approach that considers not only physical aspects but also socioeconomic, cultural, and governmental impacts. In this sense, the diversity of studies in recent years reveals a growing field of knowledge. Nonetheless, it is necessary to develop practices and actions that ensure the resilience and preservation of cultural heritage globally.

In both empirical and theoretical studies, there has been progress in understanding and addressing the intersections between climate change and cultural

heritage. These works emphasize the complexity of these relationships and offer perspectives on how to tackle the emerging challenges posed by the current climate situation. From the use of digital technologies to monitor heritage to reflections on preservation policies in the face of climate uncertainties, the studies converge on the urgency for integrative and dynamic research.

REFERENCES

ALEXANDRAKIS, G.; MANASAKIS, C.; KAMPANIS, N.A. Economic and Societal Impacts on Cultural Heritage Sites, Resulting from Natural Effects and Climate Change. **Heritage** 2019, 2, 279-305. https://doi.org/10.3390/heritage2010019

ALVEZ, C. A. **A produção recente de edifícios residenciais em São Paulo:** desempenho e conforto térmico no contexto urbano e climático em transição. 2019. Universidade de São Paulo, 2019.

BARBIERI, A. F.; VIANA, R. M. Respostas urbanas às mudanças climáticas: construção de políticas públicas e capacidade de planejamento. In: OJIMA, R.; MARANDOLA JR, E. (orgs). **Mudanças Climáticas e as cidades:** novos e antigos debates na busca da sustentabilidade urbana e social. São Paulo: Blucher, 2013.

BRASIL. MINISTÉRIO DO MEIO AMBIENTE. **A Camada de Ozônio. 2024.** Available at: https://antigo.mma.gov.br/clima/protecao-da-camada-de-ozonio/a-camada-de-ozonio.html#:~:text=O%20processo%20de%20diminui%C3%A7%C3%A3o%20da,do%20mundo%2C%20inclusive%20no%20Brasil. Acess in: 10 ago. 2024.

CARROLL, P.; AARREVAARA, E. Review of Potential Risk Factors of Cultural Heritage Sites and Initial Modelling for Adaptation to Climate Change. **Geosciences** 2018, 8, 322.

COLETTE, A. Case studies on climate change and worl heritage. UNESCO: 2007.

DASTGERDI, A. S.; SARGOLINI, M.; PIERANTONI, I. Climate change challenges to existing cultural heritage policy. **Sustainability (Switzerland)**, v. 11, n. 19, 1 out. 2019.

FATORIĆ, S., SEEKAMP, E. Are cultural heritage and resources threatened by climate change? A systematic literature review. **Climatic Change** 142, 227–254 (2017). https://doi.org/10.1007/s10584-017-1929-9

GARCÍA, B. M. Resilient Cultural Heritage For A Future Of Climate Change. 2019. **Journal of International Affairs**, 73(1), 101–120.

GILIBERTO, F; JACKSON, R. **Cultural heritage in the context of disasters and climate change:** Insights from the DCMS-AHRC Cultural Heritage and Climate Change Cohort. 2022. Report. Leeds-Edinburgh: University of Leeds and University of Edinburgh.

GRAFAKOS, et al. Integration of mitigation and adaptation in urban climate change action plans in Europe: A systematic assessment. **Renewable and Sustainable Energy Reviews**, v. 121, p. 109623, 1 abr. 2020.

ICOMOS. International Council on Monuments and Sites. The Valletta Principles for the Safeguarding and Management of Historic Cities, Towns and Urban Areas. In: **XVII ASSEMBLÉE GENERALE ICOMOS**, 2011, Paris. [...]. Paris: 2011.

IPCC. Intergovernmental Panel on **Climate Change. Climate Change 2023:** Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC, 2023. 35–115 p.

IPCC. Intergovernmental Panel on Climate Change. **Climate Change 2022: Impacts, Adaptation, and Vulnerability.** Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2022. 3056 p. Available at: https://doi.org/10.1017/9781009325844. Acess in: 15 jun. 2024.

IPCC. Painel Intergovernamental para a Mudança de Clima. **Mudança do clima e terra:** Relatório especial do IPCC sobre mudança do clima, desertificação, degradação da terra, manejo sustentável da terra, segurança alimentar, e fluxos de gases de efeito estufa em ecossistemas terrestres. Brasília: Ministério da Ciência, Tecnologia, Inovações e Comunicações, 2020.

IPHAN. Instituto do Patrimônio Histórico e Artístico Nacional. **Patrimônio Mundial Cultural e Natural.** 2014. Available at: http://portal.iphan.gov.br/pagina/detalhes/29. Acess in: 10 jun. 2024.

IWAMA, A. Y. Risco, vulnerabilidade e adaptação às mudanças climáticas: uma abordagem interdisciplinar. **Ambiente & Sociedade,** v. XIX, n. 2, p. 95–118, 2016.
JIGYASU, R. Managing Cultural Heritage In The Face Of Climate Change. 2019. Journal of International Affairs, 73(1), 87–100.

MARSELLA, S.; MARZOLI, M. Smart Cities and Cultural: Heritage Protecting historical urban environments from climate change. In: **Proceedings of the 2017 IEEE 14th international conference on networking, sensing and control** (ICNSC 2017), 2017, Calabria, ITALY. [...]. Calábria, ITALY: IEEE, 2017. p. 281–286.

NGUYEN, K. N.; BAKER, S. Climate Change and UNESCO World Heritage-Listed Cultural Properties: A Systematic Review (2008–2021). **Heritage MDPI**, 1 mar. 2023.

NU. **Resolution adopted by the General Assembly on 25 September 2015**. 2015a. [s.l: s.n.].

NU. **Objetivo de Desenvolvimento Sustentável 11:** Cidades e comunidades Sustentáveis. Available at: https://brasil.un.org/pt-br/sdgs/11. 2015b. Access in: 12 sept. 2023.

NU. **Agenda 2030 para o Desenvolvimento Sustentável**. 2015c. Available at: https://brasil.un.org/pt-br/91863-agenda-2030-para-o-desenvolvimento-sustentável. Access in: 12 sept. 2023.

NU. **Objetivo de Desenvolvimento Sustentável 13:** Ação contra a mudança global do clima. 2015d. Available at: https://brasil.un.org/pt-br/sdgs/13. Access in: 12 sept. 2023.

NU. **Relatório climático da ONU:** estamos a caminho do desastre, alerta Guterres. 2022. Available at: https://brasil.un.org/pt-br/176755-relatório-climático-da-onu-estamos-caminho-do-desastre-alerta-guterres. Access in: 12 sept. 2023.

ORR, S. A.; RICHARDS, J.; FATORIĆ, S. Climate Change and Cultural Heritage: A Systematic Literature Review (2016–2020). **The Historic Environment: Policy & Practice**, v. 12, n. 3–4, p. 434–477, 2 out. 2021.

PEITER, G; MALUF, R; ROSA, T. (Coord.). **Mudanças climáticas, vulnerabilidade e adaptação:** parte 1 - Mobilização e iniciativas de adaptação; parte 2 - Populações vulneráveis e agenda pública no Brasil. Rio de Janeiro: COEP, 2011. 288 p. (Coleção COEP. Cidadania em rede 5).

PEREIRA, N. B.; PAES, C. F. C.; PASINI, P. Patrimônio, sustentabilidade e mudanças climáticas: estado da arte e perspectivas para um mundo informatizado. In: PAES, C. F. C.; GONÇALVES, P. H. **As mudanças climáticas em sítios com valor cultural.** São Paulo: Blucher, 2023. p. 13-30.

QUESADA-GANUZA, et al. Do we know how urban heritage is being endangered by climate change? A systematic and critical review. **International Journal of Disaster Risk Reduction.** Elsevier Ltd, 1 nov. 2021.

RAJČIĆ, V.; SKENDER, A.; DAMJANOVIĆ, D. An innovative methodology of assessing the climate change impact on cultural heritage. **International Journal of Architectural Heritage.** 2017. DOI: 10.1080/15583058.2017.1354094

ROAF, S.; CRICHTON, D.; NICOL, F. A **Adaptação de Edificações e Cidades às Mudanças Climáticas:** Um guia de sobrevivência para o século XXI. Porto Alegre: Bookman, 2009.

SESANA, et al. Climate change impacts on cultural heritage: A literature review. **Wiley Interdisciplinary Reviews: Climate Change**, v. 12, n. 4, 1 jul. 2021.

SMITH, M. E.; ORTMAN, S. G.; LOBO, J. Heritage sites, climate change, and urban science. **Urban Climate**, v. 47, 1 jan. 2023.

UNESCO. **Predicting and managing the effects of climate change on world heritage.** Vilnius: UNESCO, 2006. Disponível em: https://whc.unesco.org/document/6670. Acesso em: 10 jun. 2024.

XIAO, et al. Optimizing preservation for multiple types of historic structures under climate change. **Landscape and Urban Planning**, v. 214, 1 out. 2021.

WEISSBECKER, I., CZINCZ, J. Humanitarian Crises: The Need for Cultural Competence and Local Capacity Building. In: Weissbecker, I. (org). **Climate Change and Human Well-Being**. International and Cultural Psychology. New York: Springer, 2011.

ZIEBELL, et al. Clima Urbano e Mudanças Climáticas no Patrimônio. In: PAES, C. F. C.; GONÇALVES, P. H. **As mudanças climáticas em sítios com valor cultural**. São Paulo: Blucher, 2023. p. 87–100.

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REGIONAL FORCES AND URBAN FORMS: GROWTH DIRECTION

FORÇAS REGIONAIS E FORMAS URBANAS: DIREÇÃO DE CRESCIMENTO

FUERZAS REGIONALES Y FORMAS URBANAS: DIRECCIÓN DE CRECIMIENTO

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ABSTRACT
The possibility of influence that the regional system may have on the urban forms that cities tend to assume is discussed. The difference in scale involved in this vision, which ranges from the regional scale, passes through the municipal scale, and given this situation that presents the way in which urban form, city and region are approached today, it appears that the Studies lack greater connection and assessment of influences between different scales and impacts. This research is carried out through the proposal of a methodological guide, and the instrument developed to obtain results was the collection of data and construction of variables of interest, which can provide a useful tool to study the influence of spatial effects on aggregation of spatial interaction models and how much they can contribute in different ways to substantial achievements in spatial econometric studies, in addition to suggesting statistical tools that infer the value, intensity and probable hierarchy of average flows at certain levels of aggregation of real and estimated available variables. As a way of illustrating the research, data collection with empirical research was chosen as an evaluation instrument, based on the Metropolitan Region of Serra Gaúcha (MRSG), made up of 14 municipalities that present very different forms and urban structures.

KEYWORDS
Forças regionais, formas urbanas, estrutura interna da cidade.

RESUMO
Discute-se a possibilidade de influência que o sistema regional pode ter sobre as formas urbanas que as cidades tendem a assumir. A diferença de escala envolvida nesta visão, que vai desde a escala regional e passa pela escala municipal, colocada esta conjuntura que apresenta a maneira como hoje se aborda forma urbana, cidade e região, verifica-se que os estudos carecem de uma maior conexão e avaliação das influências entre as diferentes escalas e impactos. O encaminhamento desta pesquisa se dá através da proposta de um roteiro metodológico, e o instrumento desenvolvido para obtenção de resultados foi a coleta de dados e construção de variáveis de interesse, que pode fornecer uma ferramenta útil para estudar a influência dos efeitos espaciais sobre a agregação de modelos de interação espacial e o quanto podem contribuir de diversas maneiras para realizações substanciais em estudos econométricos espaciais, além de sugerirem ferramentas estatísticas que inferem o valor, intensidade e hierarquia provável de fluxos médios a certos níveis de agregação de variáveis disponíveis reais e estimadas. Como forma de ilustrar a pesquisa, foi escolhido como instrumento de avaliação a coleta de dados com pesquisa empírica, baseado na Metropolitan Region of Serra Gaúcha

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(MRSG), composta por 14 municípios que apresentam formas e estruturas urbanas bastante distintas entre si.

PALAVRAS-CHAVE
Fuerzas regionales, formas urbanas, estructura interna de la ciudad.

RESUMEN
Se discute la posibilidad de la influencia que el sistema regional puede tener sobre las formas urbanas que las ciudades tienden a asumir. La diferencia de escala involucrada en esta visión, que abarca desde la escala regional hasta la escala municipal, plantea una coyuntura que muestra cómo, hoy en día, se aborda la forma urbana, la ciudad y la región. Se observa que los estudios carecen de una mayor conexión y evaluación de las influencias entre las diferentes escalas e impactos. El desarrollo de esta investigación se lleva a cabo mediante la propuesta de un esquema metodológico, y el instrumento desarrollado para obtener resultados fue la recolección de datos y la construcción de variables de interés, lo cual puede proporcionar una herramienta útil para estudiar la influencia de los efectos espaciales sobre la agregación de modelos de interacción espacial y cuánto pueden contribuir de diversas maneras a logros sustanciales en estudios econométricos espaciales. Además, sugiere herramientas estadísticas que infieren el valor, la intensidad y la jerarquía probable de flujos medios a ciertos niveles de agregación de variables disponibles, tanto reales como estimadas. Como una forma de ilustrar la investigación, se eligió como instrumento de evaluación la recolección de datos con investigación empírica, basada en la Región Metropolitana de la Serra Gaúcha (MRSG), compuesta por 14 municipios que presentan formas y estructuras urbanas bastante distintas entre sí.

1. INTRODUCTION

The pursuit of understanding the spatial transformations generated by the increasing number of people living in cities, the consequent expansion of urbanized areas, the impacts on space consumption, and thus, the emergence of new urban forms. This accelerated growth of urban areas has a direct impact on the structure and organization of a city and has therefore become a subject of interest in various studies.

In this research, we discuss the potential influence that the regional system may have on the urban forms that cities tend to assume. The scale differences involved in this perspective, ranging from the regional scale to the municipal scale, down to the intra-urban scale, present a context that reveals the current approach to urban form, city, and region. It becomes evident that studies lack greater connection and evaluation of the influences between these different scales and their impacts.

The direction of this research is guided by the proposal of a methodological framework, along with statistical and spatial verifications, as well as studies projecting city growth trends based on a 40-year time series (1970-2010). In this context, the tool developed to obtain results involved data collection and the construction of variables of interest, which could provide a useful tool for studying the influence of spatial effects on the aggregation of special interaction models. This approach allows for understanding the extent to which these effects can contribute in various ways to substantial advancements in spatial econometric studies. It is also possible to obtain statistical tools that infer the value, intensity, and probable hierarchy of average flows at certain levels of aggregation of available real and estimated variables—thus enabling a more refined and detailed analysis that could be overlooked in traditional models that do not consider spatial factors.

To illustrate the research, data collection through empirical research based on the Metropolitan Region of Serra Gaúcha (MRSG) was chosen as the evaluation instrument. The MRSG consists of 14 municipalities with significantly different urban forms and structures (Image 1). This diversity introduces varying levels of complexity in the region's interactions, providing an opportunity for the study to assess how distinct spatial factors develop within each municipal specificity, followed by an evaluation of the set of interactions as a whole.

Figure 1: Metropolitan Region of Serra Gaúcha map.
Source: elaborated by the authors

2. REGIONAL FORCES AND URBAN FORMS

We can say that in a given region, cities grow according to their own criteria and exhibit different urban forms, some more dispersed and others more compact. There are various reasons for these urban forms to differ, which are associated with the production and consumption of urbanized space, such as the efficiency of the spatial structure, and the consistency between infrastructure, regulations, and the space occupied by a particular urban form (Bertaud, 2003).

However, cities within the same region, with similar urban and economic structuring characteristics, often display distinct urban forms. A fundamental aspect to consider is the influence that the regional system exerts on the urban forms that cities tend to assume. This discussion is relevant because it is assumed that factors within the regional system play a decisive role in how cities spatially structure themselves over time.

According to Favaro & Pumain (2011), cities must be related in some way because they belong to the same statistical distribution, involving a specific average growth rate and standard deviation, which implies an inherent interdependence between them. Gersmehl (1970) notes that there is a problem of scale in identifying the factors that affect the interaction between two cities, as barriers to the occurrence of flows must be considered, and there is significant influence from neighboring cities and the existing routes between them. This stems from the fact that the interaction between two cities can occur on various levels and at different scales.

The term 'urban form' is associated with various situations, ranging from intra-urban issues to regional concerns. In this research, the term will be used to refer to the overall form of the city, that is, the macroscopic state resulting from the process of adaptation and transformation of the environment at a given moment. Thus, a region is presented where cities grow and assume distinct forms, and these forms are driven both by internal forces within the cities, dependent on locational factors, and by the cities' own location within the region.

3. GROWTH DIRECTION

The measurement of the urbanized area refers to the entire portion of the territory occupied by the urban sprawl, forming a visible patch, and is therefore considered a measure at the municipal scale. At other scales, the measurements of internal structures refer to the internal spatial differentiations of each city, such as the evolution of its centralities, polarizations, and densities.

The measurements of geometric deformations pertain to the overall shape of urban settlements, whose evolution is directly linked to the regional tensions within the system. In this way, deformation would select certain directions, extending the urban areas in those directions. Such deformations could be described by proper geometric measurements, such as variation of the urban perimeter, gross increase in the urbanized area, proportional deformation, directional deformation, among other metrics (Image 2).

The rate of growth of cities over the studied period is being evaluated through a supporting measure, referred to in this work as a measure of geometric deformation. Deformation is a change in the shape and dimensions of a body when a certain force is applied to it. Considering the existence of a force "pulling" a city in a particular direction, we could assume that, by correlating this principle with Hooke's Law, the deformations are extensions or compressions of a segment per unit length.

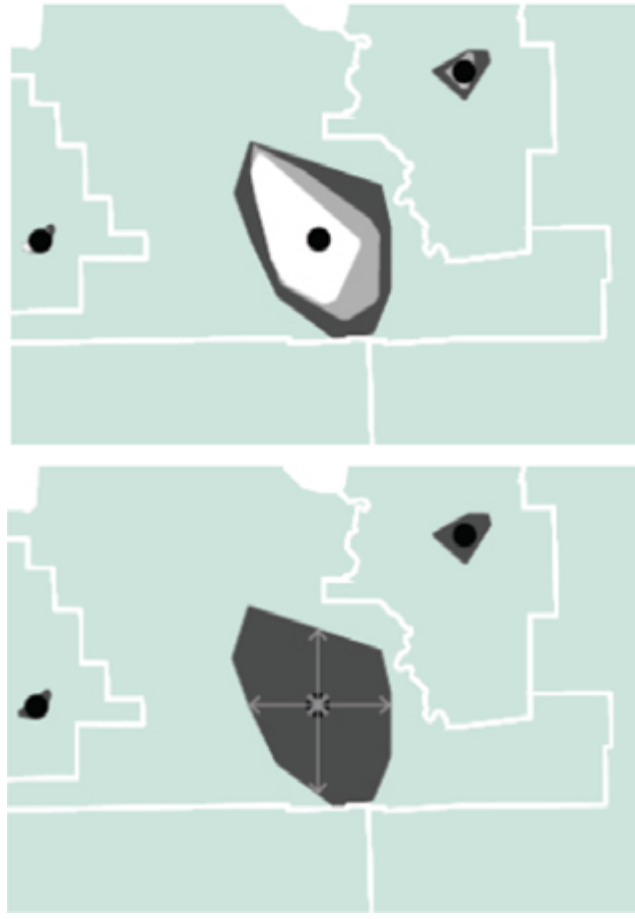

Figure 2: Example of geometric deformation mesure for the city of Bento Gonçalves: In a lighter color, the urbanized area in 1970, calculated towards the shape's vertices; in a stronger color, the urbanized area in 2010, also calculated towards the shape's vertices.
Source: article Forças regionais, formas urbanas e estrutura interna da cidade: UM ESTUDO COMPARATIVO, Autor(es): Manuela Letícia Huppes, Raquel Werner de Vargas e Tamires Lenhart Orientador: Izabele Colusso.

4. METHODOLOGICAL PROCEDURES, GROWTH PROJECTION ELABORATION

Initially, in the preliminary stages of this research, data collection was conducted with information pertaining to the Metropolitan Region of Serra Gaúcha. The objective was to gather a set of data for subsequent analysis, one of which was the growth direction from the centroid (the geometric center of each city). The data were collected in a time series spanning 40 years, with regular intervals of 20 years. This type of temporal approach allows for identifying trends in urban development that limit growth in a particular direction.

To enable a better understanding of the data and facilitate analysis, a second series of tables was created, containing only the growth direction data for each municipality in the MRSG, as shown in Table 1, in this

case illustrating only the municipality of Antônio Prado. Table 1 presents the data regarding the growth direction, represented by the letter "U," corresponding to each orientation (N for North, S for South, W for West, and E for East) for the years 1970, 1990, and 2010, followed by the growth difference for each series: from 1970 to 1990, from 1990 to 2010, and finally, the total from 1970 to 2010. The dimensions were computed in linear meters, and the differences were expressed in percentages.

Subsequently, in Excel, the Forecast Sheet command was applied, which generates predicted data based on the historical data previously presented. This tool can be used to analyze various types of projections, and in this research, we utilized it to analyze the growth direction of each municipality through the measures of its existing urban form. In this way, it was possible to establish a growth trend—based on the past period from 1970 to 2010 and its already defined growth. As a result, we have new phases of urban expansion for the periods of 2030 and 2050. In the next stage, the obtained data were added to the reorganized data table, allowing the command to be applied again to forecast growth for 2070, as shown in Table 4. The Forecast Sheet command was reapplied, this time including the data obtained for 2030 and 2050, as presented in Table 2 and Image 3.

Antônio Prado							
	1970	**1990**	**2010**	**70-90**	**90-10**	**70-10**	**Direction**
UN	665	848	861	27,52%	1,53%	29,47%	-
US	794	967	1518	21,79%	56,98%	91,18%	South: Farroupilha
UE	959	1333	1771	39,00%	32,86%	84,67%	Southeast: Caxias do Sul
UW	1168	1328	1677	13,70%	26,28%	43,58%	Southwest: Bento Gonçalves

Table 1: Synthesized data of Antônio Prado
Source: by Authors.

Timeline	Data	Prediction	Inferior Trust Limit	Superior Trust Limit
1970	665			
1990	848			
2010	861			
2030	980,9639			
2050	1085,704	1085,7043	1085,70	1085,70
2070		**1189,0338**	**1120,29**	**1257,78**

Table 2: Reorganized data including growth projections from 2030, 2050 and 2070, of Antônio Prado .
Source: by Authors.

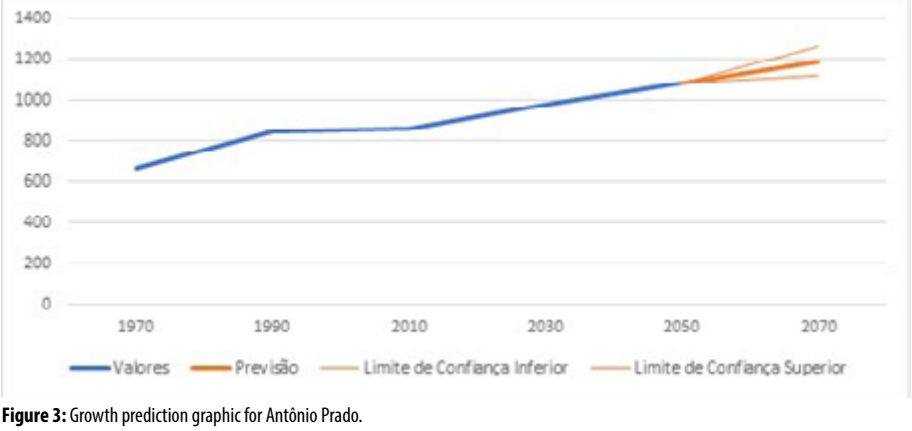

Figure 3: Growth prediction graphic for Antônio Prado.
Source: by Authors.

After obtaining all the necessary data, they were reorganized into a new Total Projections table, where the growth differences became visible through the application of a percentage formula, as shown in Table 3.

The final step was subtracting the data to measure the distance in meters on the map for each growth direction during the analyzed time intervals, ultimately generating a forecast table for each municipality, as shown in Table 4.

To achieve this, maps were developed using QGIS software. Initially, a general map was created, encompassing all 14 cities and their growth patterns over the selected time intervals for visual analysis of growth trends (1970, 1990, and 2010), as shown in Images 4, 5, and 6.

	2030	2050	2070	10-30	30-50	50-70
North	980,96	1085,70	1189,03	13,93%	10,68%	9,52%
South	1831,16	2178,18	2528,32	20,63%	18,95%	16,08%
East	2168,73	2572,19	2976,19	22,46%	18,60%	15,71%
West	1907,08	2154,09	2402,66	13,72%	12,95%	11,54%

Table 3: Total projections for Antônio Prado.
Source: by Authors.

Growth in meters			
	2010 to 2030	2030 to 2050	2050 to 2070
North	119,96	104,74	103,33
South	313,16	347,01	350,15
East	397,73	403,46	403,99
West	230,08	247,01	248,57

Table 4: Growth projection in meters for each direction of Antônio Prado.
Source: by Authors.

This process was conducted for all the municipalities in the MRSG, thereby creating a sequence of data. Subsequently, the spatial behavior of the obtained metrics was analyzed.

5. SPATIALIZATION, ILLUSTRATION AND SPATIAL VERIFICATION ANALYSES

Based on the tables presenting urban growth forecasts generated through Excel, a visual representation of these data was created to understand the spatial behavior of each city over each time series. The objective was to highlight key characteristics, such as the growth direction towards the North, South, East, and West, as well as the urban shape assumed by each municipality and the potential conurbation areas resulting from this growth.

To further facilitate the understanding of the data and forecasts obtained, individual maps were created for each of the 14 cities that make up the Metropolitan Region of Serra Gaúcha (MRSG). These maps provide a clear perspective of the projected expansions in the urban growth areas over the selected time transition periods. These cover the periods from 2010 to 2030, 2030 to 2050, and finally, 2050 to 2070, as shown in Images 7, 8, and 9.

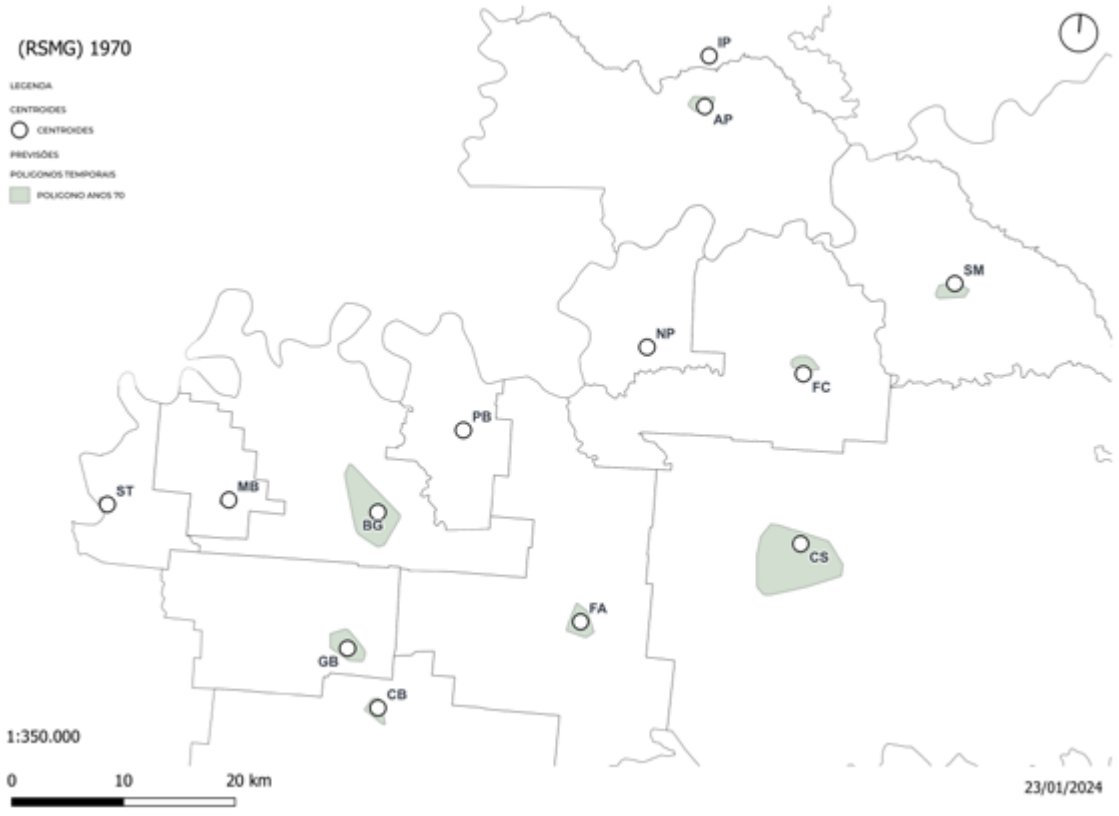

Figure 4: Growth geometry for the cities in the MRSG in the year of 1970.
Source: by Authors.

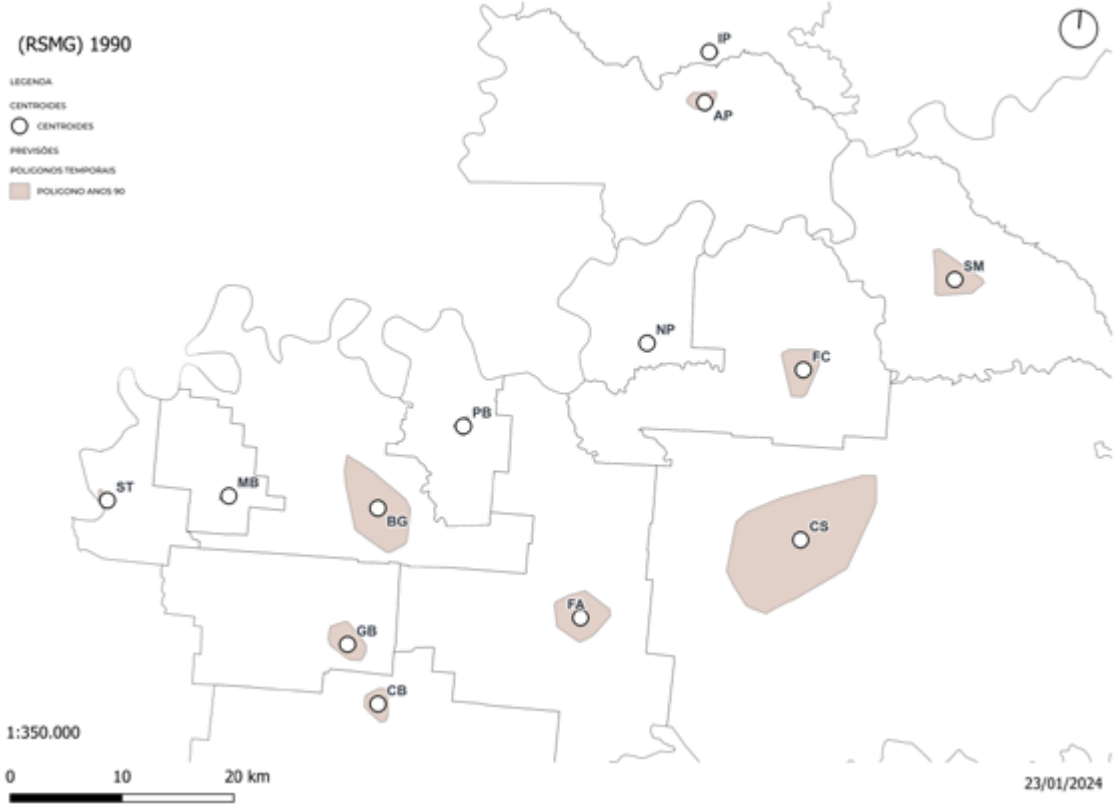

Figure 5: Growth geometry for the cities in the MRSG in the year of 1990.
Source: by Authors.

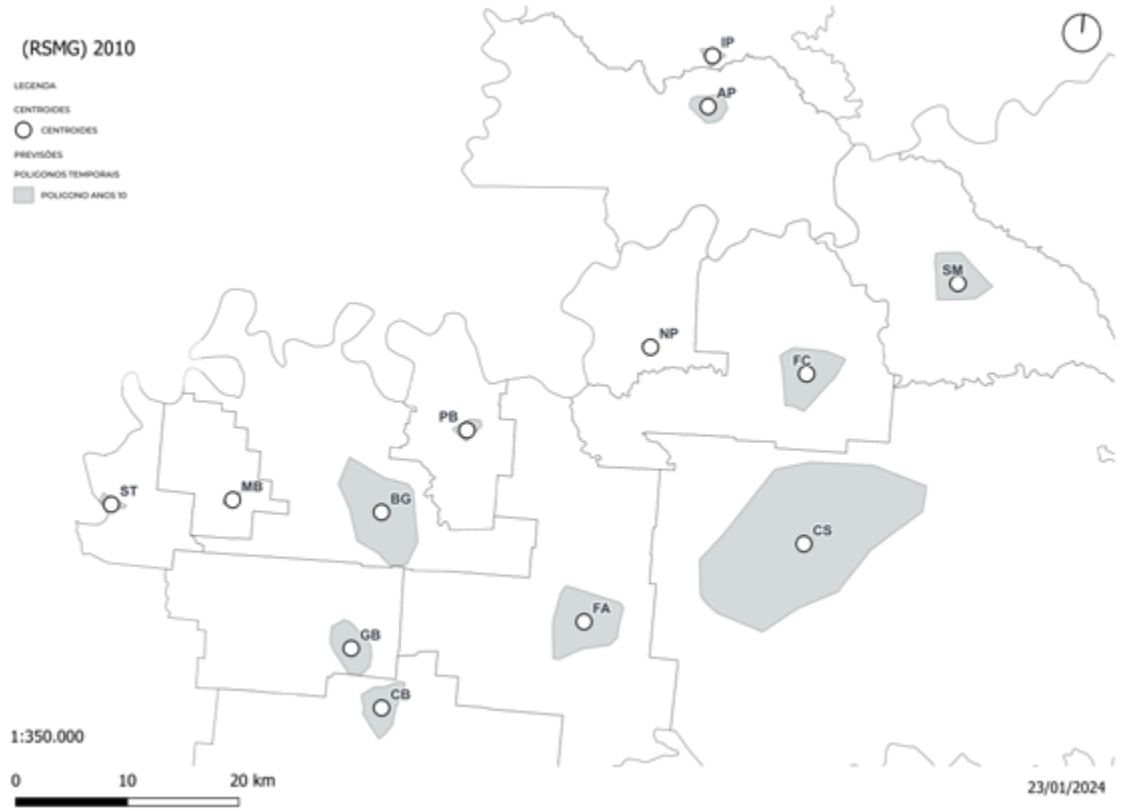

Figure 6: Growth geometry for the cities in the MRSG in the year of 2010.
Source: by Authors.

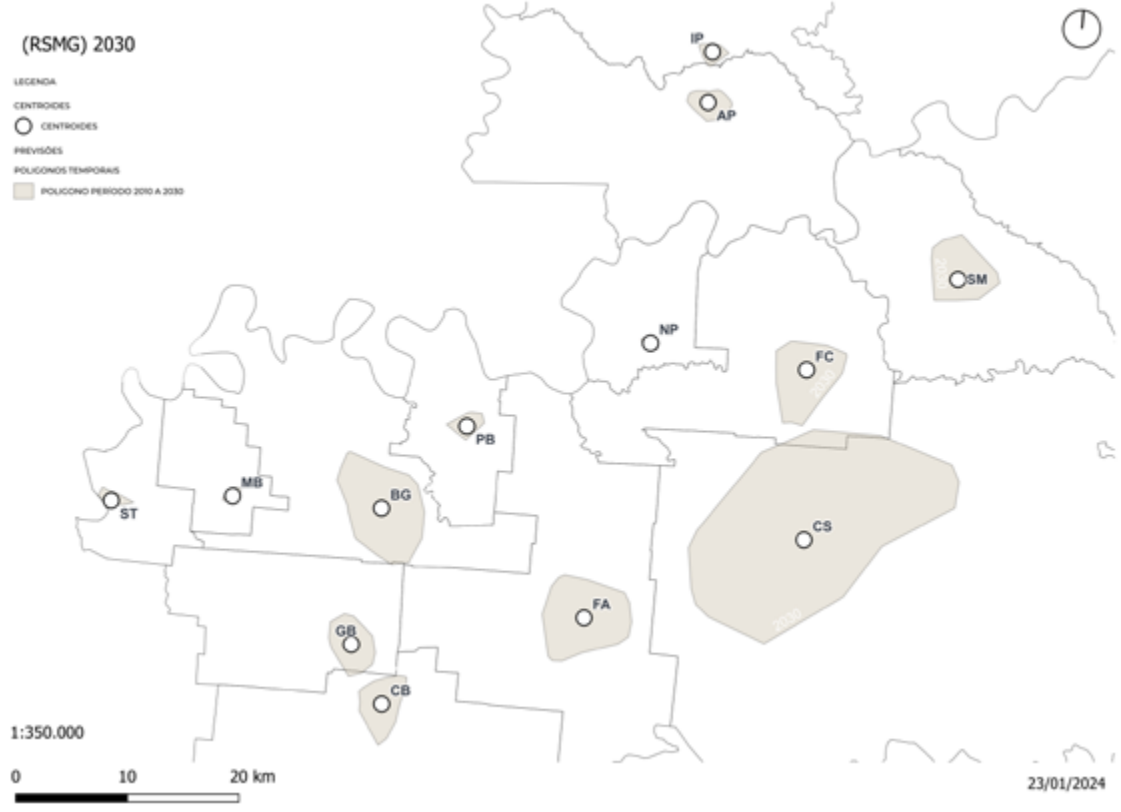

Figure 7: Growth projection geometry for the cities in the MRSG in the year of 2030.
Source: by Authors.

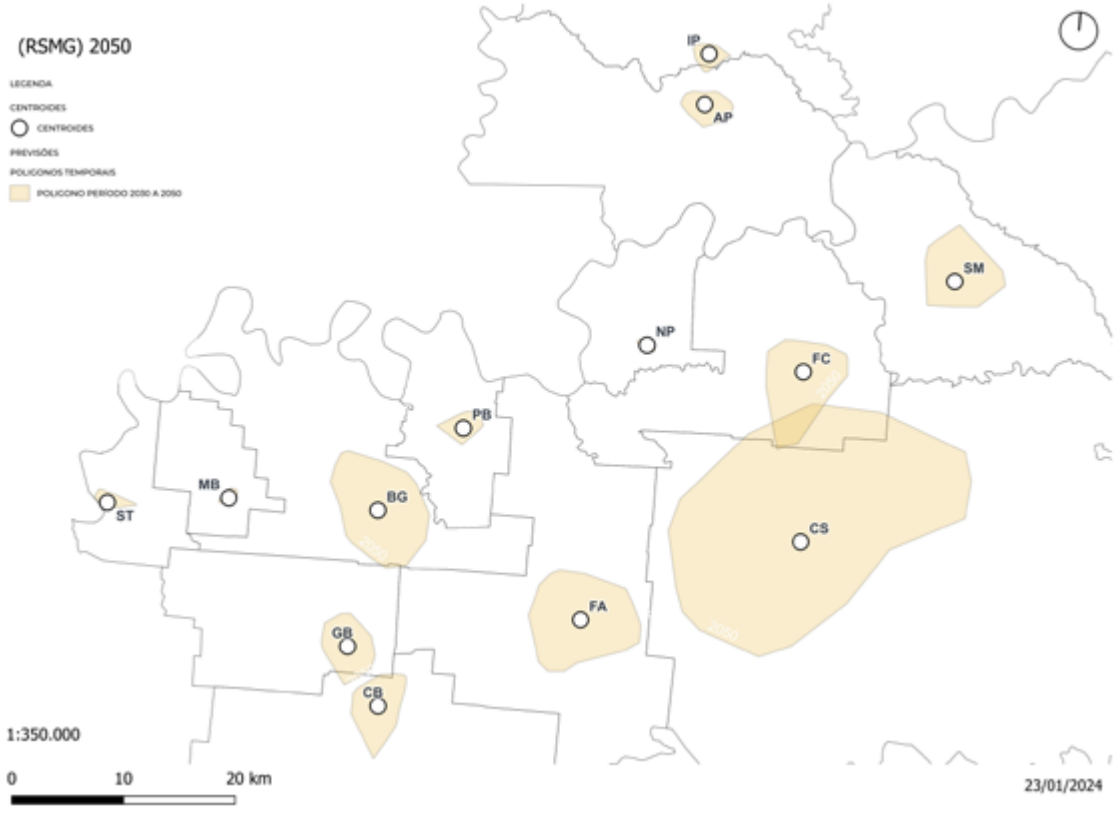

Figure 8: Growth projection geometry for the cities in the MRSG in the year of 2050.
Source: by Authors.

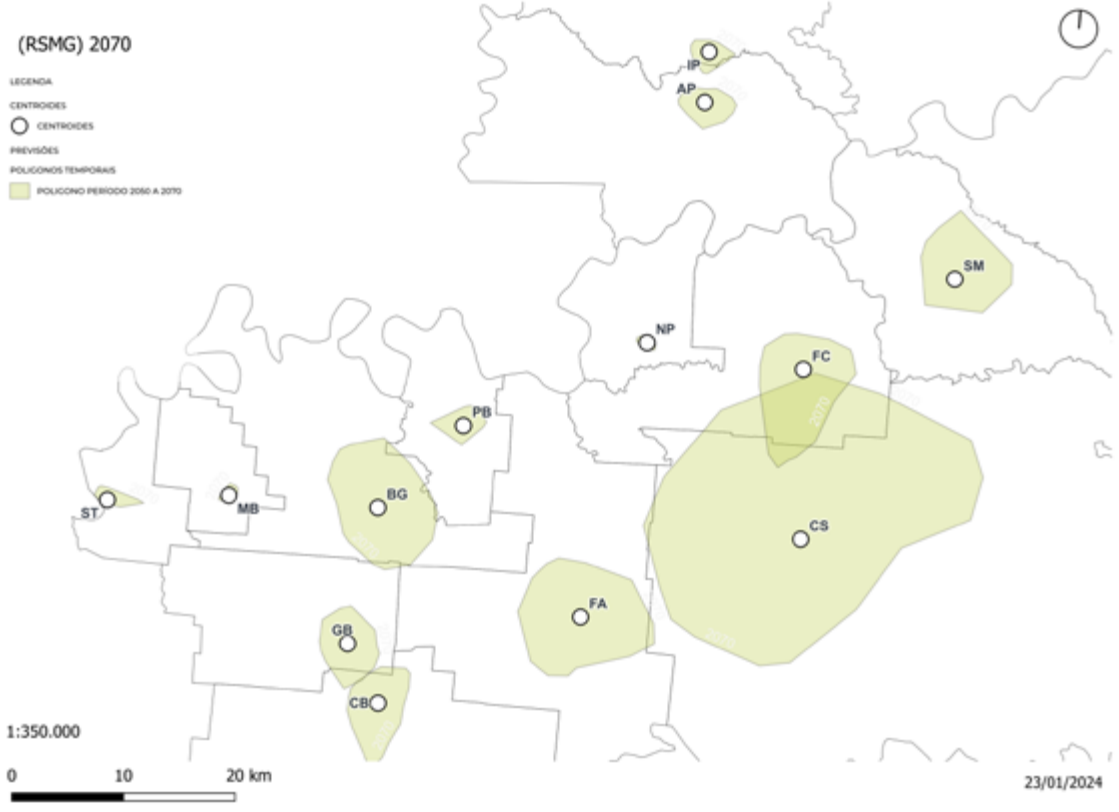

Figure 9: Growth projection geometry for the cities in the MRSG in the year of 2070.
Source: by Authors.

Through these individual representations, it was possible to closely examine each city and how its urban development is projected at different points in time. As a result, this study provides crucial information for understanding the future growth of cities in the Metropolitan Region of Serra Gaúcha, as illustrated in Image 10, using the example of the city of Bento Gonçalves.

Through these maps, it was possible to analyze the direction of growth in four distinct directions: north, south, east, and west. This approach enabled a comparison of the changes observed over the selected time intervals. Additionally, the analysis identified neighboring municipalities near the growth zones, highlighting their pull factors and corroborating previously calculated centrality data from other studies. The maps also provided forecasts of future conurbation regions, where expanding urban areas crossed municipal boundaries and extended into other areas, as exemplified in Image 11, which pertains to the cities of Caxias do Sul and Flores da Cunha.

The Image clearly demonstrates the pull effect that the city of Caxias do Sul exerts on the region. For this reason, it is possible to observe that the city of Flores da Cunha, located to the north of Caxias, tends to significantly expand its urban sprawl southward, towards the municipality of Caxias. This growth pattern is projected to form a conurbated region by the 2030s.

By consolidating the individual maps into a general map encompassing the entire region with the 14 municipalities studied, as shown in Image 12, it became possible to analyze the overall relationship between all the municipalities. This provided a more didactic and direct visualization of the centrality and global integration data discussed in this research, allowing for a better understanding of the region as a complete system.

Additionally, through the application of the methodological framework, it was possible to determine the growth projections for each of the cities in the MRSG (Metropolitan Region of Serra Gaúcha), thereby developing conclusions and hypotheses regarding how this growth occurs in each municipality. In the following Image, we can observe the marking of the centroids of each city, the municipal boundaries, and the growth patterns expressed in colored tones.

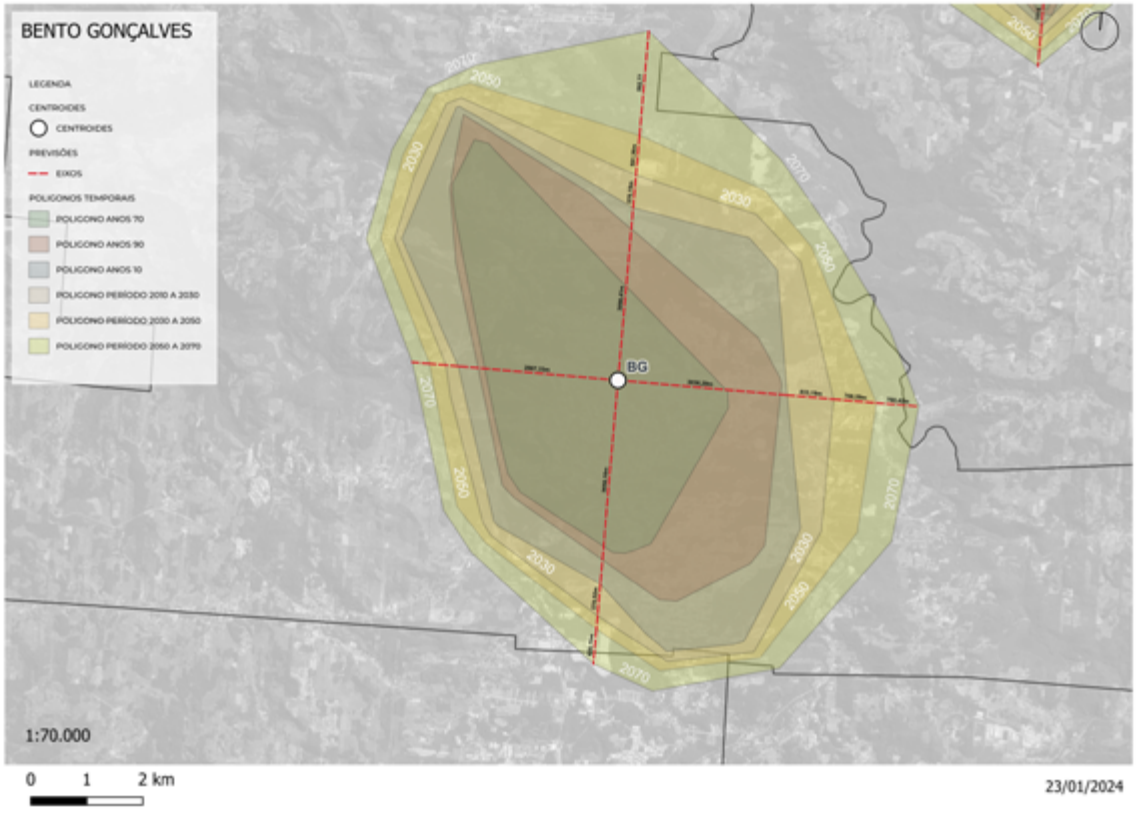

Figure 10: Growth prediction map for Bento Gonçalves.
Source: by Authors.

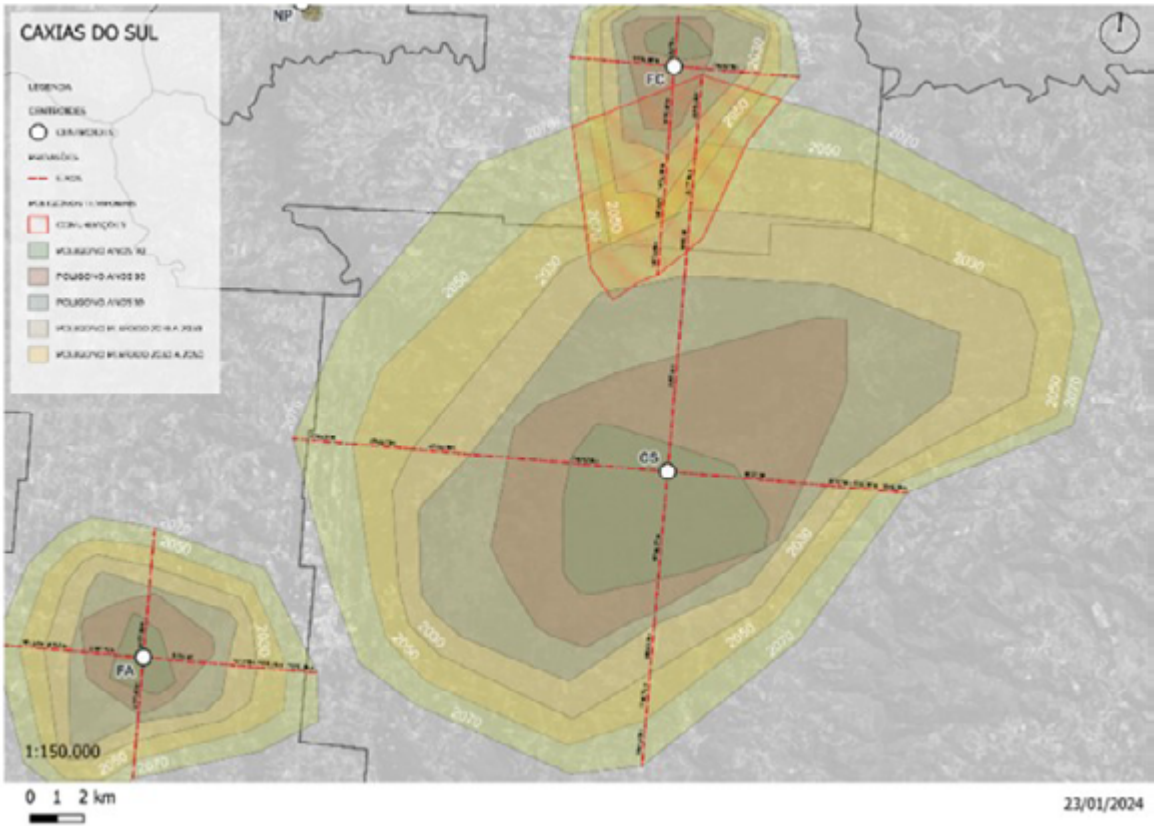

Figure 11: Conurbation prediction between Caxias do Sul e Flores da Cunha.
Source: by Authors.

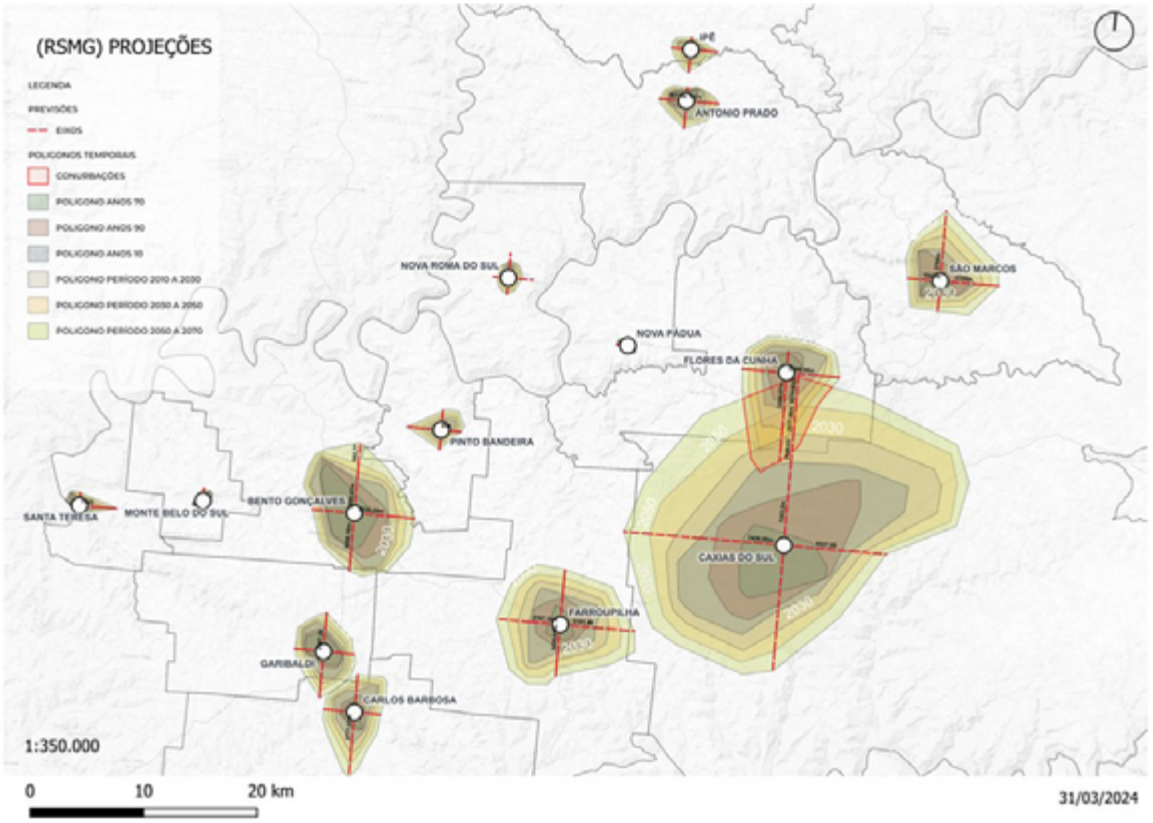

Figure 12: Growth prediction throughout the years.
Source: by Authors.

By analyzing the city of Caxias do Sul, it was determined that the primary direction of growth is towards the north, in the direction of the city of Flores da Cunha, while growth towards the west is directed toward the cities of Farroupilha and Bento Gonçalves. Growth to the east is more limited compared to the other directions, and the phenomenon of conurbation is projected to occur between Caxias do Sul and Flores da Cunha between 2030 and 2050. Based on the conclusions visually expressed in the map, hypotheses were developed to explain this growth behavior, such as the limitation of expansion towards the east. This growth barrier can be attributed to the more rugged topography in that direction, which makes urban expansion more difficult compared to flat areas, in addition to the presence of the Piaí River, which acts as a physical boundary.

The conurbation phenomenon observed between the municipalities of Caxias do Sul and Flores da Cunha occurs due to the mutual attraction between these two cities. This same attraction can also be observed between the cities of Caxias do Sul, Farroupilha, and Bento Gonçalves. Each of these cities tends to grow towards one another, demonstrating that the interaction between them is significant.

Regarding the city of Farroupilha, it was observed that its urban growth is relatively uniform. This reflects the city's high centrality in the region, as its central location connects different points, making it, along with Caxias do Sul and Bento Gonçalves, one of the largest urban areas, both currently and in future projections. However, despite its relatively uniform growth, the primary growth direction for Farroupilha is eastward, toward Caxias do Sul. Growth to the west is directed toward the BR453 highway, in the direction of Bento Gonçalves, while growth to the north is toward the city of Caravaggio (which is not part of the MRSG). Growth to the south, however, is limited.

The following hypotheses were developed based on the conclusions drawn: the city of Caxias do Sul has a direct influence on the growth of Farroupilha, along with the BR453 highway, which also contributes to the city's expansion. Growth to the south is limited by the more rugged topography.

From the map analysis, it was concluded that the main growth direction for Garibaldi is southward, towards the municipality of Carlos Barbosa. Due to this growth direction, conurbation is expected to occur between Garibaldi and Carlos Barbosa by 2070. Growth to the north of Garibaldi is directed toward Bento Gonçalves, while growth to the east and west is more limited.

For Carlos Barbosa, the primary growth direction is southward, with growth to the east and west being constrained. Conurbation between Carlos Barbosa and Garibaldi is expected by 2070, as the main southern growth follows the RST470 highway, which connects the region, while growth to the east is limited by the RS446 highway, and growth to the west is restricted by the rugged terrain, shaping a more elongated urban form.

Regarding the municipality of Bento Gonçalves, it was concluded that the most significant growth occurs to the north and east. Conversely, growth to the south and west is more limited. Growth to the north is driven by the presence of the Rio das Antas and the RS470 route. Southern growth is limited by the boundaries created by the RS444 highway, while growth to the west is constrained by the Arroio Pedrinho stream. Additionally, there is an apparent attraction factor towards the cities of Farroupilha and Caxias do Sul.

For the city of Ipê, the main growth occurs to the east and south, due to the proximity of the ERS 122 highway. Another relevant factor for this growth direction can be attributed to the attraction between the cities of Ipê and Antônio Prado. Therefore, it was concluded that the primary growth direction for the city is eastward, while growth to the north is more restricted.

In the city of Monte Belo do Sul, it was observed that the main growth occurs to the north, while growth to the east is directed toward Bento Gonçalves. On the other hand, growth to the south is limited.

In Pinto Bandeira, it was concluded that growth to the north, east, and south is similarly limited compared to growth to the west. This limitation is due to the more rugged topography in the north, east, and south, while the predominantly flat terrain to the west encourages urban expansion in that direction.

From the analysis of the city of Nova Pádua, it was concluded that the primary growth direction is westward, driven by the attraction of the Rio das Antas. Growth to the south and east is limited by rugged terrain, while growth to the north is encouraged by the more favorable, flat topography.

Regarding the city of São Marcos, the main growth directions are northward and eastward. Once again, there is a tendency for cities to expand toward flatter areas, a factor frequently observed in the cities analyzed. The flatter terrain to the north and east determines a growth trend in these directions, as seen on the map.

Analyzing the growth projection map for the city of Santa Tereza, it was observed that the main growth is eastward, towards Monte Belo do Sul, while growth to the west and

south is limited. From these analyses, two hypotheses were developed: there is an attraction factor between Santa Tereza and Monte Belo do Sul, and growth to the west and south is constrained by the Taquari River, which acts as a physical barrier, limiting the city's development.

6. FINAL CONSIDERATIONS

Based on the points raised in each of the municipalities, it was possible to identify certain patterns in the growth of urban forms in the cities of the Metropolitan Region of Serra Gaúcha. Initially, it is worth highlighting two crucial limiting factors that recur in several of the analyzed cities: the factor of topography and the presence of the ERS-122 highway. The rugged topography, characteristic of the altitude of the region as a whole, represents a significant challenge for urban expansion and becomes a limiting factor for growth, as it complicates organic expansion due to the complexity of construction – a point that ultimately concentrates urbanization in flatter and more accessible areas. The uneven terrain leads to increased costs for infrastructure development and building projects, making it less feasible to expand into hilly or mountainous zones. As a result, urban growth is funneled into more level, easily developable areas, which can lead to higher population densities and an uneven distribution of resources and services across the municipalities. Additionally, these geographical constraints can slow down development projects and increase the time required for expansion, further complicating the overall planning process.

On the other hand, another limiting factor playing a fundamental role in the analysis is the ERS-122 highway. As one of the main traffic routes in the region, this road – which passes through several of the mentioned cities – has become a growth-limiting factor. Although important for the connectivity of the cities, it has turned into a physical barrier to urban growth, as it forces expansion in directions that do not conflict with the road's extension. The highway, while essential for trade and mobility, divides urban areas and restricts how cities can grow on either side of it. This constraint creates an imbalance in the distribution of urban land and development opportunities, as some parts of the cities become more isolated or harder to access, leading to less investment and slower growth in those areas. Moreover, the need to build infrastructure around this highway adds another layer of complexity to urban planning efforts, as cities must navigate the physical limitations imposed by the road while also considering the environmental and socio-economic impacts of expanding into previously undeveloped regions.

Moreover, considering the results obtained, a relevant growth pattern was identified: the expansion of cities in the Serra Gaúcha towards the Rio das Antas. This commonality in the NE (Northeast) direction opens new hypotheses suggesting that the Rio das Antas could be an important axis of development for the Metropolitan Region of Serra Gaúcha in subsequent analyses. The natural resources and landscape around Rio das Antas may present new opportunities for economic activities, tourism, and residential expansion, thereby positioning the region as a future growth hub. The movement toward this area suggests a gradual shift in the cities' focal points, likely motivated by the search for less restricted land for expansion, as well as the potential for developing new economic centers away from the more congested central areas. This trend also indicates that future urban growth may need to integrate sustainable practices to ensure that development along the river corridor does not lead to environmental degradation or imbalances in local ecosystems.

If the direction of greatest growth is considered, the growth of the cities over the indicated time series could be evaluated, as well as future trends explored, acting in accordance with predictive planning. As an ongoing research, there are still other measures to be explored, but the methodology used thus far proves to be promising for further projections, considering physical constraints, for example. With these analyses, urban planners and policymakers could create more effective growth strategies that align with the natural landscape, addressing not only the limitations imposed by geography and infrastructure but also identifying new opportunities for sustainable growth. Regional planning could benefit from such measures when developing integrated regional public policies, such as planning new highways or identifying the location of a major attraction hub that extends beyond the borders of a single municipality. Through a collaborative and multi-municipal approach, governments could work together to create a cohesive development strategy that leverages the strengths of each city while mitigating the individual challenges they face. These coordinated efforts would be critical in creating a more balanced and prosperous future for the entire region.

REFERENCES

Bertaud, A. (2003). **Metropolitan Structures Around the World.** Marikina. accessed in August 18th, 2012, available at <http://alain-bertaud.com>

Colusso, I. (2015). **Forças regionais, formas urbanas e estrutura interna da cidade: um estudo de relações**, available at <http://www.ufrgs.br/propur/teses_dissertacoes/Izabele_Colusso.pdf>

Favaro J. M., Pumain D. (2011), Gibrat Revisited: An Urban Growth Model including Spatial Interaction and Innovation Cycles. **Geographical Analysis**, 43, pp 261-286.

Gersmehl, P. J. (1970). Spatial Interaction, **Journal of Geography**, 69:9, pp. 522-530.

Pumain (2008). The Socio-Spatial Dynamics of Systems of Cities and Innovation Processes: a Multi-Level Model, in: Albeverio S., Andrey D., Giordano P., Vancheri A. (ed), **The Dynamics of Complex Urban Systems. An Interdisciplinary Approach**, Heidelberg, Physica Verlag, pp 373-389.

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JLFR: conceptualization, data curation, formal analysis, investigation, methodology, programs, supervision and validation.

LC: conceptualization, data curation, formal analysis, investigation, methodology, programs, visualization and writing - original draft.

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SELECTION OF MATERIALS TO CREATE A MATERIAL LIBRARY IN CARUARU-PE/BRAZIL: CASE STUDY OF ORNAMENTAL STONES

SELEÇÃO DE MATERIAIS PARA CRIAÇÃO DE UMA BIBLIOTECA DE MATERIAIS EM CARUARU-PE/BRASIL: ESTUDO DE CASO DE PEDRAS ORNAMENTAIS

SELECCIÓN DE MATERIALES PARA CREAR UNA BIBLIOTECA DE MATERIALES EN CARUARU-PE/BRASIL: ESTUDIO DE CASO DE PIEDRAS ORNAMENTALES

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ABSTRACT
This study presents the first actions and steps towards creating a Material Library, which is related to the collection of ornamental, natural and synthetic stones. The work method was designed in three stages: 1. Analysis of communication problems perceived between the design and architecture areas in an ornamental stone transformation industry in the city of Caruaru - PE/Brazil; 2. Mapping of raw materials used by the company; 3. Systematization of data based on the mechanical properties and surface treatment of ornamental stones. As a result, a collection of more than 50 samples was catalogued, which will be used for the knowledge and daily use of the general population, for the learning of students, professionals and suppliers involved in the subject of material selection.

KEYWORDS
Environmental impacts; public policy; Generation profile; Cariri.

RESUMO
Este estudo apresenta as primeiras ações e etapas para a criação de uma Biblioteca de Materiais, relacionada à coleção de pedras ornamentais, naturais e sintéticas. O método de trabalho foi desenvolvido em três etapas: 1. Análise dos problemas de comunicação percebidos entre as áreas de design e arquitetura em uma indústria de transformação de pedras ornamentais na cidade de Caruaru - PE/Brasil; 2. Mapeamento das matérias-primas utilizadas pela empresa; 3. Sistematização dos dados com base nas propriedades mecânicas e no tratamento de superfície das pedras ornamentais. Como resultado, foi catalogada uma coleção de mais de 50 amostras, que serão utilizadas para o conhecimento e uso diário da população em geral, para o aprendizado de estudantes, profissionais e fornecedores envolvidos na seleção de materiais.

PALAVRAS-CHAVE
Design de Produto, Pedras Ornamentais, Seleção de Materiais, Biblioteca de Materiais

RESUMEN
Este estudio presenta las primeras acciones y pasos hacia la creación de una Biblioteca de Materiales, relacionada con la colección de piedras ornamentales, naturales y sintéticas. El método de trabajo fue diseñado en tres etapas: 1. Análisis de los problemas de comunicación percibidos entre las áreas de diseño y arquitectura en una industria de transformación de piedras ornamentales en la ciudad de Caruaru - PE/Brasil; 2. Mapeo de las materias primas utilizadas por la empresa; 3. Sistematización

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de datos basada en las propiedades mecánicas y el tratamiento superficial de las piedras ornamentales. Como resultado, se catalogó una colección de más de 50 muestras, que se utilizarán para el conocimiento y uso diario de la población en general, para el aprendizaje de estudiantes, profesionales y proveedores involucrados en la selección de materiales.

PALABRAS CLAVE

Diseño de Producto, Piedras Ornamentales, Selección de Materiales, Biblioteca de Materiales.

1. INTRODUCTION

Knowledge of the materials available on the market and their respective manufacturing processes is essential information for the development of any idea and use of any product. According to Karana (2009), it is the designer's role to select the most suitable materials for a project, from the range of options available today.

However, given the large amount of materials available for selection when using projects, this stage becomes challenging for the project's success. Currently, there are more than 160,000 materials available for design projects, and this demands a continuous research exercise from designers (XAVIER and SILVA, 2021).

At the same time that the lack of information on technical and sensory aspects delays the progress of the process, it also requires extra effort from professionals, who find themselves faced with a huge amount of available materials, and not always with the agility required to obtain information suitable for your project (DANTAS, 2016).

In rural region of Pernambuco there are a large number of micro and small companies that lack technological, administrative, marketing and design resources, among many others, which impact their competitive capacity in the local and national market.

Understanding the local reality, from a design point of view, in agreement with Baxter (2000), means recognizing that, most of the time, companies are unaware of the benefits of design actions and their impact on the development of competitive products, at best. production management and communication between the company and the consumer market.

This context, which could initially be seen as a problem, should be seen as an excellent opportunity for teachers and students from all over Brazil and, especially students of the Design Course at the Centro Acadêmico do Agreste/UFPE, to be able to share the knowledge generated and acquired in academia with society in general and, in particular, with the productive sector in the Agreste region of the state of Pernambuco.

The ornamental stone industries work on the frontier of the following areas: architecture, civil engineering and interior design. Marble and granite stores receive a large demand for orders from a wide range of professionals to meet the most varied and different audiences and desires. The pieces range from basic civil construction elements such as: door sills, kitchen sinks and bathroom washbasins; to furniture and decoration elements with high added value.

Ornamental stones, both natural and synthetic, are raw materials with unique characteristics, which require attention from extraction in the deposits to the final processing with the transformation of the blades into design objects.

The experience of one of the authors of this investigation, as an interior design analyst and responsible for communication between designers external to the company and the production line of the marble factory Atual Granitos Indústria e Comércio de Pedras LTDA - ME in the city of Caruaru - PE , brought to light the need to systematize knowledge, both commercially and academically, about the technical limitations of natural and synthetic ornamental stones, as well as their manufacturing processes.

The company's design sector believes that one of the main causes for rejecting budgets, based on original projects from designers outside the company, is related to the lack of information about the material selection area. The projects that come to the company, most of the time, do not take into account the technical limitations of the materials, and when executed without considering the specific limitations of each type of stone, they can generate rework and/or losses in the manufacturing process, increasing the costs of the final product.

Material selection is a complex step in the design process, since, in addition to the volume of existing materials, each design decision demands a series of objective and subjective variables. Objective variables involve knowledge about the physical and mechanical properties of materials, as well as their manufacturing processes. While subjective ones depend on the association of the material with a certain culture and territory.

One possible tool, among many others, that can be applied to facilitate communication between professionals involved in projects is the Material Library. Which is made up of a collection of samples, images, technical data and important information about materials and technologies related to the materials used to produce a specific artifact within the most diverse production scales.

This article presents the results of the classification and cataloging process of ornamental raw materials, both natural and synthetic, from the collection of the Atual Granitos Indústria e Comércio de Pedras LTDA –ME factory, leader in ornamental stone products in the rural region of Pernambuco. Which donated all the physical samples that make up, today, the first collection of the Material Library of the Design Course at CAA/UFPE.

This study is also part of the final work of the Design Course, linked to the Design Course of the Centro Acadêmico do Agreste (CAA), of the Federal University of Pernambuco (UFPE).

As an academic collection, this research seeks to provide technical and sensorial information on ornamental stones, both natural and synthetic, to provide students with easier and more direct access to data and material samples to support project teaching.

In this sense, the study is of great importance and its implementation is justified by the enormous possibility of guiding the specification of diverse and different materials to students. At the same time, it is justified by facilitating the understanding of its physical and sensorial aspects aimed at the ornamental stone market while seeking autonomy and security when choosing the material.

The Importance of Material Libraries for Commercial and Academic Spaces

Ashby and Johnson (2010) state that materials are the raw material of design, which dictate the opportunities and limits of design. Therefore, it is important that the designer exercises knowledge about the available materials, seeking a better allocation of these in a specific or everyday project.

Users' sensations and perceptions of materials are usually the direct result of the designer's planning. Therefore, the designer is responsible for different ergonomic factors, among many others, regarding the selection of materials. What makes Material Libraries relevant structures, where professionals from various areas can locate materials and manufacturing technologies to apply in their projects (PAGNAN, 2018; MENDONÇA et al., 2023).

In the educational field, Material Libraries contribute to professional training and practice, allowing students and young professionals to have access to information to expand their repertoire and knowledge (XAVIER and SILVA, 2021).

In this sense, for design students, access to the material with its specifications helps beyond the creative process; knowing the material in the aspects relevant to the project avoids errors and delays, since the selection of the appropriate material can be carried out in combination with the technology available in the local industry and the designer's demand.

Material libraries also benefit areas involving design practice, such as architecture, urban planning and engineering. This happens because they are resources that promote proficiency in the use of materials, deepening knowledge of new materials, new resources, technological development and the use of these materials.

Material libraries are also understood as a relevant space for different spaces, such as: academia, commerce and industry. In the absence of these spaces, display cases fulfill a similar role, that is, the satisfaction of knowing the material that is being acquired, or the material chosen for the project. However, the samples are not catalogued.

The systematization of technical characteristics is necessary to avoid inducing the choice for a commercial offer.

Research actions on the theme of material selection, in the Brazilian scenario of undergraduate Design, are on the agenda and were discussed during the 1st National Material Library Forum, held in the city of Florianópolis/SC during the 11th Project Sustainability Meeting - ENSUS, in 2023.

This event brought together several Brazilian researchers who work on this topic, with the aim of strengthening the area of materials selection in Design courses in the country. The large number of national initiatives clearly demonstrated the validity of this approach, which provides professionals in the field, sectors and social and economic segments linked to manufacturing and manufacturing, easy and quick access to essential and facilitating information for the development of new projects, products and services.

The Model and Prototype Laboratory Material Library - FabLab, at the University of Vale do Rio dos Sinos/RS, goes beyond a collection for consultation. It offers a learning environment that integrates materiality and processuality, allowing students to develop skills in product design, materials and prototyping techniques, explains Marques (2023).

At the Federal University of Santa Catarina (UFSC), the Material Library linked to the Virtuhab Research Group of the Architecture and Urban Planning department is divided into a physical Material Library (collection of physical samples itself), composed of diverse samples, end virtual Material Library (where traditional analyzes and links with sustainable issues can be found). And also, the Construteca (composed of models and prototypes demonstrating materials and related manufacturing techniques), which also includes the rapid prototyping process (FERROLI, 2023).

The Material Library of the Federal Institute of Santa Catarina (IFSC), Jaraguá do Sul Campus, aims to identify the possibilities of presenting materials that meet the demands of fashion and clothing designers, as users of virtual Material Libraries.

There is also Materialize, which is characterized as a material library network project that provides information from physical samples and in a virtual environment. Today, it operates and involves the University of São Paulo (USP), the Federal University of Rio Grande do Norte (UFRN) and the Federal University of Espírito Santo (UFES).

Dantas (2023) states that Materialize aims to develop projects and actions to build the digital physical collection. And, in particular, the sharing of information, cataloging of regional materials, and new materials resulting from academic research developed at the universities that are part of the network.

Materials are organized into groups, subgroups and types. All based on their properties and presented in an organized manner in several aspects: dimensions, weight, mechanical and wear resistance, ease of manufacturing, durability, material availability, cost, recycling feasibility, and degree of standardization.

All this so that the designer can refine the choice of material effectively and satisfactorily in the specific context of use. Considering, in addition to the material, project limiting factors such as: budgetary and technological restrictions, and labor availability in the region.

In addition to the technical variables related to the material, the aesthetic attributes, such as color and texture, are subjective variables associated with a certain culture and territory. For example, in the Agreste region of Pernambuco, Crema Marfil Marble is associated with "church marble". Pinta Verde Marble is called "cemetery tombstone marble". At the same time, Ultracompact Calacata is currently the stone that is "in fashion".

These ideals are influenced by social, economic and cultural factors. Therefore, materials require constant analysis, as the dynamics of these factors transform people's relationship with materials over time.

According to Mol (2023) there are different operational profiles for Material Libraries, such as: commercial, private or academic. The collection of the Ornamental Stones Material Library, of the Design Course of the Centro Acadêmico do Agreste (CAA) da Universidade Federal de Pernambuco (UFPE, will be of a commercial and academic nature. The commercial aspect will assist design, architecture and engineering professionals in deciding which material to use in the project. The academic aspect will provide students with practical contact with the materials and their most relevant characteristics for future projects. Initially, it will be presented and will operate with a physical collection. However, there is a strong intention that it will soon operate with a virtual collection, with curation and organization of collections.

2. METHODOLOGICAL PROCEDURES

The method proposed for this study was designed based on three phases. Phase 1. Analysis of communication problems between design and architecture during the execution of a real project. Phase 2. Mapping of the raw materials used by the company. Phase 3. Systematization of data and organization of the collection based on the mechanical and sensory properties of natural and synthetic ornamental stones.

In Phase 1, the lead time of a company service for manufacturing stone elements was monitored and recorded.

Lead time is a concept that emerged from the Toyota Production System and refers to a method for carrying out agile management and providing greater continuity to deliveries on production lines (SHINGO, 1981). This method is applicable to the supply chain as it measures the waiting time between ordering and delivery to the consumer. In this study, the project selected for this exercise was a residential kitchen.

A One of the authors of this research followed the aforementioned project from the moment the order was registered through the following stages: analysis of the original project; approval of the budget by the client; manufacturing of the stone elements; delivery and installation of the pieces according to the approved project.

The authors of this research believe that the design solutions that reach the company are carried out with little technical knowledge about the physical and sensory characteristics of the materials.

By observing the process flow, it was possible to perceive weak points in communication between the company's design sector and external architecture professionals.

In Phase 2, the catalogs of raw material suppliers were analyzed and interviews were carried out with the respective commercial representatives. Aiming to understand how the commercial sector presents its products to customers in retail.

A methodological step, which supported the mapping of the samples, was the participation of one of the authors in the Ultracompact Blades Workshop, in March 2024, with Ezequiel Netto, CEO of The Rock Brazil. This event expanded the repertoire of technical information related to suitable equipment for manufacturing structural elements with such materials. At this event, abrasive materials that can be used for finishing and others that can, on the other hand, damage the material during use were also presented.

In Phase 3, based on the data collected, a cross-referencing matrix was created to systematize the data and a collection was organized based on the mechanical and sensory properties of natural and synthetic ornamental stones.

3. RESULTS

3.1 Phase 1. Analysis of communication problems between design and architecture during real project execution.

The company Atual Granitos Indústria de Pedras e Comércio LTDA - ME focuses its operations on the area of cutting, finishing and assembling ornamental stones at the service of customers and commercial collaborators.

The company has a showcase collection with more than 180 different material samples. The company's design department is responsible for answering customers' questions about the materials (Figure 1).

Figure 1: Service area and display at the Atual Granitos Indústria e Comércio de Pedras LTDA - ME store.

Source: Authors.

In order to optimize the manufacturing process, the company provides guidance services to external designers and end customers during the execution of orders.

There are two possibilities for order entries into the company: those originating from an architecture office and those developed by the company's own design department.

In this company, the design department is responsible for several stages of the process, from receiving the project to the moment of on-site assembly. The (Figure 2) shows the stages of the production flow under the responsibility of the company's design department.

Based on the observation of the service flow, the process begins with the reception of the architectural project or the preparation of a proposal for the client.

The design sector is responsible for receiving and/or preparing projects and carrying out an initial analysis on the feasibility of the proposal.

At this stage, it is verified whether the characteristics of the materials selected in the original project are compatible with the company's technological restrictions, regarding cuts, assemblies, finishes, and details on accessories such as: sinks, wet gutter, socket tower, dispenser and tap.

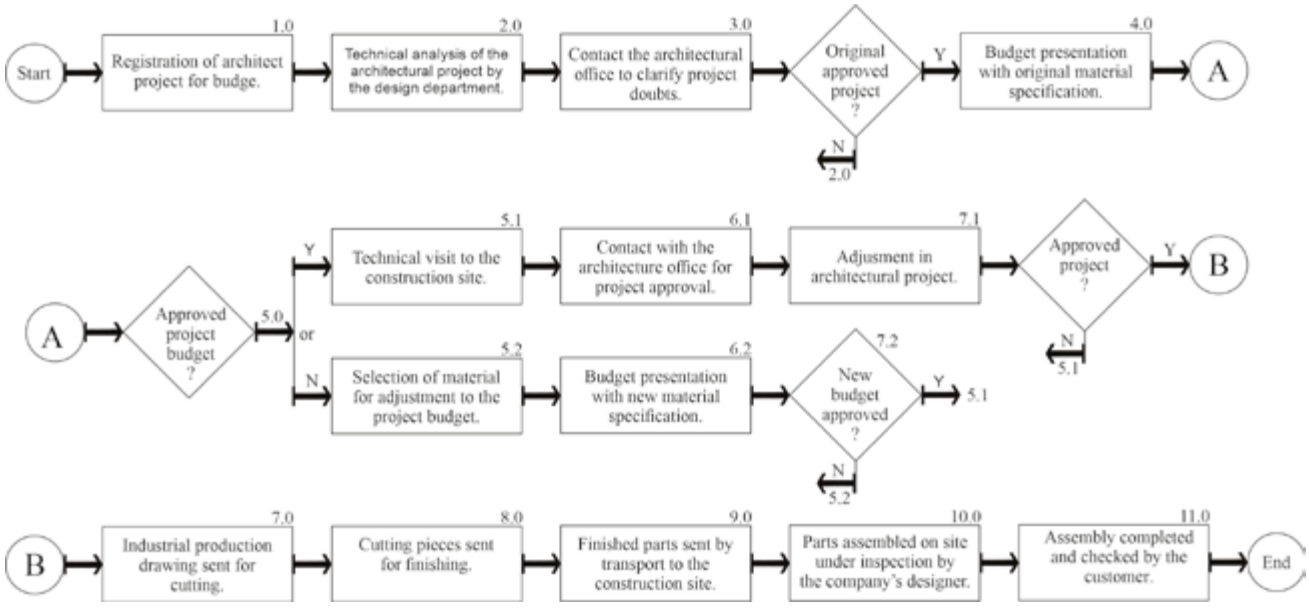

Figure 2: Flow of production steps at Atual Granitos Indústria e Comércio de Pedras LTDA – ME.

Source: Authors.

Another activity in the sector is to establish contact with the architect responsible for the project to clarify the proposed solutions. Technical adjustments are usually proposed with regard to materials and structural systems. Communication with the end customer takes place to approve the service budget.

After the client has approved the budget, technical visits are carried out to the assembly site to check for possible problems in the work that could make it difficult to install the parts. The purpose of the visits is to check the measurements to ensure the exact calculation of the quantity of stones.

The manufacturing drawings for stone elements must be reviewed twice to avoid wasting material. During manufacturing, the parts are separated by cutting plane in order to optimize the use of raw material sheets to reduce waste and material waste (Figures 3 and 4).

Figure 3 and 4: Production line and stock of ornamental stone sheets at Atual Granitos Indústria e Comércio de Pedras LTDA – ME.
Source: Authors.

In the finishing stage, the proposed joints, edge refinement, polishing and cutting adjustments are carried out. At this stage, the first quality control takes place by checking the project, with the aim of certifying the finishes and the agreement between the stones.

After the assembly and finishing tests, the second quality control deals with checking the final product to be sent to stock and, subsequently, logistics to the on-site assembly location. The parts must be organized in the transport vehicle for delivery in such a way that the parts remain anchored, without rocking, as they are made of fragile ceramic material.

During the assembly of the part on site, it is necessary to have a design professional from the company present at the construction site to monitor the assembly step by step. The project is only considered delivered when the client approves the installation.

In the case of the U-shaped kitchen, the object of study of this investigation, the original architectural project presented feasibility problems regarding the surface of the material and/or the dimensions of the industrial raw material, which burdened the first budget for the service (Figure 5). The budget was presented but was not approved, which required new technical adjustments.

The original architectural project had proposed Super Nano synthetic stone, a white material commercially recommended for environments with a high incidence of grease. However, there were problems in the dimensional specification of the industrial raw material, that is, the proposed dimensions were incompatible with the manufacturing process.

Figure 5: Original U-shaped kitchen design.
Source: Architectural project provided by the architect and client.

After technical guidance from the company's design department and the customer's haptic contact with the material samples, new solutions were perceived as possible for cost reduction, including replacing the material with another with lower added value.

The approved decision was to replace the Super Nano with the Black São Marcos Granite stone, a natural material, in black, semi-gloss, with a brushed finish and low cost (Figure 06).

Any change in material generates the need to change the structural technical specifications in the architectural project (Figure 07). And all this time invested increases the execution time of the order.

After the budget was approved, the next step was to measure the measurements on site, comparing the measurements suggested by the project with the reality of the physical space. Often, the mapping of stone installation problems is not noticed by the space designer.

In the case of the U-shaped kitchen, some of the problems noticed were: discrepancies in the type of covering applied to the wall and the height of the electrical boxes. In addition to adjustments to the architectural project that were suggested to avoid demolishing what had already been executed by the builder.

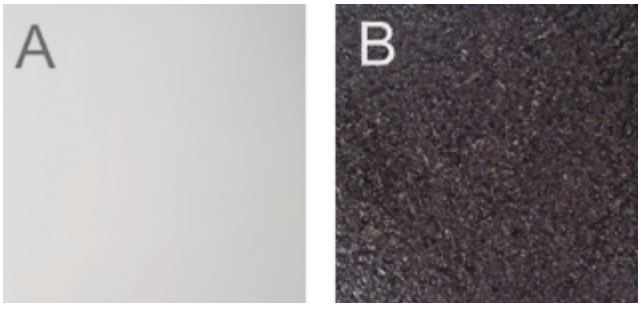

Figure 6: Differences between the material suggested by the architect (A) and the material selected for the project (B).
Source: Authors.

It is important to highlight that in a product design with ornamental stones, the detailing of the finishing in the cutting of the ornamental stone sheets and the type of cutting finish of the basins and accessories are fundamental criteria in the manufacturing process. Therefore, it is necessary to take into account the following aspects:

- Add 20mm to the length of the wet areas (where the sink and tap are installed) to embed in the wall, gluing with mortar to prevent future leaks.
- Add 40mm to the width of the side where the wet area meets the dry area (counter area) to increase the contact area of the stones.
- Add 2mm to the height of the side uprights, anticipating possible floor differences that help with water falling from the floor.
- The countertop level alignment is done by the upper section and the floor level adjustment is done by cutting the stone, adjusting according to the floor.

Figure 7: Modified U-shaped kitchen design.
Source: Authors.

Finally, in the case of the U kitchen, the lead time increased by 250% of the regular time, since the deadline to carry out a project developed internally is 60 days. It was noted that the time taken to complete the services was hampered by the lack of knowledge about the aesthetic and technical aspects and by changes in the specifications of the industrial raw material. matéria prima industrial. This problem created a chain reaction with delays in the execution of other professional services and a negative experience for the customer.

3.2 Phase 2. Mapping of the raw materials used by the company.

Raw Material

The company uses two types of industrial raw materials for architectural finishing: natural rocks and ornamental stones. Natural stones are classified as ornamental rocks, while artificial stones, composed basically of quartz, are produced in the form of sheets and classified as ornamental stones (ALENCAR, 2013).

ABNT standard 15.012:2003 (2013), apud Alencar, defines ornamental rock as natural rock material, subjected to different degrees or types of processing, used to perform an aesthetic function. These rocks are extracted from nature in deposits in the form of blocks. They are then sent to the processing industry, where they undergo the first process to transform sheets with the appropriate polishing for commercialization.

Marble and granite are noble materials used as ornamental rocks, due to their aesthetic effect, durability, mechanical resistance and flexibility in the design and dimensions of the piece. This nomenclature, from a geological point of view, generalizes its properties, but does not encompass aesthetic variations. Quartzites are not popular, but they are well accepted in the market. These ornamental rocks can be used on wet area countertops, floors, internal and external walls, as ornaments in buildings, as coverings for concrete stairs, etc. However, the physical characteristics of each rock determine the technical quality of the piece for the intended service (CRESPO, 1996).

Synthetic stones, also known as artificial agglomerated rocks, are industrial solutions for taking advantage of the high volume of solid waste generated by the extraction and primary or secondary processing of natural ornamental stones. Under express demand

from the consumer market, stones are better managed in production (AZEVEDO, 2006).

Resistance to rupture is one of the most important properties to be considered when selecting this material (ALENCAR, 2013). Each rock has a composition with a predominance of one or more minerals and, therefore, a reference on the Mohs Scale, created in 1812 by the German mineralogist Friedrich Mohs.

This scale classifies minerals according to their hardness, that is, their resistance to scratching (1 - 10). Talc (1) is the softest, and diamond (10) is the hardest of the natural minerals (Figure 8).

Talco	Gipsita	Calcita	Fluorita	Apatita	Feldspato	Quartzo	Topázio	Coríndor	Diamante
1	2	3	4	5	6	7	8	9	10

Figure 8: Mohs hardness scale.
Source: adapted from Alencar (2013).

Natural Stones

Marbles

The term marble is used commercially to designate all carbonate rocks capable of being polished and shined. These are rocks with low hardness (3 to 4 on the Mohs scale), porous and have a great variety of colors and textures. Figure 9). Exposing this material to grease and pigments can stain it. The use of abrasive substances such as bleach and aluminum degreaser can degrade the material, leaving it opaque. This material is recommended as a cladding for facades and pool edges, as it is lightweight and does not retain heat.

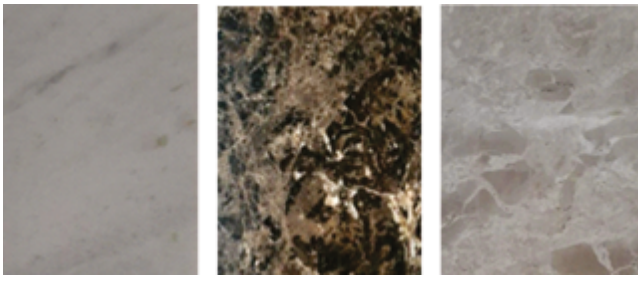

Figure 9: Samples of the diversity of colors and textures of Marbles.
Source: Authors.

Granites

Granites correspond to a broad group of silicate rocks, whose most common mineralogical association presents a composition of quartz, feldspars and micas. They are hard rocks (6 to 7 on the Mohs scale), resistant to rupture and have various colors and textures, although they are still susceptible to stains (Figure 10). The use of abrasives is not recommended, as they damage the surface. Light-colored granites are recommended for bathroom sinks, window and door frames, sills, copings, among other architectural finishes. Dark granites are recommended, in addition to those mentioned above, for kitchen countertops, as neutral soap and alcohol can be used to clean the stone.

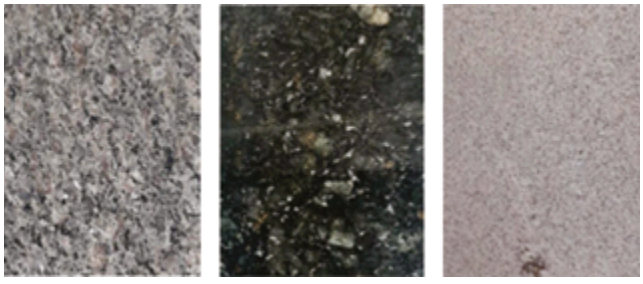

Figure 10: Samples of the diversity of colors and textures of Granites.
Source: Authors.

Quartzites

Quartzite is a metamorphic rock composed of more than 75% quartz and other elements such as muscovite, biotite, sericite, tourmaline and dumortierite. This configuration provides greater hardness (7 on the Mohs scale) and, consequently, a high extraction and processing cost when compared to marble and granite (BRANCO, 2022). The material's surface has colors and textures that attract consumers with unique architectural designs (Figure 11).

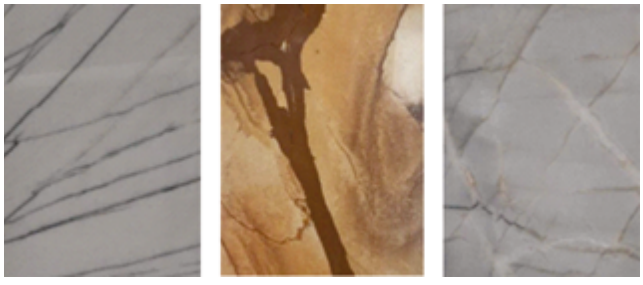

Figure 11: Samples of the diversity of colors and textures of Quartzites.
Source: Authors.

In its composition, quartz is recrystallized, which makes the rock more resistant to stains caused by grease or pigment. They are suitable for the same locations and applications as granite, and abrasive products do not damage the rock.

Synthetic Stones

Super Nano

This material has quartz, feldspar and silica in its composition. It is melted at 1600°C and reduced to nanoparticles. When cooled, a solid, homogeneous material is obtained and is extremely resistant to rupture (6 on the Mohs scale).

Figure 12: Super Nano.
Source: Authors.

The aesthetic characteristics of this material: brightness, white color and smooth texture, make it the most popular among architects and end consumers (Figure 12).

As it is easy to clean, Super Nano is associated with a hygienic material, and as it has great resistance to thermal expansion it can be applied internally and externally; however, it has a high manufacturing cost. It is manufactured in two dimensions: 1.60 x 2.80m and 1.60 x 3.00m, both with 18mm thickness and its hardness is 6 on the Mohs scale.

Quartz surface (Silestone)

Silestone is a material composed of 94% quartz and 6% resin and pigments. These components are pressed in 15 thousand tons, forming a blade with very varied colors and high performance. It has high resistance to stains, acids and high resistance to impact and scratching (7 on the Mohs scale) (Figure 13).

However, due to the resin, contact with heated products, utensils and objects is not recommended, as they can cause permanent damage. Exposure to direct and indirect sunlight (UV rays) is also not recommended, as it affects the color tone. They are manufactured in dimensions 3.06 x 1.44m and 3.25 x 1.59m, with thicknesses of 12mm, 20mm and 30mm and their hardness is 7 on the Mohs scale.

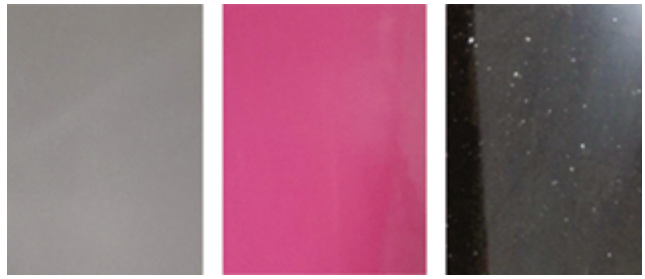

Figure 13: Samples of the diversity of colors and textures of Quartz Surfaces (Silestone).
Source: Authors.

Ultracompact

This material is composed of porcelain, glass and quartz particles, among other minerals. It is pressed at 25 thousand tons and then synthesized at 1800°C. It has high hardness (7 to 10 on the Mohs scale) and low thermal expansion. It is recommended for kitchens, floors or facades exposed to the elements (Figure 14). The manufacturing cost is high and can be found in sizes of 0.71 x 0.71m or 3.20 x 1.44m. It can also have a thickness of 8, 12, 20 or 30mm or even 2.60 x 1.00m with a thickness of 4mm.

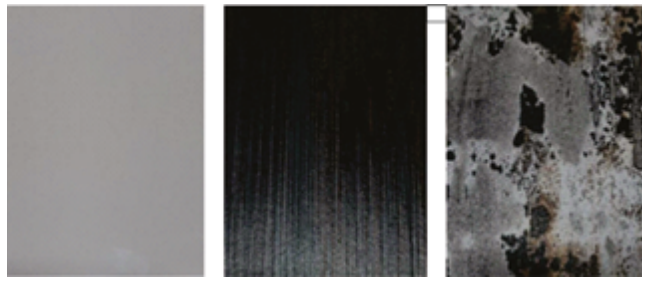

Figure 14: Samples of the diversity of colors and textures of the Ultracompacts.
Source: Authors.

3.3 Phase 3. Systematization of data and organization of the collection based on the mechanical and sensory properties of natural and synthetic ornamental stones.

In view of the data collected in Phase 2, a process of systematizing the information was proposed, based on the mechanical and aesthetic properties, as well as the costs of the ornamental stones available at the company (Table 01).

The origin of the stone is a recurring question among clients and designers and tends to add value to the project. The mineralogical composition and the mechanical property of hardness serve to specify the viable locations for the use of each material.

The dimensions of the industrial raw material are relevant to avoid amendments that are not well accepted by clients and architects.

The surface finish is the finish originating from the rock processing industries. These finishes add value and

modernity to the material, as they follow fashion trends.

Industrial finishing is carried out in the stone slab processing industry. The material cost ratio is directly proportional to the characteristics of both finishes. The selection of materials must consider both the aesthetic aspects and the production cost of the raw material.

Ornamental stones	Natural Marble	Synthetic Ultracompact
Origin	Brazil Italy	Spain
Predominant composition	Calcite Dolomite	Porcelain Class Quartz
Hardness scale (Mohs)	3 to 4	7 to 10
Dimensions	Variable	0.71 x 0.71 3.20 x 1.44 All by 8/12/20 or 30mm thick 2.60 x 1.00 with 4mm thick
Surface finish	Crude Polished Levigated Brushed Flamed	Polished Suede Volcano
Industrial finish	Simple/Rounded Half-rounded Beveled Half-rounded with freze Recess	Simple Beveled
Average cost (m^2)	R$ 470,00 to R$ 1.950,00	R$ 2.250,00 to R$ 9.300,00
Image		

Table 1: Cataloging model of samples from the company Atual Granitos. .
Source: Authors.

A physical collection with more than 50 samples of ornamental stones was proposed to serve as an orientation guide for students, designers and suppliers involved in the subject of material selection.

4. DISCUSSIONS

The opportunity to systematize the experience and publish its results will ensure developments in the classroom and in other environments that deal with local development policies. This academic experience highlights the importance of the University - Company relationship in the training of students in general, but especially for product design students.

By experiencing the reality of the local production park, students are encouraged to relate theory and design practice, understand how they should position themselves to act professionally, and put into practice the articulation between the areas of Design, Production, Communication and Market. The University-Company relationship, so necessary in this current context, depends greatly on the efforts of professors and students to raise awareness among all businesspeople about sharing this knowledge.

Monitoring the creation and realization of a kitchen project, a product requested and carried out by Atual Granitos Indústria e Comércio de Pedras LTDA - ME, made it possible to relate the main communication difficulties between the architectural project and the manufacturing restrictions of ornamental stones.

The lack of knowledge about technical limitations, raw material costs and the interpretation of architectural design in the cutting, finishing and assembly sectors of the marble factory were some of the main problems listed.

As indirect results of the study, after systematizing the data and organizing the collection of natural and synthetic stones based on their mechanical and sensory properties, there was a change in the store layout that had a positive impact on the time and quality of customer service.

At the same time, it is extremely important that the approach to the industrial environment raises the Design student's perspective, both regarding communication problems that may occur during the chain of events for the production of an artifact, and for their professional growth. To achieve this objective, it was necessary to become familiar with the raw materials, manufacturing processes and the consumer market, in addition to an in-depth understanding of the legislation in force for the sectors studied.

5. FINAL CONSIDERATIONS

The entire process of classifying and cataloging the company's ornamental stone collection met the two

motivations cited by Dantas (2016), that is, bringing students, designers and suppliers closer to the commercial and academic areas.

The commercial motivation focuses on the partnership between the companies that manufacture the materials and the designers, becoming a showcase for new materials and innovative processes.

Based on this study, the store layout was restructured by classifying the stones (natural and synthetic) and by the hardness scale of the collection. Another very positive change is that the flow of people and materials was optimized, which generated feelings of trust and security in customers when hiring the service.

There were also changes in the entrepreneur's acceptance of a calendar of events within the store. As a result, lectures on the selection of materials are currently being held.

Academic motivation, which promotes easy access for students to information and material samples to support project teaching, was met by the decision to donate samples from the collection to the Design Course at the Centro Acadêmico do Agreste - UFPE, accompanied by the installation of exhibition equipment.

This pedagogical articulation must be encouraged to allow both students and teachers to recognize the reality of companies and, from there, be able to contribute and seek innovative and sustainable solutions.

The next stage of the research will be the development of a virtual Material Library, making remote access possible for users in search of information on the aesthetic, technological and use aspects of ornamental stones.

REFERENCES

KARANA, Elvin. **Meaning of materials**. 2009, 272 f. Tese (Doutorado) – Technische Universiteit Delft. Delft/NLD, 2009.

XAVIER, Silvia Resende; SILVA, André Carvalho Mol. Comunicação de aspectos subjetivos e intangíveis dos materiais: análise de recursos para apresentação de informações em materiotecas virtuais, p. 678-691. In: **Anais do 10º Congresso Internacional de Design da Informação**. Curitiba/PR, Sociedade Brasileira de Design da Informação, 2021.

DANTAS, Denise; AUN BERTOLDI, Cristiane; TARALLI, Cibele Haddad. Materialize: Acervo de Materiais para a Economia Criativa. May 2016 Conference: I **Congresso Internacional - Workshop Design & Materiais**. São Paulo. V.1, 2016.

BAXTER. Mike. **Projeto de produto: guia prático para o design de novos produtos.** 2 ed. São Paulo. Blücher, 2000.

ASHBY, Michael; JOHNSON, Kara. **Materiais e design: arte e ciência da seleção de materiais no design de produto.** Rio de Janeiro/RJ. Elsevier, 2011.

NEVES, Hemili Luize; PAGNAN, Andreia Salvan. A Importância da Materioteca como Apoio ao Ensino de Design. **Colóquio Internacional de Design, 2017**. Edição 2017.

MENDONÇA, Rosângela Míriam. et al. Configuração de Materiotecas para Design e Sustentabilidade. **Revista Jatobá**, V. 5. Goiânia/GO, 2023.

MARQUES, André Canal; PALMITESSA, Giulio Frederico. Estruturas de uma materioteca dentro do FabLab acadêmico orientado pelo Design. **XI Encontro de Sustentabilidade em Projeto.** Florianópolis/SC, 2023.

FERROLI, Paulo Cesar Machado; LIBRELOTTO, Lisiane Ilha; SCREMIN, João Pedro. Materioteca e Ações Complementares para o Ensino, Pesquisa e Extensão. **XI Encontro de Sustentabilidade em Projeto.** Florianópolis/SC, 2023.

MARDULA, Emanuela, et al. Representação de amostras têxteis no contexto do acervo virtual de uma materioteca. **XI Encontro de Sustentabilidade em Projeto.** Florianópolis/SC, 2023.

DANTAS, Denise, et al. Ações interuniversitárias para a constituição de rede de materiotecas. **XI Encontro de Sustentabilidade em Projeto.** Florianópolis/SC, 2023.

MOL, André; XAVIER, Silvia Resende; STUTZ, Danielle Carvalho. **Materioteca do Instituto de Artes e Design:** Estratégias para Estruturação do Acervo e Planejamento para o uso Acadêmico e Multidisciplinar. Revista Técnico-Científica do Programa de Pós-Graduação em Design da UNIVILLE. Joinville/SC, 2023.

SHINGO, Shigeo. **Study of Toyota production system from industrial engineering viewpoint.** Tokyo. Japan Management Association, 1981.

ALENCAR, Carlos Rubens Araujo, INSTITUTO EUVALDO LODI, 1969- I59m **Manual de caracterização, aplicação, uso e manutenção das principais rochas comerciais no Espírito Santo: rochas ornamentais.** Instituto Euvaldo Lodi - Regional do Espírito Santo. Cachoeiro de Itapemirim/ES. IEL, 2013.

AZEVEDO, Alberto. *Manual de Rochas Ornamentais. Módulos I e II.* Relatório restrito da Pedreira Escola. Ruy Barbosa. Bahia, 2006.

CRESPO, Francisco. **Manual de Rochas Ornamentais.** Madrid: Ed. Entorno Gráfico, 1996.

BRANCO, Pércio de Moraes. **Características e Usos das Pedras Ornamentais.** Serviço Geológico do Brasil, 2022. Disponível em: https://www.sgb.gov.br/publique/SGB-Divulga/Canal-Escola/Caracteristicas-e-Usos-das-Pedras-Ornamentais-143.html. Acesso em 30 de setembro de 2022.

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THE HOUSING UNITS OF THE POSITIVE CLIMATE NEIGHBORHOOD PEDRA BRANCA SC/BR: A TYPOLOGICAL AND MORPHOLOGICAL ANALYSIS

AS UNIDADES HABITACIONAIS DO BAIRRO DE CLIMA POSITIVO PEDRA BRANCA SC/BR: UMA ANÁLISE TIPOLÓGICA E MORFOLÓGICA.

LAS UNIDADES HABITACIONALES DEL BARRIO DE CLIMA POSITIVO PEDRA BRANCA SC/BR: UN ANÁLISIS TIPOLÓGICO Y MORFOLÓGICO.

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ABSTRACT

In response to the global climate crisis, urgent measures are required to reduce greenhouse gas emissions in alignment with the goals of the Paris Agreement. As energy consumption accounts for 36% of total emissions, and buildings contribute significantly to both direct and indirect emissions, it is crucial to enhance the energy efficiency and self-sufficiency of buildings. This article conducts a case study to evaluate the formal structure, spatial layout, and sustainable strategies employed in residential units within the Pedra Branca neighborhood (Santa Catarina, Brazil), using the methodology developed by Brandão and Schneider. The findings indicate that the housing units predominantly consist of three bedrooms, along with two to four bathrooms. The analysis revealed partial integration between the kitchen and service areas, with full integration being less common. Corridor layouts were found to make the greatest contribution to sustainability and internal space quality. Although some configurations did not directly support cross-ventilation, there was a clear focus on environmental comfort and the use of passive design strategies. This study highlights the potential of such configurations to improve energy performance and contribute to the development of climate-positive neighborhoods.

KEYWORDS

Typology of the building; spatial arrangement; sustainable neighborhood; positive climate; Pedra Branca neighborhood.

RESUMO

A crise climática global exige ações imediatas para reduzir as emissões de gases de efeito estufa, em alinhamento com as metas do Acordo de Paris. Dado que o consumo de energia é responsável por 36% das emissões globais e os edifícios desempenham um papel significativo nessas emissões, é essencial promover a eficiência energética e a autossuficiência. Este artigo examina um bairro sustentável e positivo para o clima, com foco no estudo de caso das unidades habitacionais do bairro Pedra Branca, em Santa Catarina, Brasil, utilizando a metodologia de Brandão e Schneider. A análise abrangeu a estrutura formal, a distribuição espacial e as estratégias sustentáveis das habitações. Identificou-se que a maioria das unidades apresenta três quartos, dois a quatro banheiros, além de uma integração parcial entre cozinha e área de serviço,

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sendo rara a integração completa. As plantas de corredor foram apontadas como as mais adequadas para garantir a sustentabilidade e a qualidade do espaço interno. Embora outras configurações de planta não tenham favorecido diretamente a ventilação cruzada, constatou-se uma preocupação consistente com o conforto ambiental. Também foram aplicadas estratégias passivas para melhorar a eficiência energética e o bem-estar dos moradores, mesmo nas disposições menos otimizadas.

PALAVRAS-CHAVE
Tipologia do edifício; arranjo espacial; vizinhança sustentável; clima positivo; Bairro Pedra Branca.

RESUMEN
La crisis climática global exige acciones inmediatas para reducir las emisiones de gases de efecto invernadero, en alineación con las metas del Acuerdo de París. Dado que el consumo de energía es responsable del 36% de las emisiones globales y los edificios desempeñan un papel significativo en estas emisiones, es esencial promover la eficiencia energética y la autosuficiencia. Este artículo examina un barrio sostenible y positivo para el clima, con enfoque en el estudio de caso de las unidades habitacionales del barrio Pedra Branca, en Santa Catarina, Brasil, utilizando la metodología de Brandão y Schneider. El análisis abarcó la estructura formal, la distribución espacial y las estrategias sostenibles de las viviendas. Se identificó que la mayoría de las unidades presentan tres dormitorios, dos a cuatro baños, además de una integración parcial entre la cocina y el área de servicio, siendo rara la integración completa. Las plantas de corredor fueron señaladas como las más adecuadas para garantizar la sostenibilidad y la calidad del espacio interior. Aunque otras configuraciones de planta no favorecieron directamente la ventilación cruzada, se constató una preocupación constante por el confort ambiental. También se aplicaron estrategias pasivas para mejorar la eficiencia energética y el bienestar de los residentes, incluso en las disposiciones menos optimizadas.

PALABRAS CLAVE
Tipología del edificio; disposición espacial; vecindario sostenible; clima positivo; Barrio Pedra Branca.

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1. INTRODUCTON

The pursuit of sustainability and environmental quality is a pressing concern today. In this context, the United Nations (UN), through the Sustainable Development Goals (SDGs) outlined in the Development Agendas, provides guidelines aimed at promoting sustainable urban management. These guidelines advocate for strategic urban planning and the design of built environments that can significantly reduce the ecological footprint and minimize environmental impacts across various settings.

In line with these principles, several development programs have emerged, including the C40 Cities initiative, which aims to create more sustainable urban environments. One of its key efforts is the Climate Positive Development Program (CPDP), which provides financial support for the creation of neighborhoods that implement climate-positive measures. Neighborhoods participating in the CPDP must adhere to sustainable urban models from environmental, economic, and social perspectives, while also incorporating the principles of New Urbanism, which gained prominence in the 1980s [1]. This approach ensures the effectiveness of urban revitalization projects [2].

The CPDP neighborhoods focus on meeting specific sustainability criteria, including: (a) fostering user integration with the environment; (b) improving quality of life; (c) enhancing connectivity; (d) facilitating pedestrian and general user mobility; (e) promoting mixed-use development; (f) providing well-structured urban blocks; (g) ensuring diverse housing options; (h) prioritizing low-emission transportation (e.g., bicycles, public transit); and (i) managing resources such as energy, water, and waste efficiently [3].

Some buildings within these neighborhoods have been submitted for LEED (Leadership in Energy and Environmental Design) certification to either guide or verify that optimal sustainability levels have been met. This is achieved through the use of passive design strategies, innovative technologies, and sustainable materials to promote efficient and environmentally responsible construction practices [4].

For this study, the Pedra Branca neighborhood (Palhoça, Santa Catarina, Brazil), which is part of the CPDP, was selected due to its status as the first Brazilian example of this program and its international recognition. The study aims to analyze the predominant living patterns in the neighborhood, the architectural structure of multifamily buildings, and the typological and morphological trends, drawing on the research of Brandão (2008) and Schneider (1998).

2. METHODOLOGICAL PROCEDURES

This article uses the case study methodology, which consists of an empirical investigation of "a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are not clearly defined" [5, p.32]. For Yin (2005), a case study investigation:

- faces a technically unique situation where there will be many more variables of interest than data points, and as a result,
- based on multiple sources of evidence, with data needing to converge in a triangle shape, and, like, another result,
- it benefits from the previous development of theoretical propositions to conduct data collection and analysis [5, p. 32-33].

In line with the points mentioned above, the study was developed by a set of methods of different processes, in which the case study was used as a methodological basis, based on Brandão (2008), to identify the frequency that the different spatial arrangements are adopted in the elaboration of the projects. In this way, the morphological aspects of the floor plans are classified, according to the book Atlas de Plans, by Schneider (1998), in which the residential buildings were organized into eight conceptions of standard plans.

The process began with the selection of the Pedra Branca neighborhood, on which bibliographic, documentary and architectural surveys were carried out. Subsequently, the residential buildings Pátio da Pedra, Pátio Civitas and Pátio das Flores were selected for systematic observations, for which data from the respective housing units were collected.

The systematic analysis was composed of the following steps: a) Organization of the data collected; b) Description of the concepts, and historical approach of the neighborhood under study; c) Analysis of the projects of the apartment models in the study.

The data collected for the projects of the 13 apartment models were carried out through the sales websites and the construction company responsible for the construction of the planned neighborhood, as it was not possible to acquire the official documents of the designers.

The systematic studies were carried out through intensive observation of the project and the design guidelines of the PDCP with a focus on the critical analysis of the project, verifying the morphology of the plans, the

spatial configuration, passive strategies, the distribution of openings, the materials and technologies focused on sustainability.

2.1 Study Area Analysis

Pedra Branca is in the municipality of Palhoça, Santa Catarina State, Brazil (Figure 01). It began in 1997, from the partnership between the owners of the rural land and the University of Southern Santa Catarina (UNISUL). The proposal modified the socio-spatial dynamics and urban development of the region.

Figure 01: Location map of the municipality of Palhoça-Santa Catarina, Brazil.
Source: Author.

With an area of approximately 250 hectares (2,500,000 m^2), the neighborhood received innovative solutions, linked to sustainable principles, and was conceived from the integration of mixed use with an adequate urban density. The public open spaces were designed to make the neighborhood "walkable", with comfortable distances for travel (approximately 10 minutes walked or 800 meters), to prioritize pedestrians and cyclists [6], as well as the use of more sustainable transport.

In 2,300 lots, single-family and multi-family units were distributed, most of which were designed for mixed use, in which shops and services were located on the ground floor and houses on the other floors.

The design of the neighborhood was based on New Urbanism and on the book "Place Making: Developing Town Centers, Main Streets, and Urban Villages" [9]. In this sense, the concern of the proposal became the creation of compact, dense, complete and connected centralities [7,8].

The urban proposal was helped by eleven national and international architecture and urbanism studios, such as architects Jaime Lerner and Jan Gehl. They used the Charret Design methodology and had the collaboration of Federal University of Santa Catarina (UFSC) laboratory in the development of studies and evaluations of the site [8].

The project's guiding guidelines considered items such as: attractiveness, pedestrian priority, mixed use, diversity of residents, sense of community, balanced density, harmony between nature and urban amenities, connectivity and lifestyle [6,8].

In the implementation of the neighborhood the most important part of the project is the central nucleus, built in the second phase of the project, which corresponds to the Central Square, the Passeio Pedra Branca (shared street) and the first blocks with residential and commercial condominiums. In this region the study buildings were identified and selected (Figure 02).

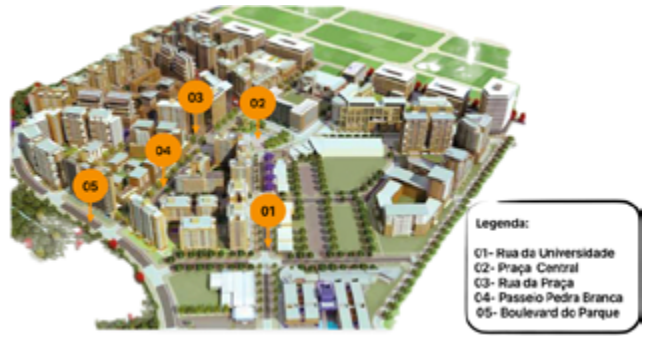

Figure 02: Implementation of the Pedra Branca neighborhood, Palhoça-SC/Br.
Source: Author.

Figure 02 shows the existence of well-defined commercial areas, leisure areas, wooded areas, and vertical buildings, with a predominance of buildings with more than three floors. Public sidewalks provide good circulation for pedestrians and cyclists. The streets were organized to allow the slow circulation of local vehicles.

The selected buildings are in the central area of the neighborhood and have commercial areas on the ground floor and, on the other floors residential or commercial use. These stand out for the constructive quality of the buildings and the concern with solar orientation, natural lighting in most environments, natural cross ventilation within the units, as well as the use of some techniques and technologies with low environmental impact such as the use of photovoltaic panels, solar heating, rainwater harvesting, economical public lighting, differentiation of typologies and flexibility in apartment plans [10].

As mentioned, the premises of sustainability achieved by the application of LEED certification punctuate actions in terms of energy, water, environmental comfort, materials, technologies and other resources. Aiming at these aspects, the buildings prioritized passive strategies, the use of technology, the awareness of users and

residents, and the effective management of water and energy resources.

The research carried out on the real estate sales sites in the region showed that the values referring to the residential units in the neighborhood varied between 190,000.00 and 1,500,000.00 reais (equivalent to 37,540.50 and 296,372.40 dollars). It was possible to conclude that the predominant social classes in the neighborhood are the upper-middle classes and the upper class [6].

It was also noted that after the implementation of the neighborhood project, in addition to the significant increase in the population with about 9,500 inhabitants/ users since 2014, evidencing the demand during its development, there was also a significant improvement in the quality of life of the surrounding neighborhood, which until then was configured as one of the most marginalized. Such improvement was favored by paved streets, expansion of access roads, greater flow of people from the center of Florianopolis to the center of the neighborhood, improvement of the region's infrastructure, consequently the commercial sector of the neighborhood became busier and more prosperous.

2.2 Typology in Architecture: Concept

When it comes to the concept, the typological approach in architecture began in the 60s disseminated by Aldo Rossi and Giulio Carlo Argan, and since then it has continued to be the object of study in academia [11,12,13].

The term typology is used to designate the basic form of buildings, the internal structure of the form, the infinite possibilities of formal variations, the idea or reference that serves as a rule for the final model [14]. It is the area of knowledge that study types, through the analysis of ordering, systematization of knowledge and architectural classification of elements. The typological classification is essential to define the needs of the architectural project [12, 15].

To design means to create typologies, to satisfy the socio-cultural changes, the functional and technological problems of each project. In the real estate sector, the patterns of apartments present typologies with great similarities in the design and partition of intimate, social and service areas, differing by the number of rooms [15, 16].

Focusing on the plan of the apartment, this study is based on the typology that admits variations in levels of detail, the simplest: number of bedrooms, bathrooms; and more complex: shape of the apartment, internal circulation and other distribution and interconnection criteria. For this analysis, the focus of authors such as Schneider [19] and Brandão [17,18] was considered, with adaptations by the authors.

Schneider [19], presented eight conceptions focusing on the floor plan organization of the residential buildings: 1) corridor type; 2) type box inserted or with central core; 3) with central living room; 4) with separation of functional areas; 5) organic; 6) fluid; 7) circuit; 8) Flexible.

In his research Brandão [17,18] presented the study of the typologies of the Brazilian real estate market using about three thousand floor plans in different cities. He established a classification considering the number of rooms, suites and bathrooms, establishing a numerical convention to identify the typologies. This classification was the basis of this study and used the number of bathrooms, with the toilet being considered as "0.5" (half a bathroom). Next he considered the number of rooms, and how many of these are suites, and the kitchen and service dependency. For example, the 1.5/3.1.1 configuration can be read as being a bathroom apartment plus a toilet, with three bedrooms, one suite and a service dependence. Thus, the term typology is used to identify the basic variants that make up the apartments, considering the combination of the number of bedrooms, suites and bathrooms and the degree of integration between kitchen and service area.

For the following analyses, the description of the compartments will be read according to the nomenclatures (Figure 3):

Figure 03: Coding for nomenclatures.
Source: Author.

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3. APPLICATIONS AND/OR RESULTS

3.1 Identification of Typologies

For the construction of the database for this study information was collected from three residential developments in the Pedra Branca neighborhood, with 13 different housing units, and floor plans with footage between 68m² and 220m².

a) Pátio da Pedra Development:

Located in the center of the neighborhood, it was designed by the Marchetti + Bonetti office and consists of four towers of buildings (Dolomites, Icaraí, Carrara and Travertine) (Figure 04). It has a total of 217 apartments, 24 of which are garden apartments, and eight shops distributed in a built area of about 42 thousand m². The apartments have two to four bedrooms, the floor plans provide the flexibility of integration with the balconies, their infrastructure provides the use of bicycles, renewable energy, water reuse, efficiency technologies and other sustainable resources.

Figure 04: Pátio das Pedras Condominium.
Source: APrepared and adapted by the authors [8].

b) Civitas Patio Development:

With a built area of 19,459m², it was designed by the ARK7 Architects office and has two towers of 14 floors, 11 floors, ground floor and two basements, with apartments ranging between 68 m² and 140m². The arrangement of the towers on the land is parallel, forming a central courtyard, where there are leisure spaces, adult and children's swimming pools and a playground (Figure 0). The commercial areas on the ground floor have direct access to public roads, contributing to the dynamics of the neighborhood. The first floor is different from the others and consists of a terrace for private use, while the others have openings to the outside and the organization of the floor plan allows for rearrangements. As for the sustainability issue, the project is equipped with technology to control the automation of the common area, avoiding excessive expenses, reuses rainwater to supply the toilets and irrigation of the garden, has a photovoltaic panel and contributes to the awareness of the inhabitants for selective waste separation.

Figure 05: Pátio Civitas Condominium.
Source: Prepared and adapted by the authors [8].

c) Pátio das Flores Development:

Composed of five towers with apartments and duplexes with two to four bedrooms, it includes mixed use with shops and offices (Figure 06). It was designed by Ruschel and Texeira Netto Architects with a central leisure patio, providing privacy for users. The apartments have between 80 m² and 183 m², with bedrooms, living room, kitchen, bathroom, service area and garage spaces. The project also encourages the selective separation of waste, uses renewable energy sources, automation and reuse of rainwater.

Figure 06: Pátio das Flores Condominium.
Source: Prepared and adapted by the authors [8].

3.2 Typological method of plans

The term typology is used in this work in a specific way to identify the basic variants that make up the apartments, considering the combination of the number of bedrooms, the number of suites and bathrooms and the degree of integration between kitchen and service area.

Evaluating the behavior of the variables, it was possible to observe that the number of bathrooms and the number of bedrooms is the items that best explain the size and size of the apartment (Chart 1).

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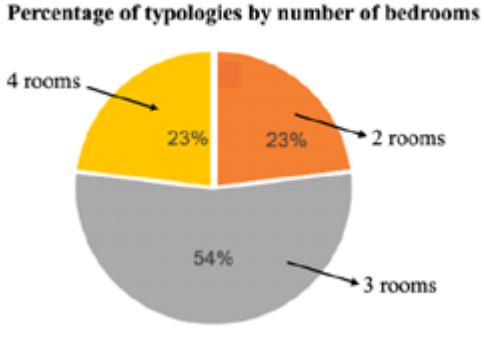
Typology by enterprise					
Ventures	**Bathroom**	**Washbasin**	**Rooms**	**Integration to Service and Kitchen**	**Typological configuration**
a) Pátio das Pedras					
Dolomitas	2	0	2	2	2.0/212
Icaraí	3	.5	3	2	3.5/332
Travertino 01	2	0	3	2	2.0/412
Travertino 02	2	.5	4	2	2.5/412
b) Pátio Civitas					
Civita (68m2)	2	0	2	1	2.0/211
Civita (101m2)	3	0	3	1	3.0/321
Civita (140m2)	4	0	3	1	4.0/331
c) Pátio das Flores					
Gardenha 01	3	.5	3	1	3.5/331
Gardenha 02	3	0	2	1	3.0/421
Gardenha Duplex	3	.5	3	1	3.5/331
Orquídea	2	.5	2	1	2.5/221
Bromélia	2	0	1	1	2.0/311

Chart 1: Number of rooms per development and configuration of the typology of the apartments of each development by Brandão's analysis [17,18] and adaptation by the authors.
Source: Authors.

The general characteristics found in the analyzed plans were:

- More than 54% of plans have three quarters, and planss with two or four represent 23% each;
- 100% of the floor plans have at least one suite;
- 30.78% of the apartments have a partially integrated kitchen and service area, and 61.53% of the apartments have a fully integrated kitchen and service area, and 7.69% have both areas completely isolated;
- 100% of the units do not have service dependencies;
- 38.46% of the apartments have areas smaller than 100m², 30.76% have between 100 m² and 150m², 23.07% have between 150 m² and 200 m², and 7.69% have areas above 200 m².

In all the projects analyzed, all housing units had a single suite, even in the smaller apartments. The integration between kitchen and service area in the Pátio Civitas and Pátio das Flores developments, have a total integration in 100% of the apartments, while in Pátio das Pedras 100% of the apartments have a partial integration with some relationship of integration between them.



Graph 1: Percentage of typologies by number of bedrooms.
Source: Elaboration by the author.

Graph 01 above shows the predominant existence of typologies with 3 bedrooms, and those with 2 and 4 bedrooms are presented with 23% each in a tie. This factor is due to the demand in the Brazilian market for apartments with a larger number of bedrooms in search of

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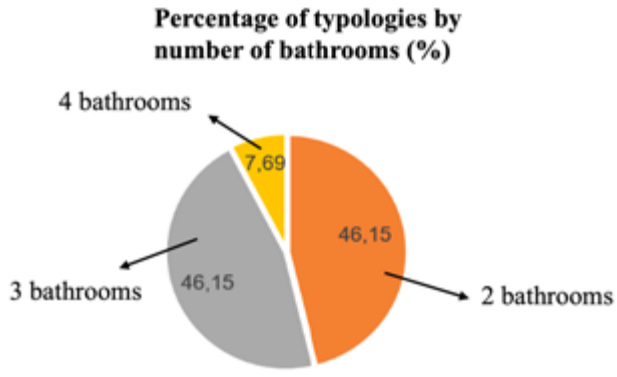
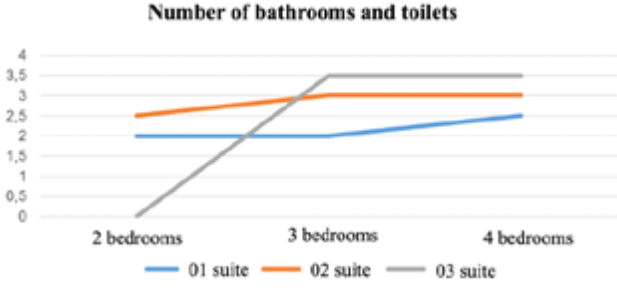
greater comfort due to the average number of inhabitants per family predominates in the country.



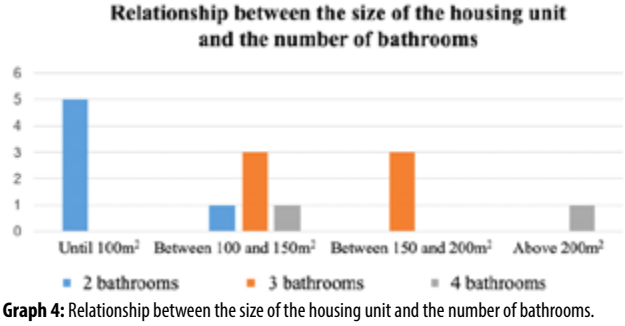
Graph 2: Percentage of typologies by number of bathrooms.
Source: Elaboration by the author.

When analyzing the number of bathrooms in the housing units, it can be observed in Graph 02 that most of the units evaluated have between 2 and 3 bathrooms, and these environments are also part of the suites, or even many times, the social bathroom also serves the bedroom, which was verified in most of the cases presented.



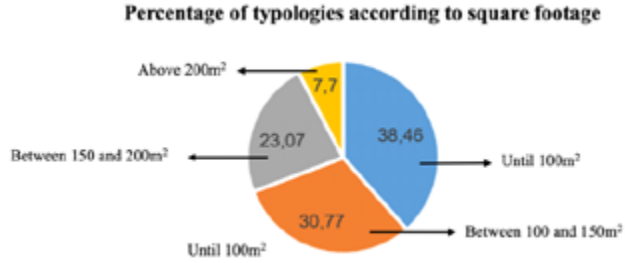
Graph 3: Number of bathrooms and toilets.
Source: Elaboration by the author.

Graph 03 in line presents the study of the typologies and it is noted the compensation made by the functionality of the project in balancing the relationship between the number of bedrooms, bathrooms and toilets, where in most cases a greater number of bathrooms and toilets prevails in addition to the number of bedrooms and suites.



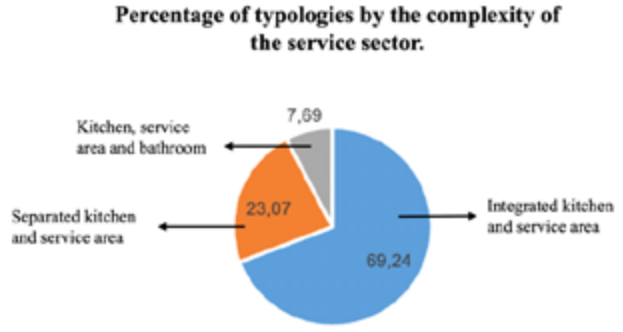
Graph 4: Relationship between the size of the housing unit and the number of bathrooms.
Source: Elaboration by the author.

The relationship between the size of the housing units and the number of bathrooms, when we look at Graph 04, it can be seen that the intermediate apartments with an area between 100m² and 200 m² are provided with at least 3 bathrooms, including toilets. The smaller apartments have up to two bathrooms with the toilet. The apartments with the largest dimensions, consequently, have more bathroom units to the detriment of the others.



Graph 5: Percentage of typologies according to square footage.
Source: Elaboration by the author.

It is observed in Graph 05 above, a greater supply of units that have up to 150m², covering dwellings with two or three bedrooms, with three-bedrooms being the majority of the typologies verified in this study.



Graph 6: Percentage of typologies by the complexity of the service sector.
Source: Elaboration by the author.

The analysis of the data presented in Graph 06 was important for the definition of the methodology for the nomenclature of the typologies, where it was verified that there is no dependence on a maid in the current configuration of Brazilian housing.

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Graph 7: Relationship between the size of the housing unit and the degree of integration between the service elements.
Source: Elaboration by the author.

From Graph 07, we observe that only buildings above 200m² have a service and kitchen sector completely isolated from the social sector and with well-defined environments. We noticed the trend of integration between the social and service sectors, but in a greater proportion in the total integration between the kitchen and service areas of apartments smaller than 150m², in the case of partial integration, its highest proportion is perceived in apartments of a maximum of 100m².

The compensation made by the functionality of the project in balancing the relationship between the number of bedrooms, bathrooms and toilets was identified, where in most cases a greater number of bathrooms and toilets prevails added to the number of bedrooms and suites.

In the relationship between the size of the housing units and the number of bathrooms, it was noticed that the intermediate apartments between 100m² and 200 m² are provided with at least three bathrooms, including the toilets. The smallest apartments have up to two bathrooms with a toilet. The apartments with the largest dimensions, consequently, have more units.

There was a greater supply of units with up to 150 m², covering houses with two or three bedrooms, these are the majority of the typologies verified. Apartments above 200 m² have a service sector completely isolated from the social and with well-defined environments, however, there is a tendency for integration between these sectors in units smaller than 150 m², total integration between the kitchen and service areas predominates, partial integration, its highest proportion, is perceived in apartments of a maximum of 100 m².

The direct relationship between the typological method and the issue of sustainability is related to the number of rooms, bathrooms and inhabitants that each housing unit can hold, configuring the average Brazilian family composed of four and five people. This factor determines the energy expenditure, water consumption and waste of each unit, which may indicate the best use of the urban infrastructure available.

3.3 Analysis of morphological aspects

In this step, the Schneider classification [19] was adopted to analyze the morphology of the planss studied, described in Figure 07 and 08, below.

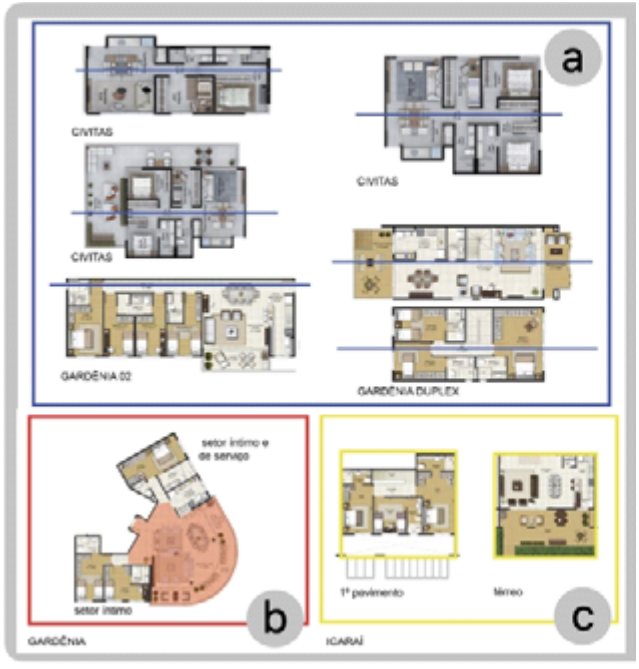

Figure 7: Classification of Typology, according to Schneider [19]. Description: a) Corridor plan – defined by axis defining environments or functions; b) Plan with central living room - privileges the living room and distributes other sectors in the surroundings; c) Inserted box-type plan - environments inside the pre-defined form, simplicity of the divisions and spaciousness of the spaces.
Source: Elaboration by the author.

Figure 8: Classification of Typology, according to Schneider [19]. Description: d) Floor plan with functional separation – well-divided and independent sectors
Source: Elaboration by the author.

By observing the plans, the presence of four typologies was verified, namely: corridor type plan, plan with central living room, inserted box type plan and plan with functional separation.

All the apartments of the Civitas development were considered as a corridor type plan, where the linearity of the central circulation for the distribution of the other juxtaposed environments is noticed, favoring the positioning of opposite window openings to improve circulation, ventilation and natural lighting. The duplex and Gardenia 02 apartments of the Pátio das Flores development were configured in a similar way. The Gardenia apartment, with the largest square footage, was configured as a plan with a central living room, noting the distribution of the other sectors in its "surroundings". As it is a corner apartment, in addition to the large amount of lighting and ventilation in the living room, the positioning of the intimate sector and service do not favor cross ventilation.

In Pátio da Pedra, the analysis of the Icaraí plan is represented by the typology of inserted box-type plan, in which the shape predefined by the square developed the internal division without modifying the principle of the initial basic form. In this typology, it should be considered that even if the environments are larger and with fewer rooms, this type of configuration can make cross ventilation difficult.

The Orquídea and Bromeliad apartments in the Pedra das Flores development, and the Dolomita, Carrara and Travertine 01 and 02 apartments in the Pátio da Pedra development were considered with the floor plan typology with functional separation, where it was possible to notice the division of the sectors through the colors represented in Figure 07. This type of configuration favors the functionality of the environments, as well as the circulation between sectors. Depending on the size and positioning of the units in the building, the apartments may or may not allow the best positioning of the windows for natural and cross ventilation, however a concern with passive strategies was identified.

For the universe of samples in the study under analysis, the presence of the other typologies defined by Schneider was not found, such as: Organic plans; Fluid plans; Circuit plan; and Flexible Plans.

4. CONCLUSIONS

The present study presented the existing architectural typologies in the multifamily residential units of the Pedra Branca neighborhood, carried out by Brandão and Schneider's methodology, to analyze thirteen housing units, ranging from 68 to 220m2, among which small and medium-sized units predominated. The conformity of the project with the contemporary Brazilian architectural period was verified.

It was found that the most frequent housing typology is three-bedroom, which reinforces Brandão's result [17, 18] The result reflects a society made up largely of medium-sized families (between four and five people). It is also observed that the number of bathrooms and toilets added together is, for the most part, equal to or greater than the number of bedrooms (between two and four bathrooms). In this sense, it is perceived that, although the size of the housing unit has been reduced, when compared to those of previous decades, the bathroom remains one of the important elements for the residence.

On the other hand, the service sector showed a significant reduction in its area, which differs from the patterns found in previous decades. The units analyzed, for the most part, had kitchens with smaller dimensions, limited to the functional aspect. The service areas, in turn, are partial or completely integrated into the kitchens, sometimes not presenting any division between them. The integrated versions configure the new standard for Brazilian housing, probably linked to the cost of the real estate market.

Regarding the size of the apartment, the reduction in square footage requires a greater amount of common spaces, which can mean a reduction in costs, due to the concentration of simultaneous use of the structures.

When it comes to the floor plan configuration, it was noted that the one that most favors natural lighting and cross ventilation is the corridor type plan, where there is juxtaposition of the environments in the circulation, favoring the opposite positioning of the windows. The floor plan with a central room allows for the best situation for the room, since it is located in the corner. The inserted box-type plan, despite having larger environments, may not favor the best positioning of the windows, since the environments are condessed. The plan with functional separation can favor depending on the positioning of the apartments in the building. These factors contribute to the improvement of the quality of the space of the units, which can contribute to the reduction of energy costs. It is important to note that the patterns studied have good flexibility in relation to the distribution and remodeling of the environments, which can be adapted according to the needs of the owner in their different stages of life, which can favor sustainability, since it will reuse existing infrastructure.

Finally, the present study identifies a concern with solutions aimed at environmental comfort and passive strategies, combined with the processes of rationalization of construction, and as a strengthening of the principles of sustainability, achieved with the implementation of LEED certification in some of the buildings.

REFERENCE

MACEDO, Adilson Costa. A carta do novo urbanismo norte-americano. **Revista Integração**, n. 48, p. 11- 21, 2007.

TAHCHIEVA, Galina. Entrevista com Galina Tahchieva. **Revista de Pesquisa em Arquitetura e Urbanismo**, São Carlos: EESC-USP, n. 2, p. 108-110, 2005.

ANDRADE, G. M.; DOMENEGHINI, J.; MORANDO, J. P.; ROMANINI, A. Princípios do Novo Urbanismo no Desenvolvimento da Bairros Sustentáveis Brasileiros. Available from: https://www.researchgate.net/publication/284011657_Principios_do_Novo_Urbanismo_no_Desenvolvimento_de_Bairros_Sustentaveis_Brasileiros. **Revista de Arquitetura da IMED**, v. 2, n.1, 2013. Acesso em: 03/ 2023.

LOTTI, M. G. M. **Processo de desenvolvimento e implansação de sistemas, medidas e práticas sustentáveis com vista a certificação ambiental de empreendimentos imobiliários – estudo de caso:** Empreendimento Bairro Ilha Pura – Vila Dos Atletas 2016. Projeto de Graduação (Engenharia Civil) - Escola Politécnica, Universidade Federal do Rio de Janeiro, Rio De Janeiro, 2015.

YIN, R. K. **Estudo de caso: planejamento e métodos**. 3.ed. Porto Alegre: Bookman, 2005.

CIDADE PEDRA BRANCA. **Um Pouco da História Pedra Branca - Cidade Criativa**, 2024. Disponível em: http://cidadepedrabranca.com.br/um-pouco-de-historia/ Acesso: 04/2024.

RUMIS, Maximo; LEIVA, Marcela. Pedra Branca: o poder transformador do urbanismo. Nº 1 – Cidade Criativa Pedra Branca. **Revista Área Arquitetura & Design da Região Sul**. Ed. Ano 13, 06/2020.

PEDRA BRANCA EMPREENDIMENTOS IMOBILIÁRIOS S/A. **Pedra Branca Cidade Criativa: melhorar a cidade para as pessoas. Palhoça:** Pedra Branca - Cidade Criativa, 2014, 92 p.

Bohl, Charles C. **Place Making: Developing Town Centers, Main Streets, and Urban Villages.** ARCHITECTURE. Editor Urban Land Institute. Ebook. Publicação, Janeiro de 2002.

LUZ, A. P. F.; COLCHETE FILHO, A. F.; MAYA-MONTEIRO, P. M. **Diretrizes para projetos sustentáveis em novas centralidades: breve revisão de conceitos.** In: XII CONLAB. Lisboa: XII CONLAB, 2015.

MONEO, R. Rafael Moneo 1967-2004: antologia de urgencia. Madrid, El croquis editorial, 2004.

YOUNES, S. **Quatremère de Quincy's Historical Dictionary of Architecture:** The true, the fictive and the real. Ed.: - 2000.

PEREIRA, R. B. **Arquitetura, imitação e tipo em Quatremère de Quincy.** São Paulo, tese de doutorado, FAUUSP, 2008.

MARTÍNEZ, A. C. **Ensaio sobre projeto**. Brasília, Ed. da Universidade de Brasília, 2000.

MONEO, Rafael. **Origen del ensayo: De la Tipología.** Artículo de la revista SUMMARIOS 79, Buenos Aires, julio, 1984, pp. 15-25. Publicado originalmente en inglés en OPPOSITIONS 13, New York, Invierno, 1978, pp. 22-45, 1978.

TRAMONTANO, M. **Evolução recente da habitação contemporânea na cidade de São Paulo.** Relatório Técnico. Programa CNPq/PIBIC. São Carlos: USP, 2000.

BRANDÃO, D. Q.; HEINECK, L. F. M. **Apartamentos em oferta no Brasil: método de tipificação de plansas e análise de diversidade.** In: III Simpósio Brasileiro de Gestão e Economia da Construção, 2003, São Carlos. Anais. São Carlos: UFSCar, 2003.

Brandão, Douglas. (2008). Tipificação e aspectos morfológicos de arranjos espaciais de apartamentos no âmbito da análise do produto imobiliário brasileiro. **Ambiente Construído**, Porto Alegre, v. 3, n. 1, p. 35-53, jan./mar. 2003. ISSN 1415-8876 © 2003, Associação Nacional de Tecnologia do Ambiente Construído.

SCHNEIDER, F. **Atlas de Plansas: vivendas.** 2. Ed: Barcelona: Editorial Gustavo Gili, 1998. 224 p.

IBGE. População estimada: IBGE, Diretoria de Pesquisas, Coordenação de População e Indicadores Sociais, Estimativas da população residente com data de referência 1o de julho de 2018. https://cidades.ibge.gov.br/. Acesso em 06/2023.

IMOVELWEB. Valor apartamento em Pedra Branca. 2018. Disponível em: Acesso em: 04/2023.

Censo 2022 do IBGE aponta: Palhoça tem 222.598 habitantes. Jornal Palhocense / Cotidiano. https://www.palhocense.com.br/noticias/censo-2022-do-ibge-aponta-palhoca-tem-222-598-habitantes. Publicado em 29/06/2023. Acesso: Março/2024.

United Nations Environment Programme, 2023. **"Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again)"**. Nairobi. https://doi.org/10.59117/20.500.11822/43922.

Canadell, J.G., P.M.S. Monteiro, M.H. Costa, L. Cotrim da Cunha, P.M. Cox, A.V. Eliseev, S. Henson, M. Ishii, S. Jaccard, C. Koven, A. Lohila, P.K. Patra, S. Piao, J. Rogelj, S. Syampungani, S. Zaehle, and K. Zickfeld, 2021. "Global Carbon and other Biogeochemical Cycles and Feedbacks". **In Climate Change 2021:** The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 673–816, doi: 10.1017/9781009157896.007

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"BECAUSE WE ALSO HAVE OUR RIGHTS": PHYSICAL-SPATIAL TRANSFORMATION WITH CHILDREN FROM MORRO DO PAPAGAIO

"PORQUE A GENTE TAMBÉM TEM NOSSOS DIREITOS": TRANSFORMAÇÃO FÍSICO-ESPACIAL, COM CRIANÇAS DO MORRO DO PAPAGAIO

"PORQUE TAMBIÉN TENEMOS NUESTROS DERECHOS": TRANSFORMACIÓN FÍSICO-ESPACIAL, CON LOS NIÑOS DEL MORRO DO PAPAGAIO

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ABSTRACT

Although child participation in decision-making is a recognized right, children are often excluded from decision-making processes that will affect the quality of their lives, including those related to urban issues. In the Brazilian context, there is a lack of studies aimed at understanding child participation in the transformation of public spaces. This study aims to explore the repercussions of a physical-spatial transformation involving children aged 9 to 10 years, residents of the Morro do Papagaio favela (Belo Horizonte, Brazil). To this end, interviews, photo-elicitation, and participant observation were conducted. Inductive thematic analysis of the data revealed the value of physical-spatial transformation as a practice that enables the exercise of children's rights to participation, sociability, play, freedom, education, use of public spaces, beauty and well-being. Identifying how children experience public spaces in the favela became crucial to understanding how transforming spaces with children can promote their citizenship.

KEYWORDS

Participation; Childhood; Physical-Spatial transformation; Favela

RESUMO

Embora a participação infantil nas tomadas de decisão seja um direito consagrado, as crianças são frequentemente excluídas dos processos decisórios que afetarão a qualidade das suas vidas, incluindo àqueles direcionados para questões urbanas. No contexto brasileiro, há uma carência de estudos que visam compreender a participação infantil na transformação de espaços públicos. O presente estudo tem como objetivo explorar as repercussões de uma transformação físico-espacial com crianças, entre 9 e 10 anos, moradoras da favela Morro do Papagaio (Belo Horizonte, Brasil). Para tal, foram realizadas entrevistas, foto-elicitação e observação participante. A análise temática indutiva dos dados revelou o valor da transformação físico-espacial enquanto uma prática que permite o exercício dos direitos infantis à participação, sociabilidade, brincadeira, liberdade, educação, uso dos espaços públicos, beleza e bem-estar. Identificar o modo como as crianças experenciam os espaços públicos da favela se tornou crucial para entender como transformar com crianças pode promover a cidadania destas.

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PALAVRAS-CHAVE

Participação; Infância; Transformação físico-espacial; Favela

RESUMEN

Aunque la participación infantil en la toma de decisiones es un derecho consagrado, los niños suelen ser excluidos de los procesos decisorios que afectarán la calidad de sus vidas, incluidas aquellas dirigidas a cuestiones urbanas. En el contexto brasileño, existe una carencia de estudios que busquen comprender la participación infantil en la transformación de los espacios públicos. El presente estudio tiene como objetivo explorar las repercusiones de una transformación físico-espacial con niños, entre 9 y 10 años, residentes de la favela Morro do Papagaio (Belo Horizonte, Brasil). Para ello, se realizaron entrevistas, foto-elicitación y observación participante. El análisis temático inductivo de los datos reveló el valor de la transformación físico-espacial como una práctica que permite el ejercicio de los derechos infantiles a la participación, sociabilidad, juego, libertad, educación, uso de los espacios públicos, belleza y bienestar. Identificar la manera en que los niños experimentan los espacios públicos de la favela se volvió crucial para entender cómo transformar con niños puede promover su ciudadanía.

PALABRAS CLAVE

Participación; Infancia; Transformación físico-espacial; Favela.

1. INTRODUCTION

Urban growth implies increasingly urban experiences in childhood. It is estimated that 68% of the global population will be urban by 2050 (ONU, 2022), and specifically, the number of children in Brazilian cities has been gradually increasing (IBGE, 2015). The impacts of global urbanisation on children's development have justified the development of initiatives and programs involving children at international, national, and local levels (UNICEF, 2018). These experiences, which propose to transform public spaces with children, are supported by the recognition of children as rights holders since the National Constitution of 1988 (Brazil, 1988), supported by the Estatuto da Criança e do Adolescente (ECA) (Brazil, 1990), which endorses children's rights to education, play, community life, inclusion, and participation. Article 12 of the Convention on the Rights of the Child (CRC), adopted by the United Nations (UN) in 1989, emphasises the right of children to participate in decision-making processes affecting their quality of life (ONU, 1989). Despite the increase in initiatives incorporating child participation in decision-making processes, in the Brazilian context, there is a lack of studies focusing on child participation in the transformation of public spaces (Ruas, 2023).

The 2030 Agenda proposed an action plan with 17 Sustainable Development Goals (SDGs) to achieve a better world for all peoples and nations by 2030 (ONU, 2015). Among these goals are to make cities inclusive and sustainable (SDG 11) and to ensure participatory and representative decision-making processes (SDG 16.7). Therefore, it is understood that to achieve these goals, all social groups must participate in decision-making, including children. This paper seeks to advance discussions on how public space transformations with children can contribute to ensuring the rights of children living in favelas. By closely examining what these children say about their relationship with the city and how they perceive the transformation of their immediate spaces, we are interested in "that children can speak 'in their own right' and report valid views and experiences" (Alderson, 2000, p. 243).

This article explores the views of children who transformed the stairs at São Jorge Alley at Morro do Papagaio, one of the oldest and biggest favelas of Belo Horizonte (Brazil). This small-scale physical-spatial intervention was called the Escadaria dos Artistas by a participating child. This intervention was part of the co-design studio PRJ057, Espaço Protótipo, held in the second semester of 2023, with children enrolled at the Escola Municipal Ulysses Guimarães (EMUG), architecture and post-graduate students, lecturers from various fields of knowledge, as well as the authors of this work. During this period, mosaics were collaboratively created and installed on the steps of the stairs at São Jorge Alley, henceforth referred to as the Escadaria dos Artistas.

To understand more deeply how the transformation of public open spaces with children can contribute to promoting their rights, this study aimed to reveal how children experienced the physical-spatial transformation of Escadaria dos Artistas. To this end, participant observation, interviews, and photo elicitation with children were conducted. An inductive thematic analysis was chosen for analysing field notes, testimonies, and photos. This paper is organised into six sections. The second section presents the theoretical framework underpinning this research. The methods of data collection and analysis are described in the third section. The fourth section details the obtained results, and the discussion will constitute the subsequent section. The sixth section contains the final considerations.

2. THEORETICAL FRAMEWORK

2.1 The right to child participation

When discussing child participation, it is necessary to consider the contexts in which children are embedded, including cultural, social, and economic contexts (Rizzini; Pereira; Thapliyal, 2007). Cultural deprivation theories that emerged in Brazil in the 1970s presumed that children and youth from oppressed classes lived in destabilised family environments marked by violence and aggression (Patto, 1997). This stigmatising narrative was thought to affect their cognitive, intellectual, and affective-emotional development (Gouvea, 1993). However, this assessment was based on criteria that denied any cultural specificities belonging to lower classes (Patto, 1997). In contrast to this elitist narrative, it is understood here that all children, including those living in the most impoverished areas of cities, possess the competence and ability to express opinions on matters concerning them, as enshrined in Article 12 of the CRC (ONU, 1989):

> 1. States Parties shall assure to the child who is capable of forming his or her own views the right to express those views freely in all matters affecting the child, the views of the child being given due weight in accordance with the age and maturity of the child.

> 2. For this purpose, the child shall in particular be provided the opportunity to be heard in any judicial and administrative proceedings affecting the child, either directly, or through a representative or an appropriate body, in a manner consistent with the procedural rules of national law.

"Participation" is a process that combines different perspectives, ideas, and interests negotiated between adults and children, resulting in a balanced decision-making process (Tomás, 2007). In meaningful participatory processes, children are recognised as active citizens able to contribute to society (Liebel; Saadi, 2012). Chawla (2002) highlights three main reasons for involving children in processes of urban planning: (i) they will have the opportunity to engage in active democratic citizenship practices; (ii) they are experts in identifying environments that may or may not meet their needs; and (iii) they can develop habits of caring for these environments. However, involving children in decision-making processes related to urban planning, management, and design continues to be a challenge within the academic sphere. Despite the growing number of initiatives that incorporate child participation in decision-making, there remains a lack of studies in the Brazilian context that focus on children's perspectives regarding their involvement in the transformation of public spaces (Ruas, 2023).

So, how can child meaningful participation be actualized? Manzini (2008) defined promising cases of social innovation as those that not only transform traditional processes but also incorporate more sustainable practices and behaviors. According to the author, social innovation "refers to changes in the way individuals or communities act to solve their problems or create new opportunities" (Manzini, 2008, p. 61, translated by the authors). It is reiterated that listening to children is not enough; their meaningful participation in urban transformation processes must be facilitated.

2.2 Being a Child in the Favelas

The right to the city means ensuring the right to participate in urban transformation processes (Harvey, 2014). From this perspective, children have the right to participate in urban planning and architectural design processes that will transform those public urban open spaces that impact the quality of their lives. Furthermore, children's point of view can help create more accessible and safer cities for all inhabitants.

Through play, children can enhance their social, physical, cognitive, and emotional skills (Ginsburg, 2007). High-quality public urban open spaces are crucial for child development because they offer opportunities for these developmental experiences. Furthermore, through play in these spaces, children build their self-identities, sense of belonging, and social responsibility (Owens, 2020). Children from Morro do Papagaio play outdoors, flying kites, climbing on gym bars installed in urban squares, cycling, etc. (Lansky, 2012).

Although children from Morro do Papagaio are more used to spending time and playing outdoors than children from middle-class neighbourhoods surrounding the favela, it is necessary to highlight that their experiences are permeated by a "state of violence" (Lansky, 2012). Young people from poorer layers of society suffer the impacts of violence that extend beyond their physical integrity and are observable through the violation of various human rights, such as job guarantees, quality education, and social inclusion (Rizzini; Limongi, 2016). Children living in favelas are exposed to violence even when processes of favela upgrading are put into practice (Lansky, 2012).

Beyond a merely spatial concept of what is periphery, "peripheral subjectivities" are constructed by individuals through an awareness of their urban living conditions and socio-spatial realities (D'Andrea, 2020). As they become part of an urban environment, children's relationships with public urban open spaces are influenced by personalization, in which their spatial affections and aversions are mapped, primarily through their movement (Sarmento, 2018). This process aligns with Tuan's concept of place, where space becomes a place as it is known and endowed with value (Tuan, 1977).

> In summary, we may say that deeply-loved places are not necessarily visible, either to ourselves or to others. Places can be made visible by a number of means: rivalry or conflict with other places, visual prominence, and the evocative power of art, architecture, ceremonials and rites. Human places become vividly real through dramatization. Identity of place is achieved by dramatizing the aspirations, needs, and functional rhythms of personal and group life (Tuan, 1997, p. 178).

Hence, children's identities are intertwined with their affective bonds with spaces (Coelho; Duarte; Vasconcelos,

2013). Children can experience the conversion of urban open spaces into places by participating in urban transformation processes. This study explores, from children's perspectives, whether urban transformation collaborative processes offer opportunities for them to exercise their rights.

3. METHODOLOGICAL PROCEDURES

This study adopted a qualitative approach to reveal how children (i) perceive the urban open spaces that structure the favela Morro do Papagaio, and (ii) experience opportunities to transform these spaces with adults. This research was conducted in the context of the co-design studio PRJ057 — this co-design studio has brought together architecture students and children to learn from each other how to transform urban open spaces collectively through hands-on learning experiences of co-design with children. A qualitative approach was adopted because it is suitable to understand phenomena from the participants' perspectives; it provides an in-depth understanding of the meanings associated by people with their everyday experiences (Denzin; Lincoln, 2006). To achieve the research aims, various data collection methods were applied: unstructured interviews, photo elicitation, and observant participation. The textual data was analysed using inductive thematic analysis.

3.1 The geographical context

Morro do Papagaio presents alleys and streets shaped by irregular constructions built by the local community with cheap materials. It is a pedestrian-friendly area with a significant cultural production. However, as many other slums in the country, overcrowding and problems associated with crime, education, health, sanitation, and housing are common.

Morro do Papagaio is surrounded by middle and upper-middle-class neighbourhoods (e.g., São Bento, Santa Lúcia, Cidade Jardim, and Santo Antônio). The Municipal Human Development Index (MHDI) of this favela is 0.683, whereas the surrounding boroughs have MHDI values ranging from 0.939 to 0.951 (PNUD; IPEA; FJP, 2022) (Figure 1). This disparity reflects the inequalities that have permeated the history of Belo Horizonte and many other Brazilian cities.

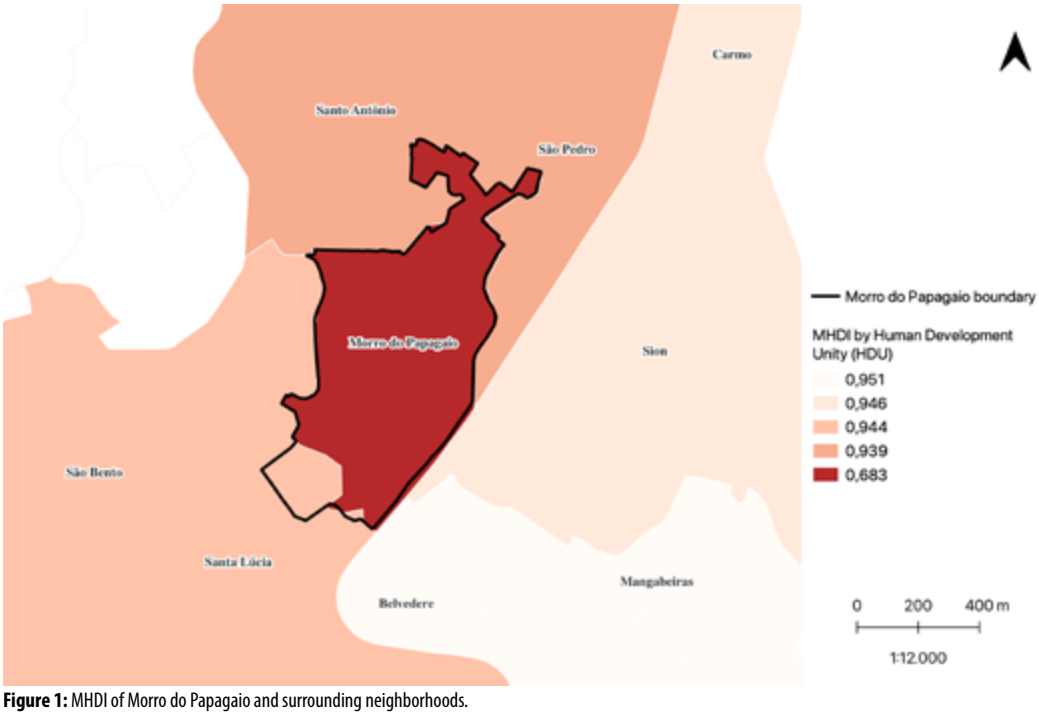

Figure 1: MHDI of Morro do Papagaio and surrounding neighborhoods.
Source: PNUD; IPEA; FJP, 2022.

Nearly 15,700 people live in Morro do Papagaio, a favela consisting of four vilas: Vila Estrela, Vila Santa Rita de Cássia, Vila Santa Lúcia, and Vila São Bento (URBEL, 2020) (Figure 2). Vila Santa Lúcia (or Vila da Barragem) is the most populous vila, with 2,503 households and an estimated population of 8,627 inhabitants, followed by Vila Santa Rita de Cássia, the second most populous vila, with 5,029 residents in 1,485 households, as shown in Table 1 (URBEL, 2020). Morro do Papagaio has a household density of approximately 3.43 residents per household. Among the four favelas, Vila Estrela has the highest concentration of inhabitants per household, with 3.5 occupants per residence.

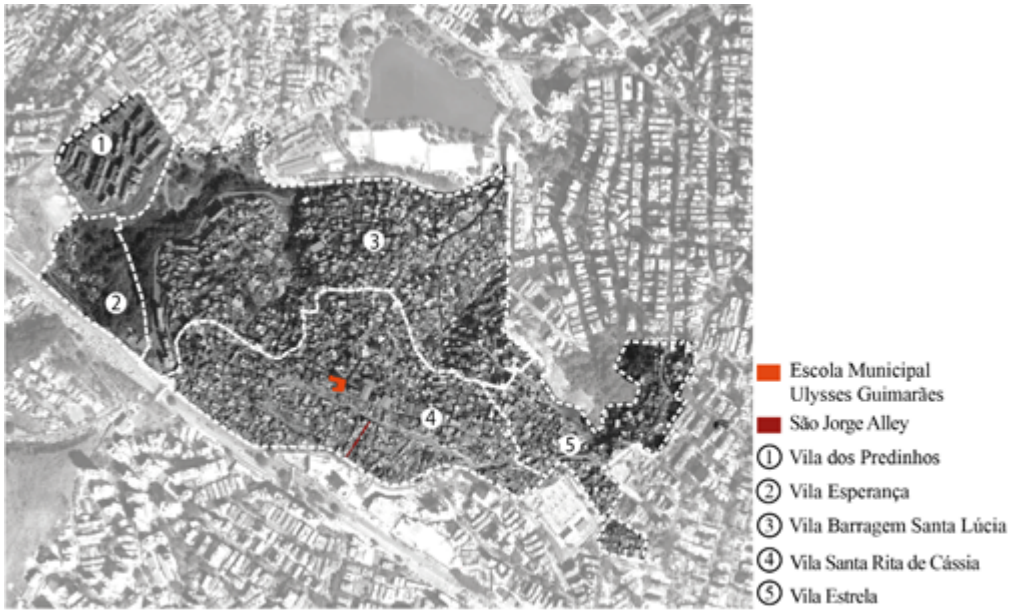

Figure 2: map of Morro do Papagaio.
Source: the authors, 2024.

Favela	Residents	Hoouseholds	Area (m^2)
Vila Barragem Santa Lúcia	8.627	2.503	231.296,00
Vila Santa Rita de Cássia	5.029	1.485	151.679,00
Vila Estrela	1.616	457	63.626,00
Vila São Bento	425	121	32.995,00
Total:	**15.697**	**4.566**	**479.596,00**

Table 1: favelas of Morro do Papagaio (total population, households and area).
Source: URBEL, 2020.

3.2 The educational context

This research was developed in articulation with the co-design studio PRJ 057 at the Escola de Arquitetura, Universidade Federal de Minas Gerais. This pedagogical approach was chosen due to the awareness that through hands-on learning experiences of co-design with children, a more enriching and socially engaged learning experience can be achieved with returns to the community. Approximately 15 architecture students and 40 children (9-11 years old) attended PRJ057. The course plan of PRJ 057 comprised the following stages: (i) research and contact with the urban open space to be transformed; (ii) research on techniques for producing and installing mosaics (iii) generation of drawings by children; (iv) selection of the drawings to be transformed into mosaics, (v) test of different techniques (Figure 3); (vi) installation of the mosaics. Figure 4 succinctly describes each stage of the co-design studio.

Figure 3: test of different techniques.
Source: the authors, 2024.

Figure 4: stages of the thematic workshop.
Source: the authors, 2024.

3.3 Data collection

Approximately 40 children were given information about the research in understandable language and invited to participate. Before the data collection, informed consents were obtained from those children who wanted to participate in this research (N=7) and their parents. To gather data, this study applied unstructured interviews, participant observation, and photo elicitation, before and after the transformation of the Escadaria dos Artistas. Interview is often used to explore children's perceptions and conceptions about a particular event; however, it is essential for the adult to establish a good rapport with the child to obtain high-quality data (Carvalho et al, 2004). It is necessary to consider that children may withhold information or lie, either due to shyness or to provide answers they think adults want to hear (Punch, 2002). Clear language should be used to maintain a horizontal dialogue (Punch, 2002).

Including photos in interviews (photo-elicitation) is valuable because it allows children to record their experiences, feelings, and sense of place (Barker; Weller, 2003). Photos are communicative mediators and a means to deepen areas of interest (Clark-Ibáñez, 2004). In this study, mobile phones were used by children as data collection tools. Following a pre-defined route, children took photos prompted by the following questions: "What do you like about this place?" and "What do you not like about this place?" (Figure 5). By taking photos and pasting "emojis", children mapped which elements evoked affection and aversion in the route. When using photo-elicitation, exploring the meanings of these records for the children is essential, thereby avoiding imposing adult-centric views on the photographs (Barker; Weller, 2003).

The researchers' participation in all co-design studio sessions as lecturers or students allowed for participant observation. Here, researchers immerse themselves in the social space of other participants to maintain a direct relationship, generate data, understand the research context, and empathise with the participants as they relativise their own social space (Minayo, 2007) Participant observation allowed for recording various situations for later analysis in conjunction with other data generation methods. Mobile phones and audio transcriptions facilitated rapid and effective note-taking in situ.

Figure 5: route undertaken by children to capture photographs.
Source: the authors, 2024.

3.4. Data analysis

This study used inductive thematic analysis (data-driven), as Braun and Clarke (2006) proposed, to identify patterns (themes) in the textual data. This flexible analytical approach can generate unexpected insights (Braun; Clarke, 2006). The authors performed multiple data readings to familiarise themselves with the data (stage 1). Relevant information was highlighted in different colours and associated with preliminary codes (stage 2). Recurring codes were grouped into themes (stage 3). These themes were reviewed to check if they adequately represented the data set (stage 4). Finally, the last stage involved writing the results (stage 5). In the following section, pseudonyms were used to ensure participant anonymity. This research was approved by the Ethics Committee of UFMG (CAAE 59886022.4.0000.5149).

4. RESULTS

4.1 Children's voices: the right to be heard

The thematic analysis revealed children associate the urban open spaces that structure Morro do Papagaio with several fears––fear of crime (e.g., theft), fear of strangers (e.g., kidnapping), fear of diseases, fear of accidents (e.g., falls), and fear of flooding. Fear of crime has reduced their autonomy to explore the outdoors. João mentioned he fears robbery while walking to school; however, when asked if he had ever witnessed such an incident, he said: "[...] only in pictures, basically." Although João has not witnessed any crime, he feels insecure. This fear have prevented children

from performing activities more independently, such as walking to and from school. Laura reported:

> Interviewer: [...] if today she [your mother] came to you and said, "You can go to school alone," would you like that?
> Laura: No. Interviewer: Why not? Laura: Because I'm afraid (interview excerpt, 2023).

Garbage, waste, and construction debris evoke fear in children because these are associated with a high risk of accidents, flooding, and disease transmission (Figure 6). Júlia mentioned that the garbage "clogs the drains and causes the houses to flood, leaving many people without food or shelter." Children view the presence of these elements in public spaces as indicative of neglect:

> Ana: Some people don't care for the world properly, so we have to treat it as well as possible.
> Interviewer: And how do we take good care of the world? Ana: By not throwing trash on the street and not cutting down trees (photo-elicitation excerpt, 2023).

Children perceive the urban open spaces that structure Morro do Papagaio as a place to play and interact with other children (Figure 7). However, they seem to experience a sense of safety when they are under the supervision of a known adult (e.g., mother). João said, "[...] every Friday I stay there (at the square) playing and seeing my friends because I invite them to play," and "Sometimes my father shows up [...] to see if everything is okay." The play involves other children, but some family members occasionally join in. It is primarily the opportunities to interact with other children that make the public urban open spaces from Morro do Papagaio be perceived as spaces adequate for playing:

> Interviewer: [...]. Can you think of something in Morro that you find really cool?
> Ana: Yes.
> Interviewer: What?
> Ana: The street (interview excerpt, 2023).

Graffiti and other artistic interventions were highly appreciated by children (Figure 4). When asked how she would feel looking at the stairs full of drawings, Júlia said she would feel safe and happy: "Because when I'm alone, I'm a bit scared, but when I'm alone and see beautiful things, I get distracted and wouldn't be as scared." Children associated artistic expressions with feelings of safety, well-being, beauty, and joy. More colourful urban open spaces are evaluated as joyful and attractive:

> Interviewer: And what do you think about the stairs? [...]
> Ana: Beautiful.
> Interviewer: Beautiful? Tell me what is beautiful about the stairs.
> Ana: The paintings on the wall.
> Interviewer: The paintings? What do those paintings convey to you?
> Ana: Joy. [...]
> Interviewer: What do you find nice about the alleys where we walked?
> Ana: First, that people paint the houses, and I think that's pretty. Some houses are very nice to see because some are colorful.

Natural elements are the category with the highest number of records, followed by artistic elements. Like artistic interventions, natural elements evoked a sense of happiness and security among the children. "I feel happy and also safe," declared Júlia when talking about the photo she took of the plants. Children enjoy contemplating plants, the sky, and mountains (Figure 8). Lorena said: "I like plants, I feel happiness; at least people are planting something to help our breathing so we can survive". The children appreciate the vistas they can contemplate from the alleys and streets that define the urban fabric of Morro do Papagaio:

> Júlia: The view, I think it's very beautiful.
> Interviewer: What's in that view, tell me?
> Júlia: There are some mountains, buildings, and houses.
> Interviewer: And what's the most beautiful thing about it?
> Júlia: The mountains in the background and the blue sky.
> Interviewer: How do you feel when you see the mountains in the background and the blue sky?
> Júlia: I feel like I'm in a forest full of cute little animals.

Figure 6: photographic records of garbage and debris.
Source: the children, 2023

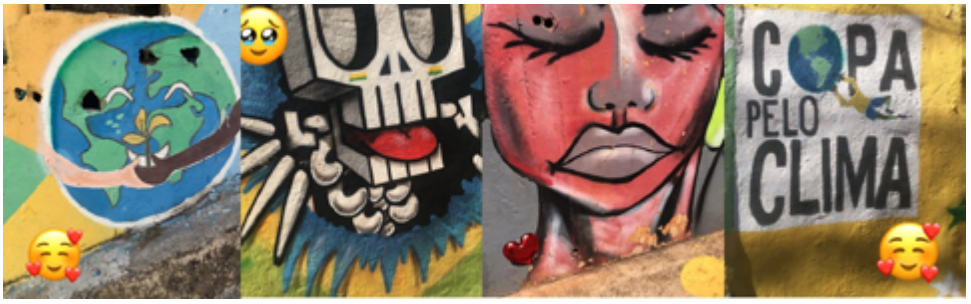

Figure 7: photographic records of artistic interventions in alleys.
Source: the children, 2023

Figure 8: photographic records of natural elements.
Source: the children, 2023

4.2 Enabling children's rights: participation, play, freedom, access to public spaces, community life, education, beauty and well-being

The children valued participating in the urban transformation of the Escadaria dos Artistas as part of the co-design studio PRJ057. Lorena said: "I want to thank you for letting me participate." When asked if she preferred to work together or alone, Ana responded: "Working together with you [...] we can ask for everyone's opinion." When questioned if the children could transform other places in the city, she said, "Yes... because we also have our rights." The data suggest that children associate collaborative work with listening to everyone's opinions and understand their right to participate in urban transformation processes. The name "Escadaria dos Artistas", which in English means "Stair of the Artists", indicates that children see themselves as artists with enough expertise to participate in processes of urban transformation.

Interviewer: [...] if the mayor came to you and asked, "João, what name should we give to this stair?" What name would you give it?
João: Escadaria dos Artistas.
Interviewer: And who are the artists?
João: Everyone who participated.

The collective transformation of the stairs also stimulated play. When asked if he would like to add anything to the transformation, Caio said he would like the participants to meet again "because it was very fun when they came." Beyond tangible marks (e.g., mosaics), participant observation revealed intangible impacts of the physical-spatial transformation, such as freedom and leisure. The children decided what to do; some preferred to sing, and others chose to help install the mosaics. The freedom to choose what they wanted to do led to enjoyment and well-being during the execution process, removing the obligation to complete predefined tasks. The children visibly enjoyed singing, placing mosaics, or making mortar as the material ran out.

Sociability also occurred between participants (children and adults) and passersby (children and adults), who expressed support, enthusiasm, and curiosity about the transformation. Some children who participated in the stairs intervention and suggested ideas for additional mosaics were not EMUG students. The thematic analysis showed that children saw themselves as active co-designers who were able to contribute processes aiming to enhance the aesthetic quality of urban open spaces that feature cities.

Interviewer: Do you think children could talk more about this with other people?
Caio: Yes.
Interviewer: Why?
Caio: Because they would have more ideas.

Interviewer: What did you think of the stairs with the tiles? With the mosaics?
Laura: Beautiful! I liked it.

Figure 9: Photographic records of the physical-spatial transformation
Source: the authors, 2023

5. DISCUSSIONS

The abandonment of urban open spaces as places for play, social interactions, and learning has been intensified by urban automobilization (Sarmento, 2018). The conversion of parks into parking lots and streets into areas for vehicle circulation has motivated using these almost exclusively as channels for movement (Sarmento, 2018). As a result, many children are progressively confined to indoor spaces. This confinement is associated with the "urban islands" (Zeiher, 2003), which characterises the relationship between children and the city in large urban centres. The islands correspond to spaces designated for children and controlled by adults, such as homes, schools, and shopping malls.

In contrast to this reality, the findings of this study indicated that urban open spaces in favelas are still perceived and used as spaces to play, explore, learn, meet friends, etc. However, different types of fear permeate their outdoor experiences.

The leading causes of external deaths among Brazilian children aged 1–14 in 2022 were accidental drowning/ submersion and traffic collisions (DATASUS, 2024). However, when in the urban open spaces of the favela, the fear of crime and strangers prevails among children. Fear of crime and strangers has reinforced the absence of children and their caregivers in urban open spaces (Gill, 2007). Bauman (2008) describes fear as a feeling generated by a potential threat arising from our survival instinct. For the author, this fear is shaped by our perception of the world, which is increasingly seen as unsafe and viewed with suspicion.

Children appreciated the presence of art and natural elements at Morro do Papagaio; these evoked well-being and feelings of safety and happiness. This confirms the results obtained by the study conducted by Norðdahl and Einarsdóttir (2015): environments feature with these elements were described by the children as more colorful and enjoyable. The demand for more colourful spaces was also revealed in the research by Ergle et al. (2015), though these colours were present in natural environments. Children have the right to enjoy beautiful spaces. The National Plan for Early Childhood (PNPI) highlights that "subjecting the child to spaces where aesthetic is disregarded, places overwhelmed by ugliness and sensory aggression, is to deny the child the right to beauty" (Brazil, 2020, p. 211).

Through the physical-spatial transformation of the Escadaria dos Artistas children could exercise their right to freedom and education, established by the ECA (Brazil, 1990), as well as their right to play, have fun, participate in community life, express opinions, express themselves, be in public places, and engage in cultural and artistic creation. In addition, Fattore, Mason and Watson (2009, p. 64) suggest that children consider "important to their wellbeing to be involved in more formal decisions about their lives" (Fattore; Mason; Watson, 2009, p. 64). When adults encourage and respect children's ability to make decisions and act independently, while also acknowledging their rights, children feel more valued, which contributes to an enhanced sense of well-being (Lloyd; Emerson, 2017). By naming the action "Escadaria dos Artistas," the children positioned themselves as protagonists of this process, revealing the empowerment that can result from their meaningful participation in urban transformation processes. The inter-relationships between children and the urban open spaces of Morro do Papagaio reinforce the difference between places for children – those assigned values and meanings by them, as Rasmussen argues – and places for children – created by adults (Rasmussen, 2004).

The physical-spatial transformation studied provided children with the necessary experiences to exercise citizenship. Among the basic criteria for the exercise of children's citizenship, it is essential that urban public spaces be accessible for children's use and appropriation, while also evoking a sense of belonging (Dias; Ferreira, 2015). Since urban open spaces are fundamental for child development, enabling their participation in their transformation can contribute to creating safer and more suitable spaces for their needs.

6. FINAL CONSIDERATIONS

Understanding how children experience and construct a sense of place is crucial for engaging them in transforming urban open spaces (Christensen; O'Brien, 2003). The physical-spatial transformation of the Escadaria dos Artistas with children left tangible marks, such as beautifying the space with colorful mosaics, and intangible ones, such as strengthening their sense of belonging. The transformation also afforded opportunities to experience freedom, social interaction, beauty, education, enjoyment, well-being and play — all rights stated by CDC (and ECA).

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REFERENCES

ALDERSON. P. Children as Researchers: the Effects of Participation Rights on Research Methodology. In: CHRISTENSEN, Pia; & JAMES, Allison. (ed.). **Research with children:** Perspectives and practices. 1st ed. London: Falmer Press, 2000. cap. 7, p. 241-257.

BARKER, J; WELLER, S. "Is it fun?" developing children centred research methods. **International Journal of Sociology and Social Policy**, [S. l.], v. 23, n. 1/2, p. 33–58, 2003.

BAUMAN, Z. **Medo Líquido.** Tradução: Carlos A. Medeiros. Rio de Janeiro: Jorge Zahar Editor, 2008.

BRASIL. **Constituição da República Federativa do Brasil.** Brasília, DF: Senado Federal, 1988.

BRASIL. Lei n.º 8.069, de 13 de julho de 1990. Dispõe sobre o Estatuto da Criança e do Adolescente. **Diário Oficial da União:** Brasília, DF, 16 jul. 1990. 284 p. Disponível em: https://www.gov.br/mdh/pt-br/navegue-por-temas/crianca-e-adolescente/publicacoes/eca-2023.pdf. Acesso em: 15 fev. 2024.

BRASIL. **National Plan for Early Childhood:** 2010-2022 | 2020-2030. Brasília: RNPI/ANDI, 2020.

BRAUN, V.; CLARKE, V. Using thematic analysis in psychology. **Qualitative Research in Psychology**, [S.l.], v. 3, n. 2, p. 77–101, 2006. DOI: 10.1191/1478088706qp063oa.

CARVALHO, A. M. A.; BERALDO, K. E. A.; PEDROSA, M. I.; COELHO, M. T. O uso de entrevistas em estudos com crianças. **Psicologia em Estudo**, [S. l.], v. 9, n. 2, p. 291–300, 2004.

CHAWLA, L. "Insight, creativity and thoughts on the environment": integrating children and youth into human settlement development. **Environment and Urbanization**, [S. l.], v. 14, n. 2, p. 11–22, oct. 2002.

CHRISTENSEN, P.; O'BRIEN, M. Children in the city: introducing new perspectives. In: CHRISTENSEN, P.; O'BRIEN, M. (org.). **Children in the City:** Home Neighbourhood and Community. 1. ed. London: Routledge, 2003. p. 1–12.

CLARK-IBÁÑEZ, M. Framing the social world with photo-elicitation interviews. **American Behavioral Scientist**, [S.l.], v. 47, n. 12, p. 1507–1527, aug. 2004. DOI: 10.1177/0002764204266236.

COELHO, G.; DUARTE, C. R.; VASCONCELOS, V. M. R. de. A criança e o espaço vivido favela: a complexidade do espaço nas interações da infância. **Oculum Ensaios**, [Campinas], n. 6, p. 74–87, 2013.

D'ANDREA, T. Contribuições para a definição dos conceitos periferia e sujeitas e sujeitos periféricos. **Novos Estudos - CEBRAP**, [S. l.], v. 39, n. 1, p. 19–36, 2020.

DATASUS – Departamento De Informática do Sistema Único de Saúde do Ministério da Saúde (Brasil); **Informações de Saúde** (TABNET). Disponível em: Acesso em: http://tabnet.datasus.gov.br/cgi/deftohtm.exe?sim/cnv/ext10uf.def. Acesso em: 6 de mar. 2024.

DENZIN, N. K.; LINCOLN, Y. S. Introdução: a disciplina e a prática da pesquisa qualitativa. In: DENZIN, N. K.; LINCOLN, Y. S. (org.). **O planejamento da pesquisa qualitativa: teorias e abordagens**. 2. ed. Porto Alegre: Artmed, 2006. p. 15–41.

DIAS, M. S.; FERREIRA, B. R. Espaços públicos e infâncias urbanas: a construção de uma cidadania contemporânea. **Revista Brasileira de Estudos Urbanos e Regionais**, Recife, v. 17, n. 3, p. 118–133, 2015.

ERGLER, C.; SMITH, Kylie; KOTSANAS, C.; HUTCHINSON, C. What Makes a Good City in Pre-schoolers' Eyes?

Findings from Participatory Planning Projects in Australia and New Zealand. **Journal of Urban Design,** [S. l.], v. 20, n. 4, p. 461–478, 2015.

FATTORE, T.; MASON, J.; WATSON, E. When Children are Asked About Their Well-being: Towards a Framework for Guiding Policy. **Child Indicators Research,** [S. l.], v. 2, n. 1, p. 57–77, 2009.

GILL, T. **No fear:** Growing up in risk averse society. Londyn: Calouste Gulbenkian Foundation, 2007.

GINSBURG, K. R. The Importance of Play in Promoting Healthy Child Development and Maintaining Strong Parent-Child Bonds. **Pediatrics,** [S. l.], v. 119, n. 1, p. 182–191, 2007.

GOUVEA, M. C. S. A criança de favela em seu mundo de cultura. **Cadernos de Pesquisa**, São Paulo, n. 86, p. 48–54, ago. 1993.

HARVEY, D. **Cidades rebeldes: do direito à cidade à revolução urbana.** Tradução: Jeferson Camargo. São Paulo: Martins Fontes, 2014.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Pesquisa Nacional por Amostra de Domicílios** (PNAD). 2015.

LANSKY, S. **Na cidade, com crianças: uma etnografia espacializada.** 2012. Tese (Doutorado em Educação) – Faculdade de Educação, Universidade Federal de Minas Gerais, Belo Horizonte, 2012.

LIEBEL, M.; SAADI, I. La participación infantil ante el desafío de la diversidad cultural. **Desacatos. Revista de Ciencias Sociales**, [S. l.], n. 39, p. 123–140, 2012.

LLOYD, K.; EMERSON, L. (Re)examining the Relationship Between Children's Subjective Wellbeing and Their Perceptions of Participation Rights. **Child Indicators Research**, [S. l.], v. 10, n. 3, p. 591–608, 2017.

MANZINI, E. **Design para a inovação social e sustentabilidade: comunidades criativas, organizações colaborativas e novas redes projetuais.** Tradução: Carla Cipolla, Elisa Spampinato e Aline Lys Silva. 1. ed. Rio de Janeiro: E-papers, 2008.

MINAYO, M. C. de S. Trabalho de campo: contexto de observação, interação e descoberta. In: DESLANDES, S. F.; GOMES, R.; MINAYO, M. C. de S. (org.). **Pesquisa social: teoria, método e criatividade.** 26. ed. Petropólis: Vozes, 2007. p. 61–77.

NORÐDAHL, Kristín; EINARSDÓTTIR, Jóhanna. Children's views and preferences regarding their outdoor environment. **Journal of Adventure Education and Outdoor Learning**, [S. l.], v. 15, n. 2, p. 152–167, 2015.

ONU - HABITAT. Programa Das Nações Unidas Para Os Assentamentos Humanos. **World cities report 2022: envisaging the future of cities. 2022**. Disponível em: https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf. Acesso em: 15 jun. 2024.

ONU – Organização das Nações Unidas. **Convenção sobre os Direitos da Criança**. 1989. Disponível em: https://www.unicef.org/brazil/convencao-sobre-os-direitos-da-crianca. Acesso em: 15 fev. 2024.

ONU – Organização das Nações Unidas. **Os Objetivos de Desenvolvimento Sustentável no Brasil.** 2015. Disponível em: https://brasil.un.org/pt-br/sdgs. Acesso em: 13 ago. 2024.

OWENS, P. E. A Fundamental Need: Linking Youth Development to the Public Realm. In: LOEBACH, J.; LITTLE, S.; COX, A.; OWENS, P. E. (ed.). **The Routledge Handbook of Designing Public Spaces for Young People: Processes, Practices and Policies for Youth Inclusion.** 1. ed. New York: Routledge, 2020. p. 7–22.

PATTO, M. H. S. **Introdução à psicologia escolar.** 3. ed. São Paulo: Casa do Psicólogo, 1997. 468p.

PNUD – Programa Das Nações Unidas Para O Desenvolvimento; IPEA – Instituto De Pesquisa Econômica e Aplicada; FJP – Fundação João Pinheiro. **Atlas do Desenvolvimento Humano no Brasil.** 2022. Disponível em: http://www.atlasbrasil.org.br/consulta. Acesso em: 28 ago. 2024.

PUNCH, S. Research with Children: The same or different from research with adults? **Childhood**, [S. l.], v. 9, n. 3, p. 321–341, 2002.

RASMUSSEN, K. Places for Children – Children's Places. **Childhood**, [S. l.], v. 11, n. 2, p. 155–173, 2004. DOI: 10.1177/0907568204043053.

RIZZINI, I.; PEREIRA, L.; THAPLIYAL, N. Percepções e experiências de participação cidadã de crianças e adolescentes no Rio de Janeiro. **Revista Katálysis**, [S. l.], v. 10, n. 2, p. 164–177, 2007.

RIZZINI, I.; LIMONGI, N. da S. Percepções sobre violência no cotidiano dos jovens. **Revista Katálysis**, [S. l.], v. 19, n. 1, p. 33–42, 2016.

RUAS, D. R. **Uma revisão de escopo sobre como as crianças têm percebido e transformado, colaborativamente, espaços públicos.** 2023. 181f. Dissertação (mestrado) – Escola de Arquitetura, Universidade Federal de Minas Gerais, Belo Horizonte, 2023. Disponível em: http://hdl.handle.net/1843/60503. Acesso em: 29 jan. 2024.

SARMENTO, Manuel J. Infância e cidade: restrições e possibilidades. **Educação**, vol. 41, n. 2, p. 232-240, 2018.

TOMÁS, C. Participação não tem Idade": Participação das Crianças e Cidadania da Infância1. **Contexto & Educação**, [S. l.], n. 78, p. 45–68, 2007.

TUAN, Y. **Space and place:** The perspective of experience. Minneapolis: University of Minnesota Press, 1977.

UNICEF. **Child Friendly Cities and Communities: Handbook.** 2018. Disponível em: https://www.unicef.org/eap/media/1591/file/Child%20Friendly%20Cities%20and%20Communities%20Handbook.pdf. Acesso em: 20 ago. 2024.

URBEL – Companhia Urbanizadora e de Habitação de Belo Horizonte. **Vilas, Favelas e Loteamentos Públicos de Interesse Social (2020)**. Prefeitura de Belo Horizonte, 2021. Disponível em: https://prefeitura.pbh.gov.br/sites/default/files/estrutura-de-governo/urbel/2021/dados_vila_favela_2020_2021.05.pdf. Acesso em: 8 mar. 2024.

ZEIHER, H. Shaping daily life in urban environments. In: CHRISTENSEN, P.; O'BRIEN, M. (ed.). **Children in the city: home, neighborhood and community.** 1. ed. London: Routledge Falmer, 2003. p. 66–81.

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ENVIRONMENTAL IMPACTS AND CHALLENGES OF SMART CLOTHING: A REVIEW FROM THE LIFE CYCLE

IMPACTOS E DESAFIOS AMBIENTAIS DE SMART CLOTHING: UMA REVISÃO A PARTIR DO CICLO DE VIDA

IMPACTOS AMBIENTALES Y DESAFÍOS DE LA ROPA INTELIGENTE: UNA REVISIÓN DESDE EL CICLO DE VIDA

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ABSTRACT
Despite the potential of smart clothing, which allows collecting and processing data about the user's conditions and reactions, the environment in which they are inserted and connecting with other artifacts around them, aiming to facilitate daily activities and improve quality of life, problems environmental issues already faced by the clothing sector can be worsened due to the incorporation of electronic components in clothing. Design can contribute to reversing this situation through interventions within the scope of the concept of these products as well as in the associated services and systems. This article presents a review of the state of the art on the topic, with an emphasis on identifying the main environmental impacts and challenges of smart clothing from the perspective of the product life cycle, to contribute to the informational quality of the Designers involved in the project of this product category.

KEYWORDS
Smart clothing; Environmental impacts; Circular Economy.

RESUMO
Apesar da potencialidade de smart clothing, que permite coletar e processar dados sobre condições e reações do usuário, do ambiente em que está inserido e se conectar com outros artefatos a sua volta, visando facilitar as atividades diárias e melhorar a qualidade de vida, os problemas ambientais já enfrentados pelo setor do vestuário podem ser agravados devido a incorporação de componentes eletrônicos nas roupas. O Design pode contribuir para reverter este quadro através de intervenções no âmbito do conceito destes produtos assim como nos serviços e sistemas associados. Este artigo apresenta uma revisão do estado da arte no tema, com ênfase na identificação dos principais impactos ambientais e desafios de smart clothing a partir da perspectiva do ciclo de vida do produto, com o propósito de contribuir para a qualidade informacional dos Designers envolvidos no projeto desta categoria de produtos.

PALAVRAS-CHAVE
Smart clothing; Impactos ambientais; Economia Circular.

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RESUMEN

A pesar del potencial de la ropa inteligente, que permite recopilar y procesar datos sobre las condiciones y reacciones del usuario, el entorno en el que se inserta y conectarse con otros artefactos que lo rodean, con el objetivo de facilitar las actividades diarias y mejorar la calidad de vida, los problemas ambientales ya El problema que enfrenta el sector de la confección puede verse agravado por la incorporación de componentes electrónicos en la confección. El diseño puede contribuir a revertir esta situación a través de intervenciones dentro del alcance del concepto de estos productos así como de los servicios y sistemas asociados. Este artículo presenta una revisión del estado del arte sobre el tema, con énfasis en identificar los principales impactos y desafíos ambientales de la ropa inteligente desde la perspectiva del ciclo de vida del producto, con el propósito de contribuir a la calidad informativa de los Diseñadores. involucrados en el proyecto esta categoría de producto.

PALABRAS CLAVE

Ropa inteligente, Diseño de moda, Residuos electrónicos, Diseño para la sostenibilidad.

1. INTRODUCTION

Computational technological advances in materials and products enable the clothing sector to envision a wide range of possibilities for products with embedded technologies. For instance, clothing that allows the measurement of vital signs and health conditions, geolocation, safety alerts regarding risky situations for the user, among others [1]. Garments that can detect external stimuli and respond to them based on computational data processing are called **smart clothing** [1-2].

The concept of smart clothing is characterized by incorporating electronic components into fabrics and garments to collect and process data about the user's conditions and reactions, the environment in which they are located, and to connect with other artifacts and actors around them, aiming to facilitate the user's daily activities and improve their quality of life [1]. In this category of products, the fabric or the garment itself is the wearable and performs its function with greater naturalness and wearing comfort when compared to other types of wearables, in addition to having contact with a larger area for monitoring and interaction with the body [3].

Despite the potential of smart technologies in the clothing sector, their incorporation generates reflection on the actual environmental, social, and economic impacts [4-5]. From an environmental perspective, the conventional clothing sector already presents various impacts, some quite severe, throughout the product's life cycle, from raw material extraction to product disposal [6]. Thus, the advent of wearable electronic products carries the risk of further increasing these environmental impacts [4-7]. The potential increase in environmental impact in Smart Clothing is mainly due to the profile of the materials used and the energy demanded in data capture and storage. Smart clothing differs from conventional clothing primarily in the materials used in these products; to make clothing smart, it is necessary to incorporate electronic devices and other non-textile materials [1-4]. According to O'Nascimento [8], nowadays, there is a wide variety of materials that can be used in wearable and smart clothing projects, such as materials composed of electroactive and photoactive polymers, elastomers, bio responsive polymers, shape-memory alloys, chromogenic materials, and composite polymers. The incorporation of these materials means that their manufacturing process differs from conventional clothing, and their use also differs from the basic characteristics of non-technological pieces; thus, the environmental impacts also differ and need to be specifically analyzed.

In sustainability, the preventive approach is the most appropriate to address environmental impacts. Additionally, the specific approach of Design for Sustainability allows designers to anticipate the entire life cycle of the product based on the materials and processes involved. In this way, it is also possible to foresee the product's environmental impacts and make decisions that mitigate these impacts [9].

In the case of smart clothing, it is important to investigate environmental impacts and challenges based on this approach, as these products are still in the development phase and gaining market space. Therefore, an anticipatory study is relevant. This article is an excerpt from larger research on the environmental sustainability of the end of life of smart clothing. To broadly understand this type of product, this article aims to explore the existing literature to identify the main environmental impacts and challenges of smart clothing from a holistic view of the product's life cycle.

1.1 Defining Smart Clothing

The concept of smart clothing has a history that can be traced to the 1960s. At that time several advances occurred in the computational area, allowing the development of new technologies and new products with electronic data processing and communication systems. That period witnesses the creation of the concept of wearable technologies, which can be defined as an innovation approach that uses the body as the basis for the arrangement of electronic technologies, enabling the incorporation of sensors and actuators in proximity of it and the transformation of the functioning of artifacts to a new level, the electronic computational level [8]

One of the similarities between smart clothing and wearables is the relationship with the body. Wearables are computational technologies or electronic sensory devices that are worn on or near the body (Barfield and Caudell, 2001; Tehrani and Michael, 2014; Bower and Sturman, 2015). Another similarity is the digital and computational aspect of the wearable, independent of its function and relationship with the user's body (see Figure 1).

Figure 1: Example of smart clothing available on the market.
Source: Ottobock website (2024).

The Ottobock piece is a neuromodulation suit for relaxing spastic and tense muscles, activating weak muscles and relieving related pain, made for people with neurological diseases that affects the body in a degenerative way [41].

Hexoskin shirt (see Figure 2) offers biometric smart shirts equipped with sensors that monitor heart rate, breathing rate, and activity levels.

The data collected by the shirt is transmitted to a smartphone app or a compatible fitness device for analysis and tracking [42].

2. METHODOLOGICAL PROCEDURE

This article adopts a qualitative approach with an exploratory-descriptive character and a basic nature. To identify relevant themes, gather preliminary information for formulating the research problem, and generate keywords for the next stage of the Systematic Literature Review (SLR), an initial Non-Systematic Literature Review (NSLR) was conducted. Subsequently, the SLR was carried out to collect data and critically analyze the existing literature on the topic, focusing on identifying key emphases and concepts involved.

During the NSLR, searches were conducted in the Brazilian Digital Library of Theses and Dissertations, CAPES Journals, and Google Scholar databases for publications made from 2013 to 2023. The focus was on analyzing the literature on smart clothing, environmental impacts, and related areas pertinent to this study. This stage aimed to gain a better understanding of the constructs involved, the relationships between them, and the identification of key terms and authors.

The protocol used to conduct the SLR was proposed by Conforto, Amaral, and Silva [10]. This stage focused on understanding information related to smart clothing and the environmental impacts of the product's life cycle. The search protocol was developed based on the question, "What are the environmental impacts of the life cycle of smart clothing?" The search period covered 2018 to 2023, and searches were conducted on the Google Scholar and CAPES Journals platforms. The keywords used to generate the search strings were electronic devices, electronic components, sustainability, clothing, fashion, garment, end-of-life, waste, wearables, and smart clothing. The research scope was limited to peer-reviewed international journals published in English, with the first 30 results in order of relevance from the application of the search strings being considered for Filter 01 (title/abstract). Exclusion criteria included the presence of terms such as material engineering, operational processes, digital fashion, business models, and other terms unrelated to design.

Table 1 shows the Systematic Literature Review protocol.

Figure 1: Hexoskin.
Source: Hexoskin website (2024).

Search period	6 years (2018-2023)
Journal Profile	Peer reviewed
Language	English
Search Criteria	Top 50 in order of relevance
Inclusion criteria	Smart clothing, sustainability, end of life, e-waste, IoT, design, fashion, life cycle
Exclusion criteria	Fiber and material engineering, operational process, digital fashion, business models
Search Platform	CAPES periodicals, Google Scholar, Web of Science
Filters adopted	Filter 1: title, abstract and keyword analysis; Filter 2: reading introduction, method, discussion, and final considerations; Filter 3: complete reading
Search fields	All of them
Search strings	"smart clothing" AND "sustainability" "smart clothing" AND "electronic waste" "interactive clothing" AND "electronic waste" AND "sustainability" "smart clothing" AND "life cycle" "e-textiles" AND "end of life cycle" "intelligent clothing" AND "circular design" "wearables" AND "iot in fashion" "e-textiles" AND "electronic waste" AND "end of life cycle" "smart garments" AND "sustainability" AND "end of life cycle" "iot in fashion" AND "sustainability"

Table 1: SLR protocol.
Source: Author (2024).

Only the articles that met the criteria presented were included, which were important for clarifying ideas and constructing the literature.

3. RESULTS

To analyze the results from the consulted literature based on the product's life cycle, they were divided according to the stages of **pre-production, production, distribution, use, disposal,** and **design.**

3.1 Clothing Life-Cycle

The clothing sector already is a complex, wide and heterogeneous arrangement of a large diversity of stakeholders, with an also large variety of relationship dynamics and inputs/outputs [43].

Based on Modefica [44], Gwilt [45] and Salcedo [46], the clothing life cycle can be described as having eight phases:

1) pre-production: the pre- production is the phase where the materials are extracted, from plantation and harvest in the case of natural and artificial fibers, or from petroleum, in the case of synthetic fibers;

2) production: The production phase characterizes the spinning, weaving and dyeing of fibers, making them ready to be commercialized and transported to clothing producers as fabrics;

3) transportation;

4) design: the design phase covers the activities of concept definition, selection of fabrics and trimmings, mapping the collection's product mix and development modeling process, this being the step that will shape the subsequent impacts of launched products [45];

5) confection: the confection and production phase are when the fabric turns into clothing, using techniques such as modeling, cutting and sewing, including prototyping and transport for factions. In turn, distribution is the stage where products go to the places it will be sold to the final consumers;

6) distribution;

7) use and maintenance: after transported and sold, the use stage is, according to Gwilt [45], the way in which clothing is used and maintained and carried out, it directly implies the conditions and period of time that will take to be discarded;

8) disposal: finally, the last phase of a clothing product is the disposal, in it, textile articles are discarded, becoming post-consumer textile waste. Disposal activity can be carried out in different ways, it is directly linked to the behavioral aspect of the consumer. Nonetheless, the disposal phase does not mean that the textile can not be used anymore.

3.2 Pre-production

The production of electronic components and fabrics requires large amounts of energy and resources for the manufacturing of Smart Clothing. Currently, no country can produce all the materials used in ICT - Information and Communication Technology - products, as a substantial number of mineral deposits are only found in specific locations [11].

The manufacturing of these electronic devices requires a diverse mix of ferrous and non-ferrous metals, ceramics, polymers, printed circuit boards, and more than 1,000 other substances [12-13]. In addition to the extraction of these materials, there is also the refining of these minerals, metals, and polymers, which involves processes such as laser cutting, electrical welding, and electroplating, all of which generate pollutants in the air, water, and soil [14].

The production of fabrics and garments also represents a significant environmental challenge, especially considering that the fashion industry is one of the most polluting in the world. According to Gurova et al. [11], this industry is responsible for a considerable portion of global wastewater, accounting for about 20% of the total, and contributes approximately 10% of global carbon emissions. For example, an average kilogram of textile has a carbon footprint of 15 kg.

Also, to select materials for smart clothing it is necessary to comprehend the combination of the textiles with the electronic devices and other components. As well, the designer needs to be careful with the compatibility of the life-cycle spans of the textile materials and the electronics [11]. This could create barriers for the use of natural fibers, for example, since the life span of cotton for example is much lower than electronics components.

Nevertheless, all the fibers have virtues and problems in terms of sustainability. In the smart clothing context, it is important to analyze how to balance the impacts from the products' life cycle [11], for example by comprehending the impacts of the extraction, the combination methods of the textiles with the electronics, the usability and comfort, the washability and ease of care, the total life span and the post-use options (like reuse, repair and recycle).

3.3 Production

The sustainability of a smart wearable, as emphasized by Dulal et al. [7], depends on the individual sustainability of each component and its respective production processes. The production aspects of smart clothing throughout its life cycle, from raw material extraction to disposal, can have negative environmental impacts, such as the use of non-renewable and scarce resources, water contamination, energy consumption, and greenhouse gas emissions [4]. The level of integration between electronic devices and textiles also significantly influences the impact on clothing production, not only by enabling recycling and reuse but also by facilitating cleaning, washing, and technological upgrades.

The usual clothing production process, as detailed by Li et al. [14], involves steps such as spinning, dyeing, cutting, sewing, and finishing. Chemicals are often used to improve aesthetics and usability, resulting in severe pollution. Moreover, significant carbon dioxide emissions, high water demand, and the use of hazardous chemicals occur both during cutting and sewing and in the finishing stages [11].

The production of Information and Communication Technology (ICT) components, as observed by Gurova et al. [11], requires large quantities of toxic materials, such as semiconductors, printed circuit boards, and precious metals like gold, silver, palladium, platinum, base metals, and heavy metals like lead, mercury, arsenic, chromium, among others [15]. However, this combination of electronic materials with textiles can result in the generation of fiber dust, tons of metal scrap, and fabric remnants [14].

If well designed, the toxic materials do not present any risk for the user as they stay in closed containers. The risks they present are related to the pre-production, production and disposal phases, when they normally are not isolated.

3.4 Distribution

The distribution of smart clothing involves transporting the products from factories to retail locations and, ultimately, to consumers. However, this process has a significant environmental impact, as highlighted by Gurova et al. [11]. Carbon emissions and air pollution are direct consequences, especially when fossil fuel-dependent modes of transportation, such as trucks and airplanes, are used. Simplifying supply chains by utilizing local production facilities is one of the suggestions proposed by Gurova et al. [11] to reduce this environmental impact, as the

complexity and geographical dispersion of supply chains, especially for the production of textiles and electronic equipment, make these distribution challenges an increasing environmental concern.

Additionally, the incorporation of electronic materials and components makes the global manufacturing process quite different from conventional clothing, involving the use of global supply chains and, therefore, a higher demand for transportation.

The transportation and distribution of smart clothing is related to energy consumption, greenhouse gases emissions, and air pollution, which contributes to this industry's environmental impacts. Despite the contribution of the dematerialization on the ICT industry, for example with digital and online software instead of a CD-ROM or physical products, in the smart clothing sector it is still necessary to transport some devices to produce the product and to make it available to the consumer.

3.5 Use

When using smart clothing, the environmental impact increases due to the significant energy consumption required to keep them operating. The electronic components integrated into smart textiles consume more energy compared to common electronic devices and regular clothing. This increase in consumption stems from the additional communication and control unit inherent in smart IoT devices, which demands an energy surplus [16]. As a result, even when tasks are completed or the garment is turned off, the smart clothing continues to consume energy, keeping the system active remotely. This higher energy demand puts additional pressure on the electrical grid, which largely depends on energy supplied by hydroelectric plants, in the Brazilian context. These plants emit greenhouse gases, contributing to environmental pollution and global temperature increases, thereby exacerbating sea level rise [16].

Another factor at this stage is the early disposal of wearables due to users' lack of familiarity. According to Ju et al. [17], users often face difficulties during their initial uses, which can lead to frustration and the perception that the product does not meet their expectations or is unnecessary, resulting in the discontinuation of its use. Additionally, the lack of proper collection points for appropriately disposing of smart clothing when it stops functioning is also a significant challenge [18]. These two factors combined contribute to a growing environmental impact.

The functional aspects of smart textiles and clothing are a critical component of use. However, these functions do not necessarily translate into a longer-lasting user-product attachment, and individuals may still abandon the use of these technologies due to factors that also relate to the behavioral level of design, such as the difficulty of maintenance and care for the products and the lack of direct application of the collected data in daily life [19].

Especially for lay users, maintaining smart clothing can negatively affect ease of use and become one of the primary reasons for unsustainable user behavior. In addition to the inherent care and maintenance activities of traditional textiles and clothing, such as laundry, ironing, and repairs (e.g., stitching, buttons, holes, etc.), new activities and skills are required for the maintenance and care of smart textiles and clothing. Charging, accessing and/or storing collected data, specialized laundry requirements (e.g., removing hardware components, hand washing) are examples of new and additional maintenance and care activities [19].

3.6 Disposal

One of the main stages of the life cycle that involves concerns regarding environmental impacts is disposal. In addition to the difficulties already faced in the garment sector with post-use waste disposal, smart clothing presents a new environmental challenge: electronic waste (e-waste) generated from the garments themselves [4]. E-waste is considered a non-homogeneous and complex mixture of potentially toxic components [20-21].

The substances released by e-waste can be classified as hazardous or non-hazardous, with hazardous substances including those with characteristics such as flammability, corrosivity, reactivity, toxicity, pathogenicity, carcinogenicity, teratogenicity, and mutagenicity. These include heavy metals, polycyclic aromatic hydrocarbons, polybrominated diphenyl ethers, and polychlorinated dibenzo-p-dioxins; non-hazardous substances include metals such as Cu, Se, Pt, and Ag, among others [22-25].

The main materials used in smart clothing are sensors, conductive wires and fabrics, microcontrollers, LEDs and display screens, batteries, actuators, connectors and cables, antennas, wireless connection modules, and insulating materials [8]. Despite the miniaturization of these devices to maintain comfort, flexibility, and wearability requirements, the components used contain potentially toxic and scarce materials when improperly disposed [26],

including high-risk environmental materials such as lead, mercury, cadmium, chromium, halogenated or brominated flame retardants, chlorinated substances, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, and refrigerant gases [27-33]. Improper disposal of these materials can negatively impact the environment and various forms of life, including human health.

In the context of disposal, the recycling process itself can contribute to the release of hazardous primary electronic waste residues (Hg, Pb, Cd, PCBs, and other secondary toxic e-waste substances, including polycyclic aromatic hydrocarbons, dioxins, and furans), primarily resulting in soil and water contamination, soil solubilization, leaching, and bioaccumulation [34-35].

To analyze disposal, it is also important to understand the forms of technology integration into clothing, as this impacts the environmental challenges of the product and how it will be dismantled and discarded. There are two approaches to making smart clothing from the textile perspective: first, producing electronic textiles (e-textiles) and then making the garments; or first making the garments and then incorporating the technology into them. The first approach often results in products that are more difficult to dismantle, as electronic components may be directly incorporated into the fibers and textile structure [4]. Another possible approach, considering the electronic nature, is to create circuits and devices using various materials, which are then integrated into the garments and textiles, a principle related to the maker movement. Alternatively, ready-made solutions from manufacturers can be used and integrated into pre-made garments.

3.7 Design

The development of products through design for sustainability involves various aspects, including the stages of pre-production, production, use, and end-of-life, and the application of strategies for prevention, minimization of occurrences, and mitigation of environmental impacts already at the conceptual development phase [36]. In the context of environmental sustainability, one of the potential contributions of design lies in the ability to design the artifact considering the entire life cycle before it is produced, meaning there is a possibility to foresee the product's impact before it exists [37].

By anticipating the product's impacts in every aspect that requires decision-making, such as material selection, processes, and final performance, it is possible to apply strategies at the conceptual phase that address each impact and make the product more suitable with better environmental performance indicators [37]. Factors such as washability, durability, aesthetics, ease of use, programming, maintenance, and updates must be considered to avoid premature disposal of such products.

3.8 Challenges on reuse, repair and recycle of Smart Clothing

Unlike traditional clothing, smart garment pieces contain integrated electronic components, like sensors, batteries, and microcontrollers [1, 38]. In the context of end-of-life approaches, the technological complexity makes the reuse process different from when it comes to conventional clothing. Strategies aiming at reuse within the scope of the artifact and the combination with systems to support transferring the product can increase the ease of extending the life cycle and favor the implementation of reuse [9, 36]. Examples include second-hand stores, and banks of EEE parts for reuse and exchange schemes.

The reparability of smart garments also becomes a problem since both materials have distinct repair needs. Clothes are normally repaired for small issues like holes, seams, or hems unraveling, while basic electronics repairs often involve replacing easily accessible batteries and other components [39]. When it comes to smart clothing, these repair methods, which are seen as straightforward, become difficult following the level of integration between the electronics and fabric. Insufficient reparability promotes short product life cycles through premature obsolescence [39, 40]. In the analysis of specific strategies to enable repair, it was demonstrated that its application demands adaptation in how clothing companies usually operate, relating to customers and in the conventional market paradigm, which aims to sell new products. In the case of making repairs possible, the manufacturer and/or retailer must pay attention to after-sales, especially in cases where parts for exchanging and adapting the product are not available at the time of purchase. The possibility of providing services that contribute to extending the life cycle was also identified, such as software upgrades and updates and specific spaces for repair and customization within stores.

In the recycling matter, currently, there are some regulations for the disposal of components that contain WEEE (Waste Electrical and Electronic Equipment) that could be applied to the disposal of smart clothing

[39]. Still, these regulations have gaps regarding smart clothing specifications and particular issues [39]. Even though smart clothing is already reaching recycling facilities, they are often discarded incorrectly because of the lack of proper infrastructure to handle the material [4]. Additionally, the recycling issues are associated with the challenge of achieving the economic and financial viability of managing the electronic waste present in Smart Clothing, since smart clothing pieces have a low mass of electronic components per product of electronic components when compared to other types of EEE (EPPINGER et al. 2022).

3.9 Life-cycle impacts

The environmental implications of the presence of electronic components on clothing is better explained when structured around the life cycle stages, as illustrated in Figure 3. To facilitate the comprehension of the content, the table 2 shows the whole life cycle of smart clothing and the impacts regarding each phase.

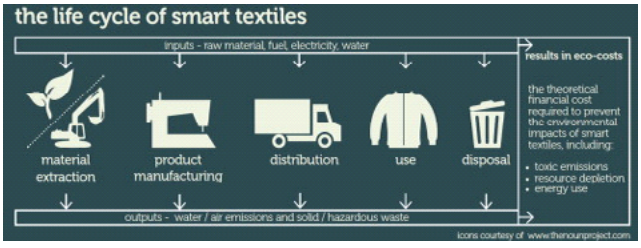

Figure 3: Smart clothing environmental impacts.
Source: Velden, Kuusk and Kohler (2015).

Life-cycle phase	Impacts
Pre-production	• Requires large amounts of energy and resources, such as mix of ferrous metals, non-ferrous metals, ceramics, polymers, printed circuit boards and more than 1000 other substances; • Refinement of these ores end up generating pollutants in the air, water and soil; • Fabric pre-production is responsible for a considerable portion of global waste water, representing around 20% of the total, in addition to contributing approximately 10% of global carbon emissions;
Production	• Chemicals pollution; • Cutting and sewing and in the finishing stages, there are significant emissions of carbon dioxide, a large demand for the use of water and dangerous chemicals; • Use of toxic materials; • Combination of electronic materials with textiles can result in the generation of fiber dust, tons of metal scrap and fabric scraps;
Distribution	• Carbon emissions and air pollution are direct consequences, especially when using modes of transport dependent on fossil fuels, such as trucks and planes;
Use	• Electronic components integrated into smart textiles consume more energy compared to ordinary electronic devices and clothing This increase in consumption arises from the additional communication and control unit inherent in smart IoT devices, requiring a surplus of energy (Yugank et al., 2022). • Energy production emits greenhouse gases, contributing to environmental pollution and rising global temperatures, thus exacerbating sea level rise (Yugank et al., 2022).
Disposal	• Generates a new environmental challenge: electrical and electronic waste (WEEE) from clothing items; • Substances released by WEEE can be classified as dangerous, including heavy metals, polycyclic aromatic hydrocarbons, poly dibenzofurans, ethers brominated diphenyls and polychlorinated dibenzo-p-dioxins;

Table 2: Smart clothing environmental impacts.
Source: Velden, Kuusk and Kohler (2015).

This table summarizes the environmental impacts of smart clothing and can be used to compare conventional clothing, waste of electronic equipment and clothing with technology embedded. These three types of product are related and can be explored together to comprehend smart clothing challenges, impacts and possible solutions.

4. DISCUSSION

When analyzing the environmental impacts of smart clothing and comparing it with the conventional clothing sector, it is possible to verify that this type of product increases existing environmental challenges, since impacts occur at all stages of the life cycle of both the clothing and of electronic devices together. Therefore, additional negative environmental impacts can be identified throughout the product life cycle. From the extraction of materials in pre-production, to production processes, smart clothing demands the application of materials and manufacturing procedures different from conventional textiles, such as toxic materials, semiconductors, printed circuit boards in precious metals such as gold, silver, palladium, platinum, base metals and heavy metals such as lead, mercury, arsenic, chromium, among others (Huang et al., 2022), meaning that the environmental impacts of these clothes are not restricted to those linked to textiles and apparel, but come close to the impacts of electrical and electronic equipment.

The use and maintenance of these products also differ from the washing, drying and ironing of conventional fashion products, as the electrical and electronic equipment present in the clothes require greater energy and water consumption for their electrical operation, in addition to requiring specific cleaning care to avoid damaging the product equipment. Disposal also presents itself as a problematic step within the environmental scope, since the current infrastructure for repairing and recycling clothing and electronic equipment does not support products that integrate clothing and electrical and electronic technologies.

Smart clothing adds further complexity to the Design process as it has the layer of digital processing and the associated ethical considerations. Complexity is enhanced with issues such as data security, ethical and legal issues of data ownership, user privacy, interoperability (connectivity between artifacts from different manufacturing companies), higher complexity in interface use, social acceptance, increased user dependence on technologies, decreased of human contact and excessive use of unnecessary fashionable technologies for commercial purposes only. In this context, the fashion designer needs to be attentive and capable of addressing all these issues raised during the development of smart clothing, so that the positive impacts outweigh the setbacks.

Under the waste hierarchy "prevention" is the most effective strategy to deal with environmental impacts. In this respect Design for Sustainability approaches at the conceptual stage can anticipate solutions for the entire life cycle of smart clothing. Such approaches can contribute to predict/envision the environmental impacts of the product and make decisions that mitigate these impacts (Manzini and Vezzoli, 2008). In the case of smart clothing, it is important to investigate the environmental impacts and challenges based on this approach since these are products that are still in the development phase and gaining space in the market, so an anticipatory study is pertinent.

In addition to the aforementioned advantages, smart clothing presents potential benefits for the challenges presented by sustainability. There are, also, a growing number of solutions that substantially mitigate the inherent environmental impacts of smart clothing. Tat et al. (2022) presents solutions that are capable of capturing movement or heat from the user and transforming it into energy to power various devices or the smart clothing item itself. The insertion of electronic devices close to the body allows another energy source to be associated with the biomechanical energy supply, as only one source may be insufficient to generate electricity or fail due to energy supply circumstances that are sometimes unlikely to be available, such as solar irradiance in rainy or cloudy weather. As smart textiles are diverse and can link multiple parts of the body, they could also bring together multiple energy sources, producing a hybrid system. For example, a structured micro textile cable, using the shuttle-flying process on an industrial loom to weave polytetrafluoroethylene with photoanode and copper electrode strands, could simultaneously harvest solar and biomechanical energy (i.e., when exercising in the sun) (Tat et al., 2022).

Still in terms of environmental benefits, smart clothing allows the development of products that consume less energy than other electronic devices for the same function. Also compared to other non-wearable electronic devices, smart clothing has the advantage of requiring the miniaturization of components and consequent minimization of the use of resources, as they are pieces

that need to be comfortable, flexible and aesthetically pleasing (Tat et al., 2022).

5. FINAL CONSIDERATIONS

Finally, it was possible to analyze the impacts of smart clothing from the product life cycle concept, highlighting the potential of design as a development approach with environmental awareness, particularly regarding products based on emerging technologies, such as smart clothing. Additionally, anticipatory studies of the environmental impacts and challenges of this type of product can contribute to risk mitigation and the development of intrinsically more sustainable products, given that they are not yet widely available in the market and are at an early stage of innovation.

This study contributes to the expansion of research in Brazil on smart clothing and to the understanding of environmental impacts as a means to guide the development of heuristics and guidelines for these products based on Design for Sustainability. The study also advances environmental awareness in the design field, which, beyond theory, should address theoretical and practical aspects related to the product life cycle to develop sustainable solutions, especially for products still in the exploration phase and with embedded computational technologies.

For future research, it is recommended to explore topics such as the social and economic impacts of the smart clothing life cycle, as well as seeking solutions for the challenges identified in the literature.

REFERENCES

JIANG, S. et al. **Applications of Smart Clothing:** Brief Overview. 2021. Communications in Development and Assembling of Textiles Products. 2. 123-140.

LEE, J.; KIM, D.; RYOO, H.-Y.; SHIN, B.-S. Sustainable Wearables: Wearable Technology for Enhancing the Quality of Human Life. **Sustainability**, v. 8, n. 5, p. 466, 2016. MDPI AG.

AHSAN, M. et al. **Smart Clothing Framework for Health Monitoring Applications**. Signals, v. 3, n. 1, p. 113–145, 2 mar. 2022.

KÖHLER, A. R. **Anticipatory eco-design strategies for smart textiles : perspectives on environmental risk prevention in the development of an emerging technology.** Delft Academic Press. 2013.

VELDEN, N. M. et al. **Life Cycle Assessment and Eco-Design of Smart Textiles:** The Importance of Material Selection Demonstrated Through E-Textile Product Redesign. Materials and Design, 2015, 313-324, 84.

FLETCHER, K., GROSE, L. **Moda & sustentabilidade:** Design para mudança. 1. ed. São Paulo: SENAC. 2012.

DULAL, M. et al. **Toward Sustainable Wearable Electronic Textiles.** ACS Nano, 2022, 19755-19788, 16(12).

O´NASCIMENTO, Ricardo. **Roupas inteligentes:** Combinando moda e tecnologia. São Paulo: Senac, 2020.

MANZINI, Ezio; VEZZOLI, Carlo. **O desenvolvimento de produtos sustentáveis:** os requisitos ambientais de produtos industriais. 1. ed. 2. reimpr. CARVALHO, A. Traduzido por: CARVALHO, A. São Paulo: Editora da Universidade de São Paulo, 2008. Título original: Lo sviluppo di prodotti sostenibili: I requesiti ambientali dei prodotti industriali.

CONFORTO, E. C.; AMARAL, D. C.; SILVA, S. L. DA. **Roteiro para revisão bibliográfica sistemática:** aplicação no desenvolvimento de produtos e gerenciamento de projetos. Trabalho apresentado no 8° Congresso Brasileiro de Gestão de Desenvolvimento de Produto, Porto Alegre, 2011.

GUROVA, O., MERRITT, T. R., PAPACHRISTOS, E., VAAJAKARI, J. **Sustainable solutions for wearable technologies:** Mapping the product development life cycle. Sustainability, Aalborg, 12, 20, 2020.

SHEVCHENKO, T.; LAITALA, K.; DANKO, Y. **Understanding Consumer E-Waste Recycling Behavior:** Introducing a New Economic Incentive to Increase The Collection Rates. Sustainability (Switzerland), 2019, 11(9).

AKRAM, R. N. et al. **Trends of Electronic Waste Pollution and Its Impact on the Global Environment and Ecosystem.** Environmental Science and Pollution Research, 2019, 16923-16938, 26 (17).

LI, Q.; XUE, Z.; WU, Y.; ZENG, X. **The Status Quo and Prospect of Sustainable Development of Smart Clothing. Sustainability.** 2022, 14, 990.

GHULAM, S.; ABUSHAMMALA, H. **Challenges and Opportunities in the Management of Electronic Waste and Its Impact on Human Health and Environment.** Sustainability (Switzerland), 2023, 15(3).

YUGANK, H., SHARMA, R., GUPTA, S. **An Aroach to Analyse Energy Consumption of an IoT System.** International Joppurnal of Information Technology (Singapore), 2022, 2549-2558, 14(5).

JU, N.; LEE, N. **Consumer Resistance to Innovation:** Smart Clothing. Fashion and Textiles, 2020, 7(1).

VESKE, P.; ILÉN, E. Review of the End-of-Lide Solutions in Electronics-based Smart Textiles. **Journal of the Textile Institute,** 2021, 1500-1513, 112(9).

CHARTER, M.; PAN, B.; BLACK, S. **Accelerating Sustainability in Fashion, Clothing and Textiles.** [s.l.] Taylor & Francis, 2023.

WILLIAMS, I. D. **Global Metal Reuse, and Formal and Informal Recycling from Electronic and Other High-Tech Wastes.** Metal Sustainability, p. 23–51, 19 ago. 2016.

KUMAR, S, S.; CHAUHAN, A.; SARKAR, B. **Supply Chain Management of E-Waste for End-of-Life Electronic Products with Reverse Logistics.** Mathematics, 2023, 11(1).

AWASTHI , A.; ZENG , X.; LI, J. **Environmental pollution of electronic waste recycling in India:** a critical review. Environ Pollut , v. 211, p. 259–270, 2016.

BAHERS, J.-B.; KIM, J. **Regional approach of waste electrical and electronic equipment (WEEE) management in France.** Resources, Conservation and Recycling, v. 129, p. 45–55, fev. 2018.

BRASIL. Lei 12.305, de 02 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos; altera a Lei nº 9.605, de 12 de fevereiro de 1998; e dá outras providências. Diário Oficial da República Federativa do Brasil, Poder Executivo, Brasília, DF, 03 ago.

ZHANG, K.; SCHNOOR, J. L.; ZENG, E. Y. **E-Waste Recycling: Where Does It Go from Here?** Environmental Science & Technology, v. 46, n. 20, p. 10861–10867, 3 out. 2012.

ZENG, X., LI, J., STEVELS, A.L.N., LIU, L. **Perspective of electronic waste management in China based on a legislation comparison between China and the EU.** Journal of Cleaner Production, v. 51, p. 80–87, 15 jul. 2013.

SRIVASTAV, A. L. et al. **Concepts of circular economy for sustainable management of electronic wastes:** challenges and management options. Environmental Science and Pollution Research, v. 30, 28 fev. 2023

WIDMER, R. et al. **Global perspectives on e-waste.** Environmental Impact Assessment Review, v. 25, n. 5, p. 436–458, jun. 2005.

SEPÚLVEDA, A. et al. **A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling:** Examples from China and India. Environmental Impact Assessment Review, v. 30, n. 1, p. 28–41, jan. 2010.

DIAS, P., MACHADO, A., HUDA, N., & BERNARDES, A. M. . **Waste electric and electronic equipment (WEEE) management:** A study on the Brazilian recycling routes. Journal of Cleaner Production. 2018. 174, 7–16. Disponível em: <https://doi.org/10.1016/j.jclepro.2017.10.219>. Acesso em: 20 de julho de 2023.

OLYMPIO, K. P. K. et al. **What are the blood lead levels of children living in Latin America and the Caribbean?** Environment International, v. 101, p. 46–58, abr. 2017.

LECLERC, S. H.; BADAMI, M. G. **Extended producer responsibility for E-waste management:** Policy drivers and challenges. Journal of Cleaner Production, v. 251, p. 119657, 1 abr. 2020

YONG, Y. S.; LIM, Y. A.; ILANKOON, I. M. S. K. **An analysis of electronic waste management strategies and recycling operations in Malaysia:** Challenges and future prospects. Journal of Cleaner Production, v. 224, p. 151–166, jul. 2019.

PALANISAMY, KRITHIGA; SUBBURAJ, RAMPRADHEEP GOBI. **Integration of electronic waste management: a review of current global generation, health impact, and technologies for value recovery and its pertinent management technique.** Environmental Science and Pollution Research, v. 30, n. 23, p. 63347–63367, 14 abr. 2023.

LIU, H. et al. **E-waste recycling induced polybrominated diphenyl ethers, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins and dibenzo-furans pollution in the ambient environment.** Environment International, v. 34, n. 1, p. 67–72, jan. 2008.

SHEN, C. et al. **Dioxin-like compounds in agricultural soils near e-waste recycling sites from Taizhou area, China:** Chemical and bioanalytical characterization. Environment International, v. 35, n. 1, p. 50–55, jan. 2009.

SAMPAIO, Claudio P. et al. **Design para a sustentabilidade:** Dimensão Ambiental. Curitiba: Insight, 2018.

LEWIS, H.; GERTSAKIS, J.; GRANT, T.; MORELLI, N.; SWEATMAN, A. **Design + Environment**: a Global Guide to Designing Greener Goods. Sheffield: Greenleaf, 2001. 200 p.

RUCKDASHEL, R.; KHADSE, N.; PARK. J.; Smart E-Textiles: Overview Of Components And Outlook. **Sensors**, 2022, 22(16).

HARDY, D., WICKENDEN, R., MCLAREN, A. Electronic Textile Reparability. **J. Clean.** Prod. 2020, 276.

EPPINGER, E., SLOMKOWSKI, A., BEHRENDT, T. Design For Recycling Of E-Textiles Current Issues Of Recycling Of Products Combining Electronics And Textiles And Implications For A Circular Design Approach. In **Recycling Recent Advances.** Intechopen: London, Uk, 2022.

Exopulse Mollii Suit | **Reduces spasticity, activates muscles.** In: <https://www.ottobock.com/en-gb/product/28XP1000> Accessed in jul. 2024.

HEXOSKIN. Hexoskin **Smart Shirts - Cardiac, Respiratory, Sleep & Activity Metrics.** In: <https://hexoskin.com/srslti-d=AfmBOoqzYOCgxcH0zQwlpZjwZuKYxlT25i8cgkvGcgt-sRc81Ud3LuC-t>. Accessed in sep. 2023.

YEE, L. W.; HASSAN, S, H.; RAMAYAH, T. **Sustainability and Philanthropic Awareness in Clothing Disposal Behavior Among Young Malaysian Consumers.** SAGE Open, v. 6, n. 1, p. 1-10, 2016. In: https://journals-sagepub-com.ez22.periodicos.capes.gov.br/doi/10.1177/2158244015625327.

INSTITUTO MODEFICA. **Possibilidades para moda circular no Brasil:** padrões de consumo, uso e descarte de roupas. São Paulo, 2020b.

GWILT, A. Producing sustainable fashion: the points for positive intervention by the fashion designer. In: GWILT, Alison; RISSANEN, Timo (Eds.). **Shaping sustainable fashion: changing the way we make and use clothes. Londres:** Earthscan, 2011.

SALCEDO, E. **Moda ética para um futuro sustentável.** Tradução: FRACALOSSI, D. São Paulo: GG Moda, 2014.

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DURABILITY EVALUATION OF WATTLE AND DAUB WALL PANELS: EXPERIMENTAL HOUSING BUILDINGS 001 AND 002 IN SÃO CARLOS - SP

AVALIAÇÃO DA DURABILIDADE DE PAINÉIS DE PAREDES DE PAU A PIQUE: EDIFÍCIOS EXPERIMENTAIS DE HABITAÇÃO 001 E 002 EM SÃO CARLOS - SP

EVALUACIÓN DE LA DURABILIDAD DE PANELES DE PARED DE BAHAREQUE: EDIFICIOS EXPERIMENTALES DE VIVIENDAS 001 Y 002 EN SÃO CARLOS - SP

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ABSTRACT

Between 1998 and 1999, two experimental housing units were built at USP São Carlos (SP) with the aim of researching the use of low-carbon technologies in social housing projects. In both units, prefabricated modular panels were designed and executed in wattle and daub, with a modular base of 75 cm and a height of 2.40 m, using sawn pine as one of their experimental sealing subsystems. This research proposes to evaluate the performance of the panels with a focus on durability, by defining and verifying the fulfillment of performance requirements and criteria, considering design and implementation detail characteristics. This verification is established through the visual identification of pathological manifestations, such as cracks, stains, and detachment on the surface of the panels, using photographs of the facade taken by drone flights.

KEYWORDS

Wattle and Daub; Earth construction; Durability Evaluation

RESUMO

Entre 1998 e 1999, duas unidades habitacionais experimentais foram construídas na USP São Carlos (SP) com o objetivo de pesquisar o uso de tecnologias de baixo carbono em projetos de habitação social. Em ambas as unidades, painéis modulares pré-fabricados foram projetados e executados em pau a pique, com uma base modular de 75 cm e uma altura de 2,40 m, utilizando pinho serrado como um de seus subsistemas experimentais de vedação. Esta pesquisa propõe avaliar o desempenho dos painéis com foco na durabilidade, definindo e verificando o cumprimento de requisitos e critérios de desempenho, considerando características de projeto e detalhes de execução. Essa verificação é estabelecida através da identificação visual de manifestações patológicas, como fissuras, manchas e descolamento na superfície dos painéis, utilizando fotografias da fachada tiradas por voos de drones.

PALAVRAS-CHAVE

Pau a Pique; Construção em terra; Avaliação de Durabilidade

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RESUMEN

Entre 1998 y 1999, se construyeron dos unidades habitacionales experimentales en la USP São Carlos (SP) con el objetivo de investigar el uso de tecnologías de bajo carbono en proyectos de vivienda social. En ambas unidades, se diseñaron y ejecutaron paneles modulares prefabricados de bahareque, con una base modular de 75 cm y una altura de 2,40 m, utilizando pino aserrado como uno de sus subsistemas experimentales de sellado. Esta investigación propone evaluar el rendimiento de los paneles con un enfoque en la durabilidad, definiendo y verificando el cumplimiento de los requisitos y criterios de rendimiento, considerando características de diseño y detalles de ejecución. Esta verificación se establece mediante la identificación visual de manifestaciones patológicas, tales como grietas, manchas y desprendimiento en la superficie de los paneles, utilizando fotografías de la fachada tomadas por vuelos de drones.

PALABRAS CLAVE

Bahareque; Construcción en tierra; Evaluación de Durabilidad

1. INTRODUCTION

Between 1998 and 1999, at the University of São Paulo, São Carlos Campus (SP), two Experimental Housing Units were constructed as part of the research project "Social Housing: Architectural Design and Production of Components in Reforestation Wood and Raw Earth,"funded by FAPESP (Proc. 95/9716-9).

The construction of these buildings aimed to research the use of low-carbon technologies in social housing, focusing on their construction processes and the performance of these systems over time. The two experimental housing units, 001 and 002, respectively (Figure 1), were constructed using a structural system of eucalyptus sawn timber pillars and beams, combined with three types of wall systems: straw clay, wattle and daub, and air cushion.

The wattle and daub, also known as "taipa de mão", "taipa de sopapo" and "pau-a-pique" in Brazil, according to the Ibero-American Network of Architecture and Construction with Earth (PROTERRA), is classified as a "mixed technique." This terminology is used to describe techniques that are characterized by the presence of a structural framework system made of wood or bamboo, which supports the infill and coating of earth (GARZÓN, 2011). As this technique utilizes abundant raw materials, does not produce waste in the absence of industrialized components, requires low energy, and has low carbon emissions during its production (JOAQUIM, 2015), it can be considered environmentally sustainable and a viable alternative for the construction sector. Due to these factors, the mixed technique was one of the construction techniques chosen to be tested in the experimental buildings, utilizing prefabrication processes of modular panels.

As initially proposed in 1995, this article aims to evaluate the durability of the 9 panels applied in Unit 001 and the 18 modular panels used in Unit 002, both employing the mixed technique.

2. METHODOLOGY

The methodology used was adapted from Souza (1981) and followed these steps:

a) Identification of User Requirements; Qualitative performance requirements and Quantitative performance criteria to be met;

b) Characterization of the buildings and their design conditions;

c) Characterization of the exposure conditions;

d) Development of spreadsheets for identifying pathological manifestations and analyzing their possible causes;

e) Performance evaluation with verification of compliance with the established requirements and criteria.

Figure 1: Experimental Housing Units 001 (Left - East view) and 002 (Right - West view)
Source: Elaborated by the Authors (2022)

2.1 Identification of performance parameters to be met

Among the various user requirements applicable to buildings listed by ISO/DO 6241, which serve as the basis for performance evaluation in SOUZA's (1981) method, the requirement defined for the present research was Durability Requirements.

To evaluate the durability of the mixed technique panels in the two buildings, qualitative requirements and quantitative criteria were defined. The established requirements focus on the integrity of the coating, where the presence of gaps between the panels and the main wooden structure and detachment of plaster exposing the internal structure of the framework are unacceptable. The acceptable criterion for the presence of cracks is that they must be less than 1mm in width.

2.2 Characterization of the buildings and their design conditions

To understand the performance of the buildings over their lifespan, it is necessary to list the set of actions that act upon them and how these relate to their specific design characteristics. For construction techniques involving raw earth, construction practices that address issues such as protection against weather conditions and site-specific characteristics related to moisture and sun exposition are essential to ensure that the buildings maintain their functionality and durability after occupation (LOPES, 1998). The relevant data were collected from technical visits, alongside the continuous reading and review of research reports prepared between 1996 and 2000 for FAPESP (Proc. 95/9716-9), which describe in detail the construction stages, establishing the characterization of the buildings, their design, and exposure conditions.

The mixed technique was used in both Housing Units through prefabricated panels. In Unit 001, panels measuring 3.00 x 2.40m and 1.50 x 2.40m, from pillar to pillar, were tested, with the interface (panel-pillar) filled with castor oil resin (Figure 2). In Unit 002, four modular panels measuring 0.75 x 2.40m were used to fill the 3m span. The interface (panel-pillar and panel-panel) with a dry joint was resolved by placing joint covers (2.5 x 5.0 cm) in wooden slats (Figure 3).

2.3 Characterization of the exposure conditions

Regarding the climatic conditions to which the mixed technique panels are subjected, it's possible to see in In Figure 4, that the yellow panels (001) have their faces oriented towards the East, West, and South. The blue panels (002), on the other hand, are oriented towards the North, South, and West, receiving sunlight in the afternoon and being exposed to greater temperature fluctuations throughout the day

Figure 5 refers to the average rainfall index of the city of São Carlos throughout the year, with a notable increase in rainfall between November and February.

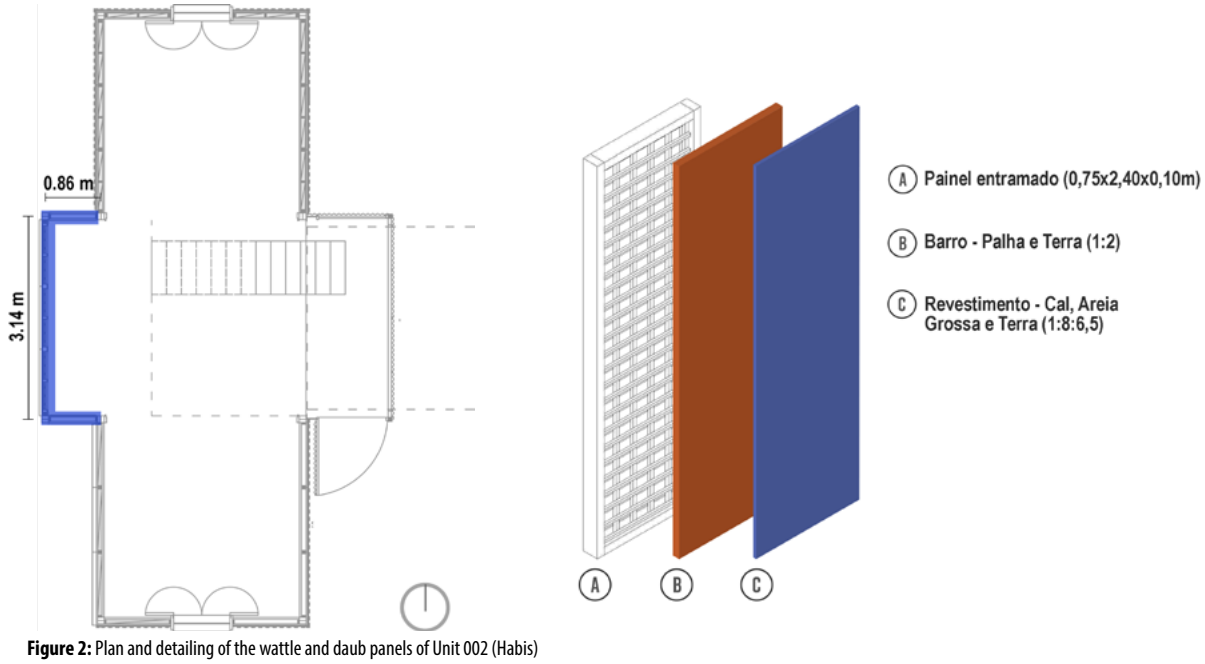


Figure 2: Plan and detailing of the wattle and daub panels of Unit 002 (Habis)
Source: elaborated by the Authors (2022)

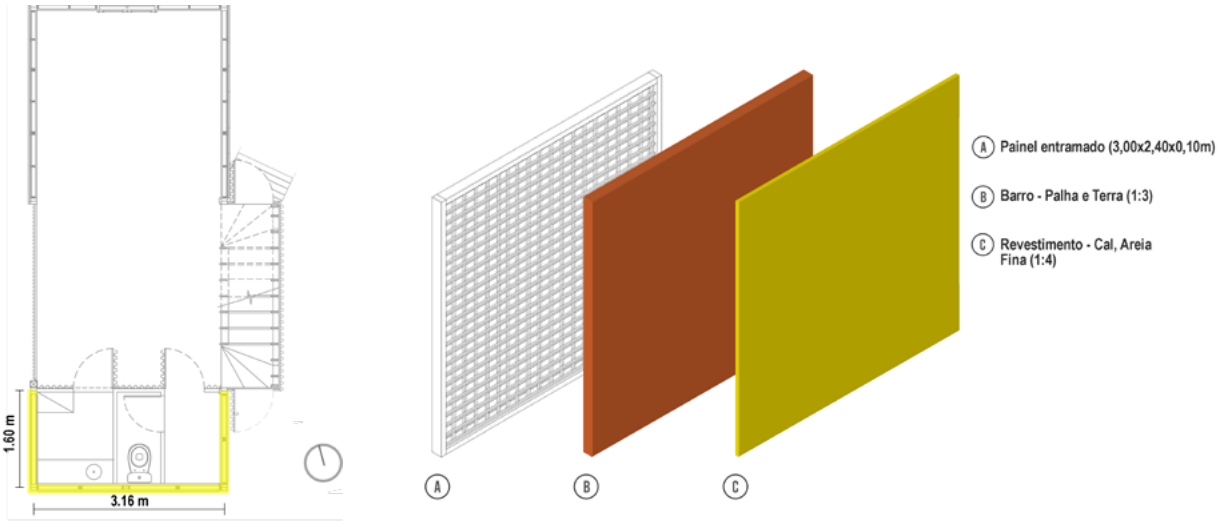


Figure 3: Plan and detailing of the wattle and daub panels of Unit 001 (Nomads)
Source: elaborated by the Authors (2022)

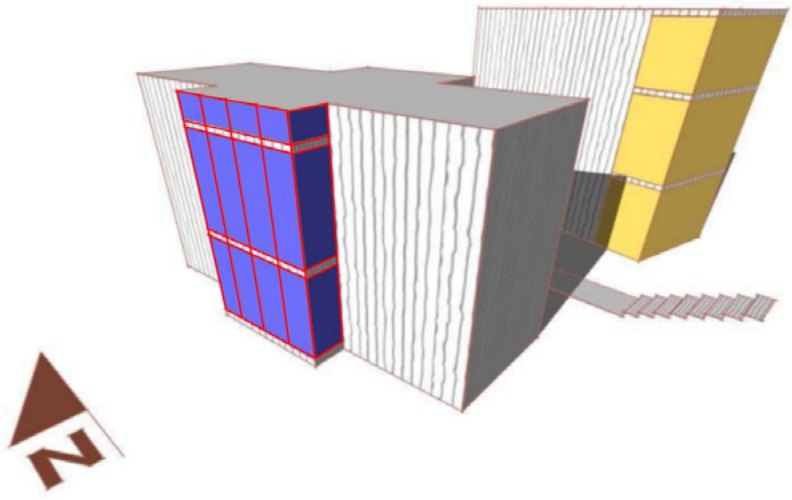


Figure 4: Orientation of the wattle and daub panels: UE1 (yellow) and UE2 (blue)
Source: (adapted in 2023 from Maia et al., 2009)

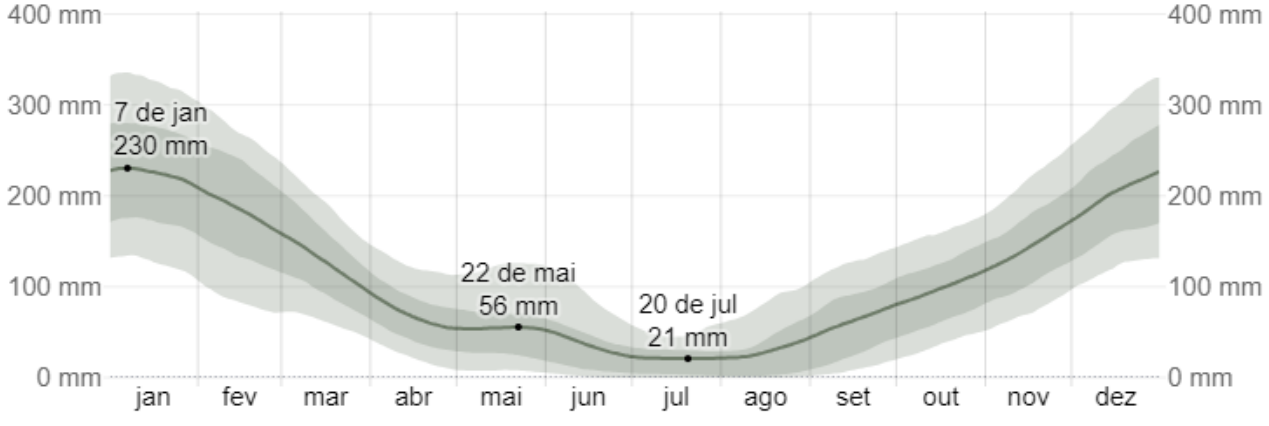


Figure 5: Average rainfall of the city of São Carlos, Brazil.
Source: Weathersparks (2024)

2.4 Identification of the pathological manifestations

The verification of the criteria and requirements is conducted through a visual analysis of pathological manifestations, including cracks, stains, and detachments. For this purpose, the "Dji Mavic Air 2" drone (Figure 4) was used to capture photographs of the facades of both buildings. Since the goal was to create a high-resolution photogrammetric 3D model of the buildings that could capture the smallest details on the facades, a total of 282 photographs were taken for Unit 001 and 269 for Unit 002.

The photogrammetry was carried out using the point cloud processing software Agisoft Metashape Pro (Figure 5) and was later edited in the Cloud Compare software (Figure 5) at the Digital Design Laboratory of the Institute of Architecture and Urbanism (IAU-USP).

Figure 6: Drone Mavic Air 2 capturing the façades of Unit 001 (Left), Photo captured (Right).
Source: Elaborated by the Authors (2022)

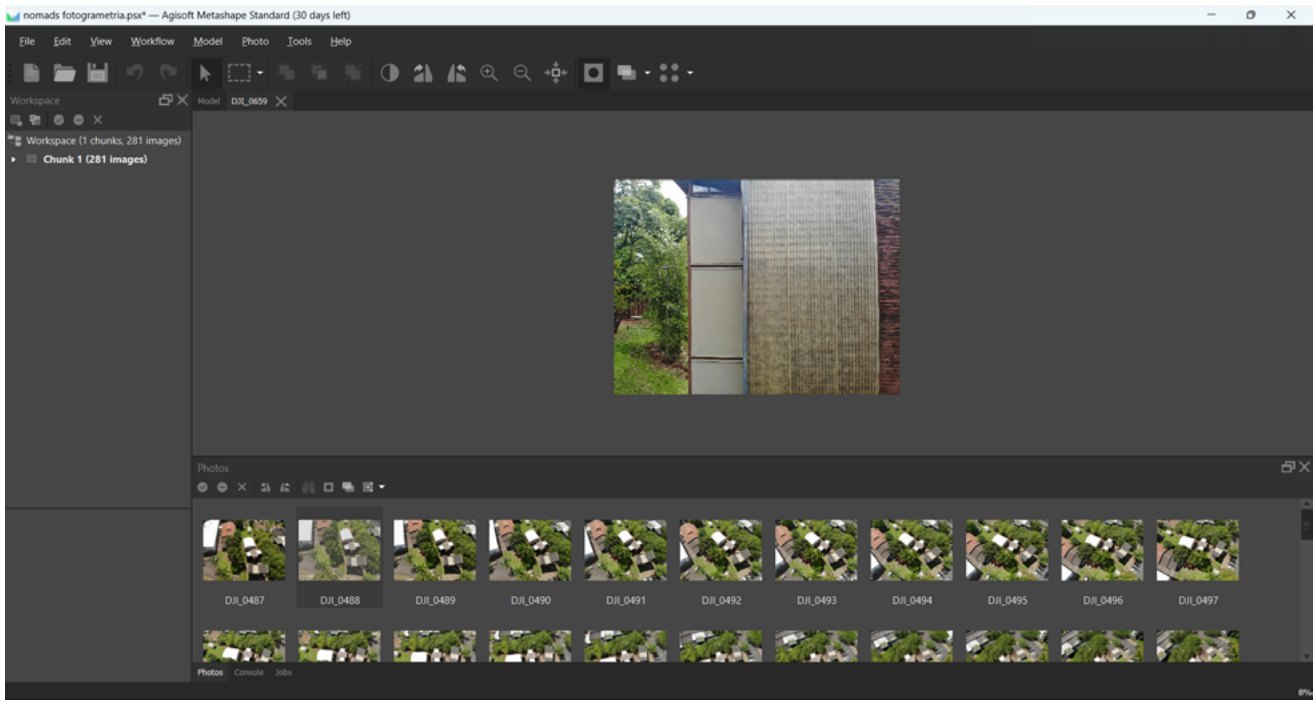


Figure 7: Interface of the Agisoft Metashape Pro point cloud processing software
Source: Elaborated by the Authors (2022)

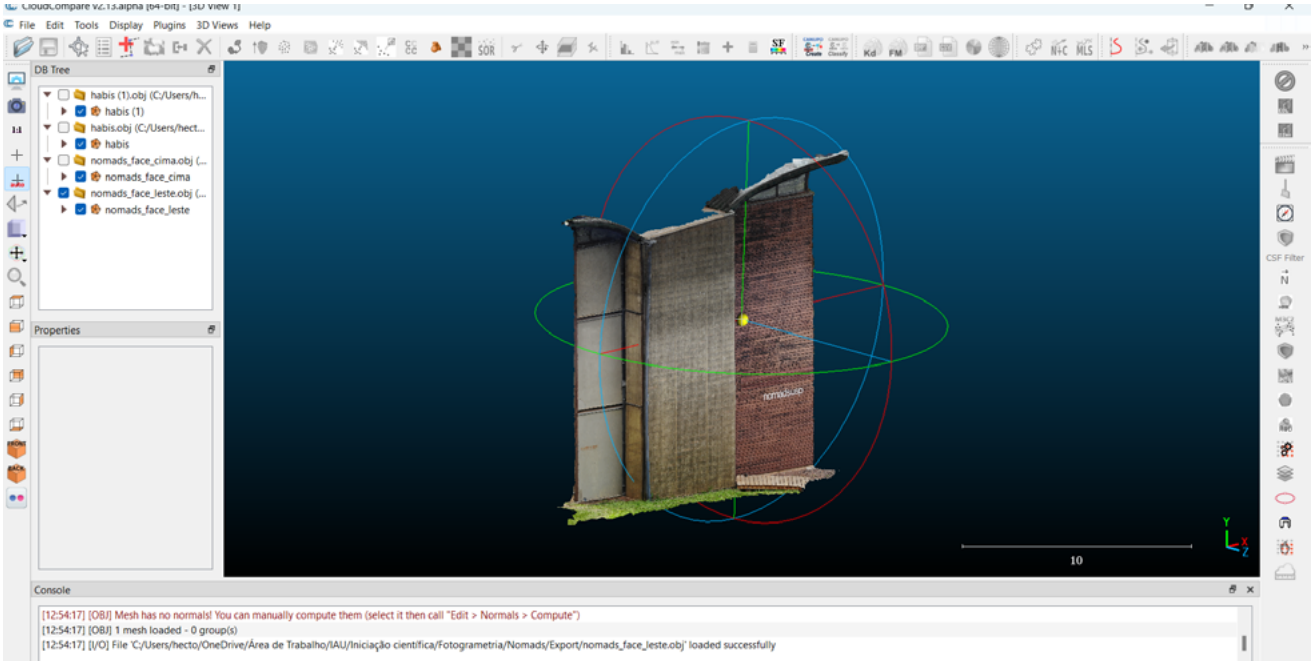


Figure 8: Three-dimensional model of the East face of 001 in Cloud Compare software.

Source: Elaborated by the Authors (2022)

Figure 9: Process of overlaying technical drawings and photogrammetry for pathology identification.

Source: Elaborated by the Authors (2022)

After exporting the facade images from the photogrammetry software, technicalelevation drawings of each building were superimposed to identify pathologicalmanifestations in each panel of mixed technique (Figure 6).

For the preparation of the Performance Evaluation Worksheet, for the identification ofthe pathological manifestations in the panels, the coding PXNY was created:

- **P:** represents the type of pathological manifestation identified, with Fissures (F) and Detachments (D).
- **X:** corresponds to the initials of the cardinal directions: North (N), South (S), East (L), and West (O).
- **N:** is the increasing numerical enumeration of the panels on each face, going from top to bottom.
- **Y:** is the alphabetical code (A, B, C...) assigned to each pathology from top to bottom.

Finally, a spreadsheet was developed with the identified pathological manifestations observed during the research, along with all collected data on site implementation and project details. Each panel was then subjected to a verification and classification process based on whether it met the defined requirements and criteria.

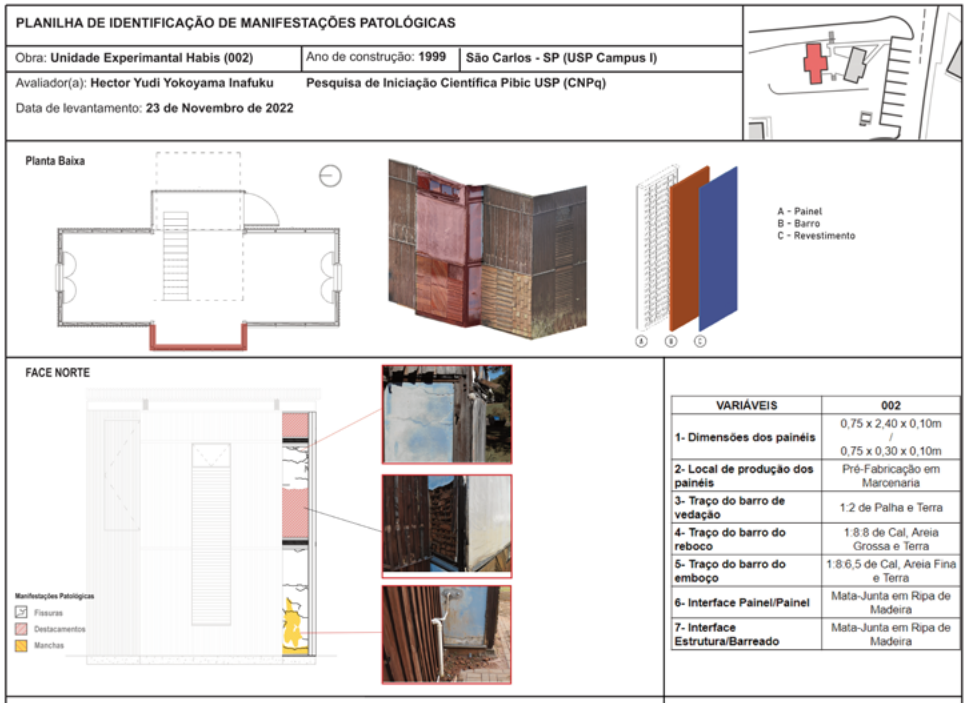
Figure 10: Pathological Manifestations of Unit 001 (East Façade)
Source: Elaborated by the Authors (2022)

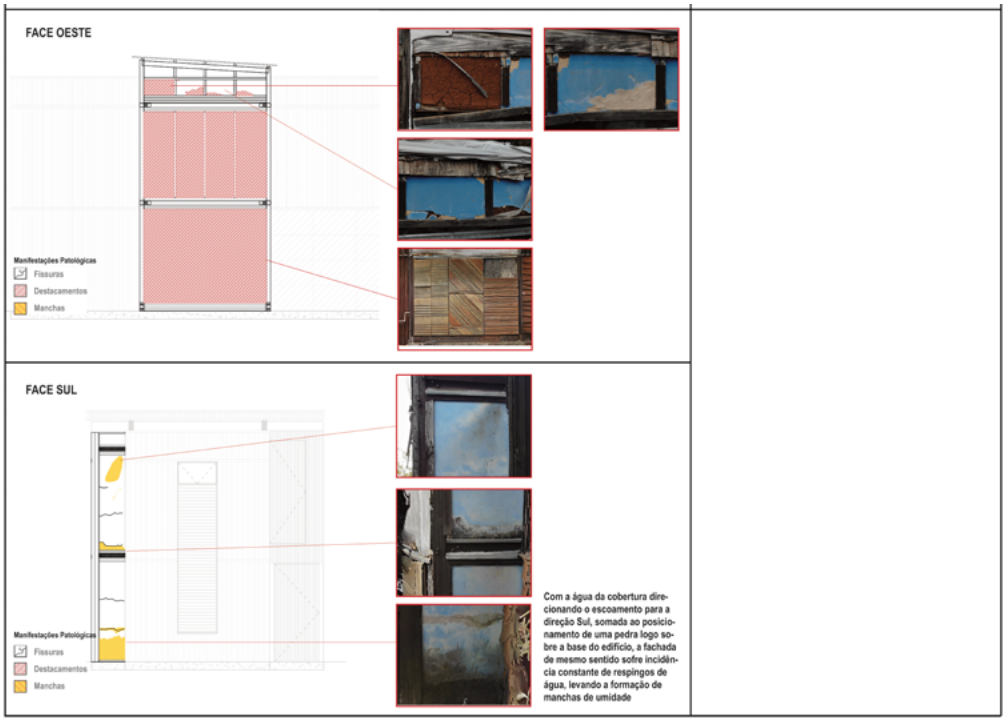
3. RESULTS

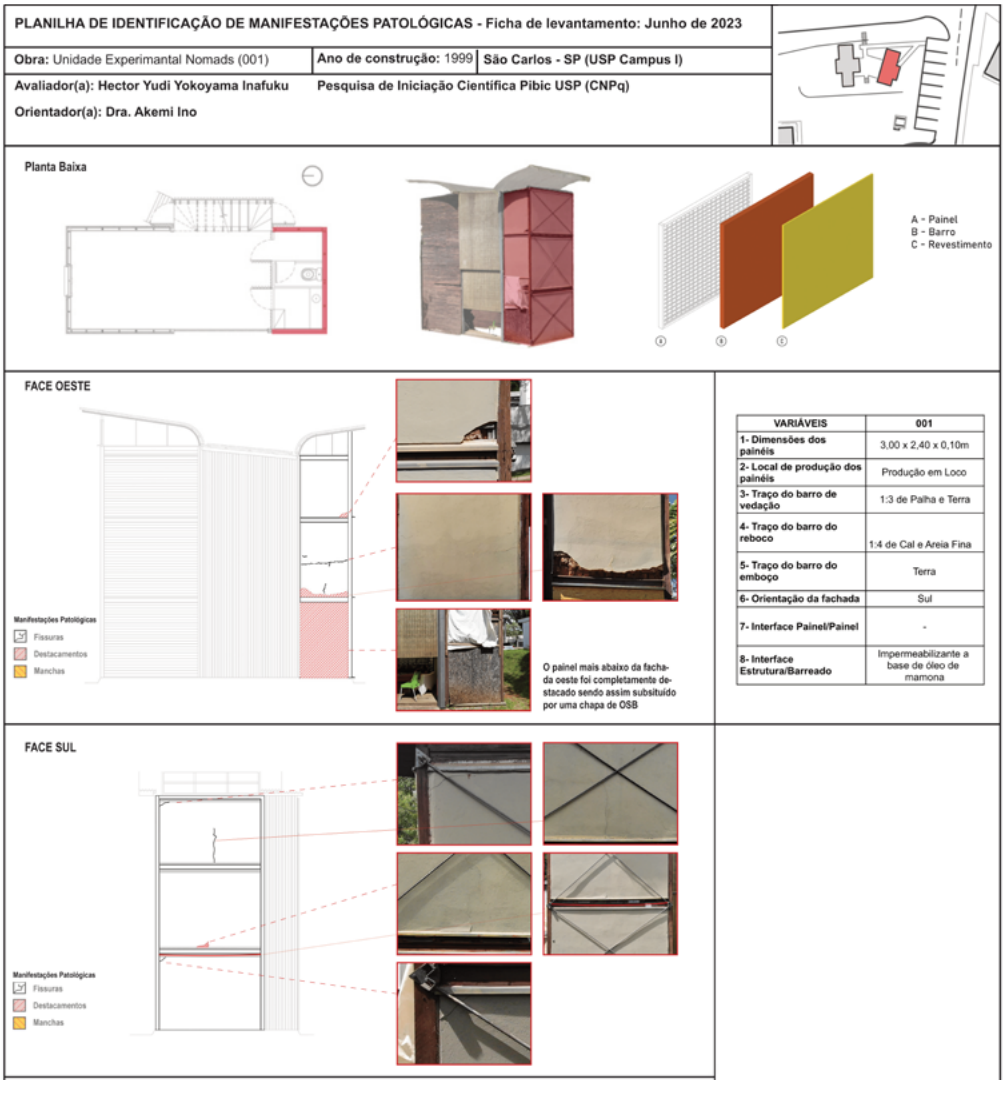
One of the products of the research is the pathlogy identification spreadsheet, which, in addition to recording the defects observed on each façade, includes data about the building to be evaluated, such as its location, floor plan, and perspective. The spreadsheet also contains the characterization of the panel design with its layered composition (Figure 11 and 12).

Of the nine panels evaluated in Unit 001, four met all the established requirements and criteria, with two located on the South face and two on the East face. The three panels on the West face did not meet the requirements.

In Unit 002, out of the 18 panels evaluated, only four met the defined requirements and criteria, with three on the South face and one on the North face. The panels on the West face were completely removed, and the lower floor wall was replaced with OSB paneling over the sawn timber frame.







VARIÁVEIS	001
1- Dimensões dos painéis	3,00 x 2,40 x 0,10m
2- Local de produção dos painéis	Produção em Loco
3- Traço do barro de vedação	1:3 de Palha e Terra
4- Traço do barro do reboco	1:4 de Cal e Areia Fina
5- Traço do barro do emboço	Terra
6- Orientação da fachada	Sul
7- Interface Painel/Painel	-
8- Interface Estrutura/Barreado	Impermeabilizante a base de óleo de mamona

Figure 12: Identification Sheets for Pathological Manifestations.
Source: Elaborated by the Authors (2022)

4. RESULTS ANALYSIS

In a comparative analysis, the dimensions and number of pathological manifestations innUnit 002 were significantly higher, with 6 stains, 13 cracks, and 14 detachments, compared to Unit 001, which had 5 stains, 6 cracks, and 5 detachments (Table 1). Overall, only 22% of the panels in Unit 002 met the established criteria and requirements, whereas in Unit 001, the percentage was 44%.

structure caused by under dimensioning, which, due to wind, may have contributed to the formation of cracks at the corners. Both FS1B and DS2A could be related to deformation in the lower beam, which is more noticeable in panel S2, as indicated by the horizontal line in Figure 13. This deformation may have led to the weight of the earth contributing to the formation of these cracks.

Building	Evaluated panels	Pathological Manifestations			Panels that met the established Criteria and Requirements
		Stains	Cracks	Detachments	
001	9	5	6	5	4 (44%)
002	18	6	13	14	4 (22%)

Table 1: Summary of Performance Evaluation of the wattle and daub Panels in Units 001 and 002.
Source: Elaborated by the Authors (2022)

4.1 Unit 001

In the panels facing the South side (S1; S2; S3) of Unit 001, shown in Figure 13, a total of four stains and two cracks were identified in panel S1, with one located at the upper left corner (FS1A) and another running vertically from the base towards the top of the panel (FS1B). In panels S2 and S3, a detachment (DS2A) was identified, similar to FS1B, also at the base of the panel on the beam structure, along with a crack (FS3A) found at the upper left corner of panel S3.

Among the possible causes for the formation of cracks FS1A and FS3A is potential movement in the

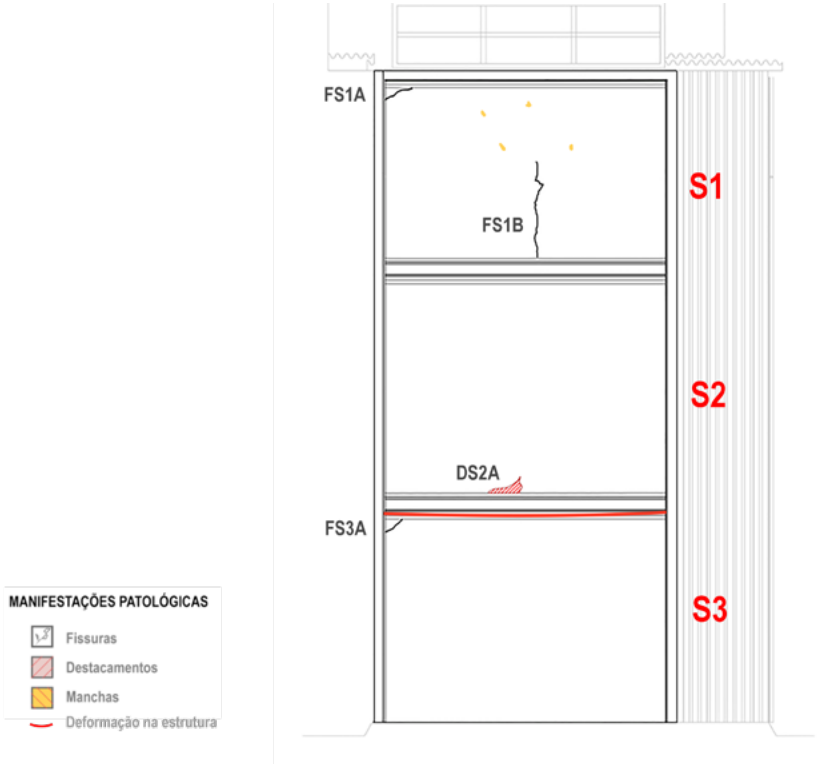


Figure 13: Pathological Manifestations on the South Façade (Unit 001).
Source: Elaborated by the Authors (2022)

Regarding the East face (L1; L2; L3), shown in Figure 14, the identified issues aremostly stains, with only one detachment (DL2A) located at the lower left corner of panel L2.

Both the East and West faces show good performance in terms of the interfaces between the earth and the wooden structure, which may be attributed to the castor oil resin applied in the mixed technique.

The West face stands out compared to the others due to the severity of its issues. In addition to the crack (FO1A), both panels O1 and O2 show significant detachments (DO1A; DO2B) concentrated in the lower region of the panel, as well as a detachment (DO2A) in panel O2 at the earth-structure interface. Panel O3 is notable for the complete removal of the earth and its coating (Figure 15).

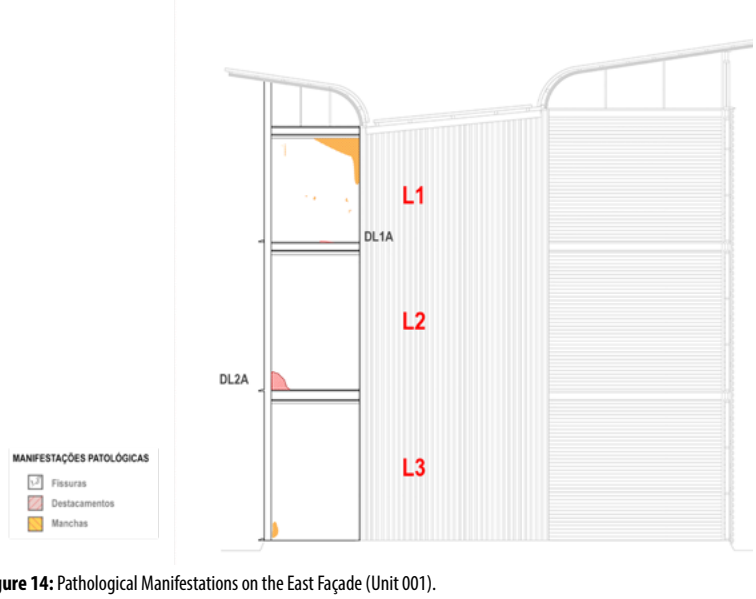


Figure 14: Pathological Manifestations on the East Façade (Unit 001).
Source: Elaborated by the Authors (2022)

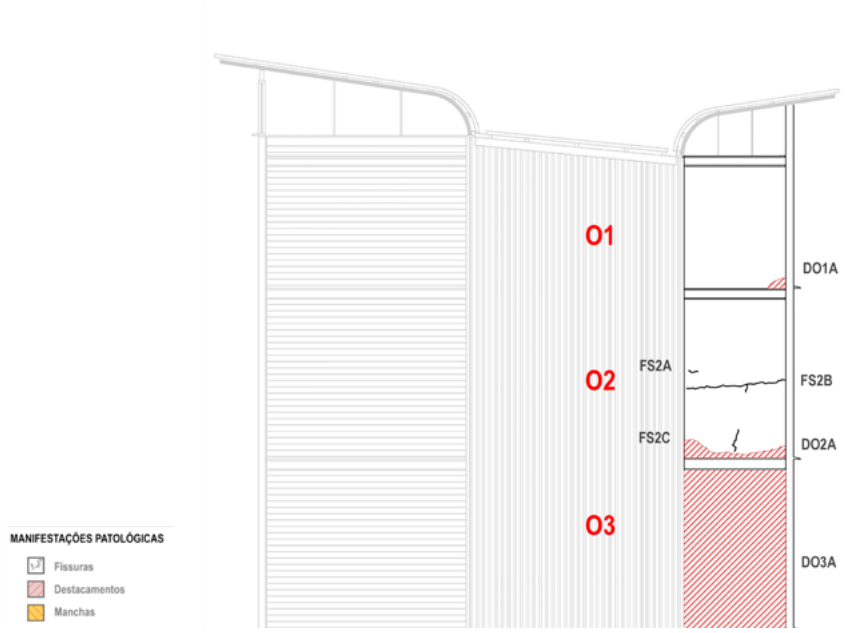


Figure 15: Pathological Manifestations on the South Façade (Unit 001).
Source: Elaborated by the Authors (2022)

When analyzing the three façades, a pattern of concentrated cracks and detachments at the corners of the panels (FS1A; FS3A; DL2A; DO1A; DO2A) becomes evident. A possible cause of this pattern is the movement of the structure due to wind, making the corner regions susceptible to cracking. Consequently, the presence of cracks and deformations facilitates water infiltration into the seal, leading to the rotting of the framework and detachment of the earth.

The temperature fluctuations experienced by the panels on the West face in the late afternoon may also be a possible reason for none of the panels meeting the established requirements. Combined with the previously mentioned issues, the identified pathologies manifestations could be related to the dimensional variation of the wood caused by temperature changes, affecting the material interfaces and contributing to water infiltration and accumulation in the wooden framework, leading to its decay.

Finally, it can be stated that only panels S1, S3, L1, and L3 meet the established criteria and requirements.

4.2 Unit 002

On the South face (Figure 16), there is a predominance of moisture stains caused by direct contact with water splashes. Despite this, it is the only face without any detachments, having only cracks with less than 1 mm of width.

The West face (Figure 17) has the highest number of sealant detachments, with faces O2 and O3 being completely detached.

The North face (Figure 18) shows complete detachment in panel N1 and partial detachment in panel N2, with a significant presence of cracks. Additionally, there isextensive moisture staining on panel N3, particularly near the ground.

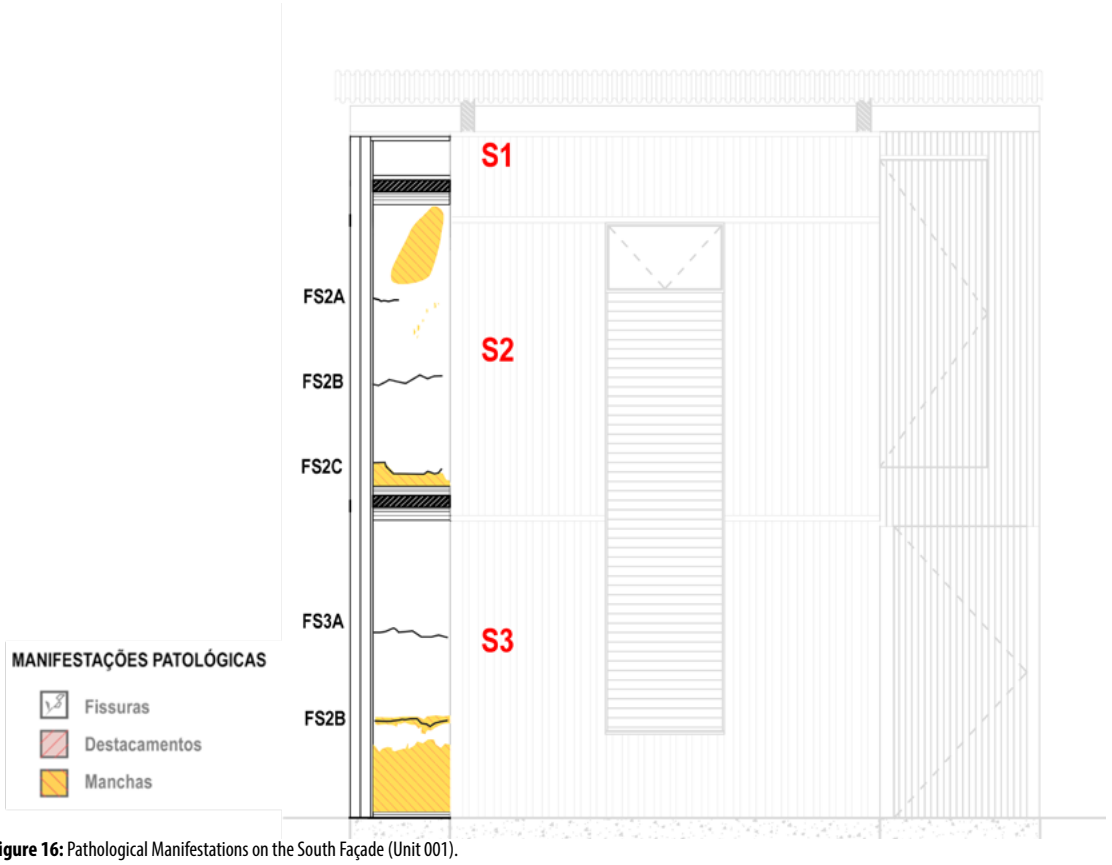


Figure 16: Pathological Manifestations on the South Façade (Unit 001).
Source: Elaborated by the Authors (2022)

Figure 17: Pathological Manifestations on the South Façade (Unit 001)
Source: Elaborated by the Authors (2022)

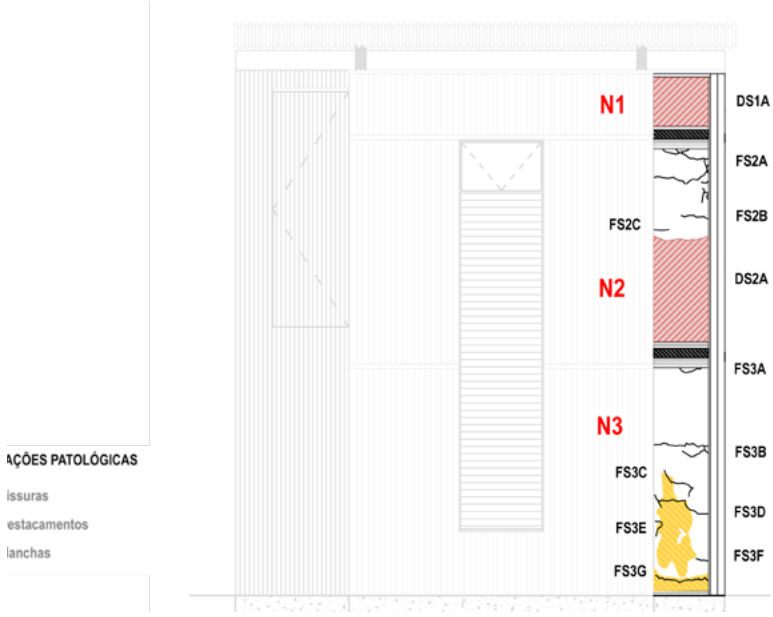


Figure 18: Pathological Manifestations on the South Façade (Unit 001).
Source: Elaborated by the Authors (2022)

4.3 Analysis of possible causes of the pathological manifestations

The durability of the wattle and daub technique heavily relies on the proper execution and detailing of the interfaces between the panels and the earth. Given that moisture is the primary factor in the deterioration of "taipa" (LOPES, 1998), the near-total detachment of the West façade of Unit 002 is related to the solution used for 75cm modular panels with exposed frame joints covered with wooden joint covers. Exposure to high solar radiation and dimensional variations in the wood led to formation of gaps, infiltration and accumulation of rainwater, initiating the rotting of the timber frame and consequent loss of support, causing detachment of the earth. Another moisture-related factor to consider as a cause of the wall detachments in Unit 002 is the lack of eaves, combined with the fact that the panels were elevated only 20 cm above the foundation, relative to ground level. Considering that the minimum foundation height to avoid wall deterioration due to moisture is 40 cm (LOPES, 1998), the proximity of the walls to the ground may have created conditions for water splashes and accumulation, which compromised the integrity of the walls.

Another noteworthy aspect of Unit 001 was the use of castor oil resin at the interface between the coating and the pillar. This flexible component allowed for the absorption of dynamic dimensional changes between the two materials, preventing the formation of gaps between the panel (earth) and the wooden pillar, and ensuring good performance over 25 years.

Thus, it can be concluded that the main cause of the performance difference between the two buildings is related to the design details concerning the protection of construction elements from contact with and accumulation of water and moisture at different interfaces between construction systems. This includes the adoption of 75 cm modular panels with exposed frames, compared to the single 3 m panel solution that covered the entire span from pillar to pillar, as used in Unit 001, along with the absence of eaves and a low-height foundation relative to ground level.

5. FINAL CONSIDERATIONS

The mixed technique, despite its numerous economic, technical, social, and environmental benefits, like any other construction process, requires careful prior planning. This includes conducting a site study and technical feasibility analysis to ensure optimal performance, durability, and functionality of the building (LOPES, 1998).

After about twenty-five years of use, the research that led to the creation of Experimental Housing Units 001 and 002 remains a valuable subject for investigation. It allows for numerous studies on the performance of the five subsystems (structure, cladding, joinery, roofing,

and installations) as proposed in the FAPESP Young Researchers in Emerging Centers project. It is important to note that exposure conditions were crucial for the performance of the mixed techniques in the cladding subsystem. Therefore, during the design phase, it is essential to develop tools, techniques, and construction processes that ensure the desired durability and performance of the "taipa de mão" walls, considering the exposure conditions they will face.

Understanding wattle and daub as a technique still stigmatized and often associated with "poverty and unsanitariness" by common perception in Brazil, scientific studies on this traditional technique can help combat these harmful and misguided views and open new perspectives for necessary changes in the construction industry, seeking more sustainable and less harmful solutions.

REFERENCES

INO, Akemi; SHIMBO, Ioshiaqui; TRAMONTANO, Marcelo. Projeto Jovens Pesquisadores Proc. FAPESP nº 95/9716-9, "**Habitação Social: Concepção Arquitetônica e Produção de Componentes em Madeira de Reflorestamento e em Terra Crua**". 2000.

GARZÓN, Lucía Esperanza. "Técnicas mistas". **Técnicas de construção com terra**, Bauru - SP, Faculdade de Engenharia de Bauru da Universidade Estadual Paulista Júlio de Mesquita Filho, 2011. Disponível em: <https://redeterrabrasil.net.br/publicacoes-proterra/>

JOAQUIM, Bianca dos Santos. "**TERRA E TRABALHO: O lugar do trabalhador nos canteiros de produção da Arquitetura e Construção com Terra**". Dissertação (Mestrado em Arquitetura, Urbanismo e Tecnologia) - Instituto de Arquitetura e Urbanismo de São Paulo, São Carlos, 2015

SOUZA, Roberto de. Avaliação de desempenho aplicada a novos componentes e sistemas construtivos para habitação. In: **Simpósio Latino-Americano Sobre Racionalização da Construção e Sua Aplicação às Habitações de Interesse Social**, São Paulo, 25 a 28 de Outubro de 1981. Anais… São Paulo, Instituto de Pesquisas Tecnológicas do Estado de São Paulo, 1981, v1 p 247-256

LOPES, Wilza Gomes Reis; INO, Akemi. **Taipa de Mão no Brasil:** Levantamento e análise de construções. Dissertação (Mestrado em Arquitetura, Urbanismo e Tecnologia) - Instituto de Arquitetura e Urbanismo de São Paulo, São Carlos, 1998

INAFUKU, Hector Yudi Yokoyama. "Avaliação de Desempenho de painéis em Taipa de mão: Edificações Experimentais de Habitação 001 (Nomads) e 002 (Habis)". In: **Simpósio Internacional de Iniciação Científica e Tecnológica da USP** - SIICUSP, São Carlos, Universidade de São Paulo, 2023.

Clima e condicões metereológicas médias em São Carlos. **WEATHERSPARKS**, 2024. Disponível em: [https://pt.weatherspark.com/y/30178/Clima-caracter%C3%ADstico-em-S%C3%A3o-Carlos-S%C3%A3o-Paulo-Brasil-durante-o-ano] Acesso em: 15/09/2024

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AI: conceptualization, formal analysis, investigation, methodology, visualization, writing - original draft, writing - review & editing, data curation, resources and supervision.

Conflict declaration: nothing has been declared.

RESIDE: REPRESENTATIVE DATABASES FOR MULTI-CRITERIA DECISION TOOL

RESIDE: BANCOS DE DADOS REPRESENTATIVOS PARA FERRAMENTA DE DECISÃO MULTICRITÉRIO

RESIDE: BASES DE DATOS REPRESENTATIVAS PARA HERRAMIENTA DE DECISIÓN MULTICRITERIO.

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ABSTRACT
RESIDE is a software that allows designers and decision-makers to simultaneously consider issues related to energy consumption for environmental conditioning and water heating, construction costs and public policies from the initial planning stages of residential developments. However, its use is conditional on the existence of a database for the context analyzed. Understanding the growing importance of addressing the innate complexity in sustainability-oriented design activities, this article presents a procedure to identify representative databases for the state of Minas Gerais, in order to enable the use of the RESIDE multi-criteria decision tool.

KEYWORDS
Multicriteria Decision Method; Thermoenergetic Performance; Housing Policy.

RESUMO
O software RESIDE permite aos projetistas e tomadores de decisão desde as fases iniciais de planejamento dos empreendimentos residenciais considerar simultaneamente questões relacionadas ao consumo de energia para condicionamento ambiental e aquecimento de água, custos de construção e políticas públicas. Contudo, sua utilização é condicionada à existência de um banco de dados para o contexto analisado. Entendendo a importância cada vez maior de abordar a complexidade presente na atividade de projeto voltado a busca pelo desenvolvimento sustentável, este artigo apresenta um procedimento para identificação e construção de bancos de dados representativos para o estado de Minas Gerais, a fim de viabilizar a utilização da ferramenta de decisão multicritério RESIDE.

PALAVRAS-CHAVE
Método de Decisão Multicritério; Desempenho Termoenergético; Política habitacional.

RESUMEN
El software RESIDE permite a los diseñadores y tomadores de decisiones, desde las etapas iniciales de planificación de los proyectos residenciales, considerar simultáneamente cuestiones relacionadas con el consumo de energía para acondicionamiento ambiental y calentamiento de agua, costos de construcción y políticas públicas. No obstante, su uso

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está condicionado a la existencia de una base de datos para el contexto analizado. Entendiendo la importancia cada vez mayor de abordar la complejidad presente en la actividad de diseño orientada a la búsqueda del desarrollo sostenible, este artículo presenta un procedimiento para la identificación y construcción de bases de datos representativas para el estado de Minas Gerais, con el fin de viabilizar el uso de la herramienta de decisión multicriterio RESIDE.

PALABRAS CLAVE
Método de Decisión Multicriterio; Desempeño Termoenergético; Política habitacional.

1. INTRODUCTION

It is increasingly observed in various spheres of society that human activities are expanding in complexity. Mitchell (2009) begins her work by defining complexity through biological (environmental), economic, and social examples. Throughout the work, although the author does not directly reference the concept of sustainable development, the in-depth exploration of complexity science and its implications in computational fields and information processing allows for inferences about how these concepts influence project activities aimed at sustainability.

The building design processes have grown more complex as they address an increasing number of criteria, which aligns with the principles of sustainable development. However, there is not always enough time or tools available to make decisions with the required accuracy. The challenge of improving the environmental performance of buildings, in a context of growing concern over reducing negative environmental impacts, has driven the search for innovative, effective, and accessible tools to assist in decision-making moments for entrepreneurs and designers. In this scenario, where designers are under pressure to enhance their responsiveness within tight deadlines, applications that incorporate multicriteria analysis methods emerge as strategic solutions, enabling the simultaneous consideration of various quantitative and qualitative factors in the processes of planning and designing buildings.

Considering this reality and the increasing energy demand for environmental conditioning in residential buildings—between 2005 and 2017, the ownership of air conditioning units in homes grew by 9% per year (EPE, 2018)—the RESIDE tool (Loura et al., 2019) was developed to assist in the multicriteria decision-making process regarding solutions for building envelopes and water heating systems (SAA) for bathing, taking into account the costs and benefits of these solutions in the early stages of residential project design. The RESIDE framework was designed with the Brazilian construction market context in mind, integrating the thermal and energy performance of residential buildings with the costs associated with envelope solutions and SAA, aiming to meet the needs of public administrators involved in housing policy and entrepreneurs. For the former, RESIDE enables the formulation of housing policies based on energy efficiency in a consistent and responsible manner. From the perspective of entrepreneurs or designers, this software can directly assist in decisions for specific projects.

To make the software applicable to multiple national climate and urban-related contexts, it is necessary to develop databases that represent a given reality. This article aims to document the development stage of representative databases for the state of Minas Gerais, encompassing different economic and climatic scenarios, as well as construction typologies. The effort here is to achieve a relevant scope that allows free use of RESIDE throughout the state. Additionally, it discusses the importance of providing easily accessible digital multicriteria analysis tools in the design process to support technical decisions based on the rational use of environmental and economic resources.

2. LITERATURE REVIEW

RESIDE is a software developed based on the ELECTRE-III (ELimination and Choice Expressing Reality) method, introduced by Roy (1977). This method constructs its classification process from a set of preferences. Generally, two alternatives are compared at a time to determine whether there is (i) a strong or weak preference for one action over another, (ii) indifference between the actions, or (iii) incomparability between the actions. The evaluation of each action or alternative \(A_i \) (where \(i = 1,2, ..., n \)) across various criteria \(Cr1, Cr2, ..., Crm \) is performed using a vector with several attributes \(\{E_{i1}, E_{i2}, E_{i3}, ..., E_{im}\}\). Preference limits include "P," which indicates the difference beyond which a strict preference can be established, "Q," which marks the difference beyond which no preference can be established, and "V," the veto limit for each criterion, representing the difference beyond which the comparison between two actions should be ignored.

In summary, setting up the evaluation matrix requires (i) a list of alternatives, (ii) criteria and their respective weights, and (iii) the definition of the limits. After performing calculations and tests for over-ranking, agreement, and disagreement, the algorithm constructs two matrices—one for agreement and one for disagreement—in which all possible pairs of actions are compared. From these, a third matrix, called the credibility matrix, is generated. The classification of alternatives is established based on this credibility matrix, with alternatives ordered from the best to the worst based on their descending ranking.

Despite being developed in the 1970s, ELECTRE-III remains widely used for classifying alternatives based on multiple criteria. A brief review of recent literature from 2019 to 2024 shows that this multi-criteria decision-making

(MCDM) method continues to be relevant for decision support in areas related to energy, sustainability, and the built environment. For instance, Ebadi Tork Ayesha et al. (2019) utilized ELECTRE-II as a tool for determining the site for solid waste treatment infrastructure. Battisti (2022) employed ELECTRE-III to develop an evaluation method capable of synthesizing judgments based on recognized objective parameters within Strategic Environmental Assessment procedures. Kosova et al. (2022) used MCDM tools, including ELECTRE-III, to analyze resilience in a county in Albania. Labed et al. (2024) introduced a flexible multi-criteria decision-making system for regional planning, developed from an enhanced version of ELECTRE-III. Finally, Salvador et al. (2024) conducted a literature review demonstrating that this method has frequently been applied to supplier selection, either alone or integrated with other MCDM methods.

In RESIDE, ELECTRE-III is applied to create representative databases for different contexts based on output from thermal energy simulations, construction material and service costs, and targets available in national planning instruments such as the National Energy Plan and the National Energy Efficiency Plan. A database must be created for each residential construction typology, considering whether it is single-family or multi-family, the number of floors for multi-family units, and the construction standard (Social Housing, Normal or High standards), according to NBR 12.721 (ABNT, 2006). Users should first select the most appropriate database for the construction typology of interest based on the climate and urban contexts. The next step requires the user to establish analysis alternatives. The software provides multiple options that can be chosen in each of its parameters, such as (i) eight building orientations, (ii) two options of opening-to-floor-area ratios, (iii) presence or absence sun shading devices on windows, (iv) opening rates on opposite and adjacent facades, (v) six types of wall systems, (vi) six roofing systems, and (vii) 14 water heating systems.

For each comparative analysis, users can select up to 16 distinct alternatives within a climate context, considering the same construction typology. These alternatives are evaluated based on six criteria: (i) percentage of hours of passive thermal comfort, (ii) condition of cross-ventilation, (iii) number of degree-hours for cooling, (iv) percentage variation in costs of envelope solutions, (v) government incentives for water heating technology, and (vi) complexity of the complete SAA (Water Supply and Sanitation) infrastructure for bathing. The characteristics of the ELECTRE-III method, based on non-compensatory analysis and incomparability between solutions, are crucial for ensuring the reliability of results in RESIDE. This approach prevents the favoring of alternatives that are highly valued by one or a few criteria but less valued by others. Since the criteria used are of varying levels of importance to different stakeholders in construction planning, non-compensatory analysis helps protect the interests of those with decision-making power while preventing the neglect of other important criteria.

Figure 1: RESIDE alternatives interface for parameters selection.

Source: created by the authors.

The software suggests weights for each criterion, but users can specify the weights that are most relevant to their analysis. Each database includes eight reference cases, one for each building orientation relative to geographic north, based on standard envelope solutions (walls and roofs) established by NBR 12.721 (ABNT, 2006) and the most common SAA solution in the analyzed context. For representative cities in Minas Gerais, this is typically the electric shower. This does not imply that this alternative is better or worse than others in that context. In fact, it reflects the current market practice in local construction, which is crucial in order to support the decision-making process.

The classification of alternatives is obtained by clicking "Calculate Result." RESIDE also allows users to perform a sensitivity analysis of the ranking. According to Tervonen et al. (2005), defining weights is one of the most critical parameters for multicriteria analysis using ELECTRE-III. Therefore, RESIDE emphasizes the importance of users being able to validate the ranking by varying criterion weights. Sensitivity analysis is not the only validation method. During database development, uncertainty analyses are conducted throughout the process of defining values of each criterion. Additionally, the ELECTRE-III method itself verifies the credibility of the generated matrices. Thus, the sensitivity analysis performed after ranking aims to evaluate the stability and consistency of the presented ranking.

The classification of alternatives is obtained by clicking "Calculate Result." RESIDE also allows users to perform a sensitivity analysis of the ranking. According to Tervonen et al. (2005), defining weights is one of the most critical parameters for multicriteria analysis using ELECTRE-III. Therefore, RESIDE emphasizes the importance of users being able to validate the ranking by varying criterion weights. Sensitivity analysis is not the only validation method. During database development, uncertainty analyses are conducted throughout the process of defining values of each criterion. Additionally, the ELECTRE-III method itself verifies the credibility of the generated matrices. Thus, the sensitivity analysis performed after ranking aims to evaluate the stability and consistency of the presented ranking.

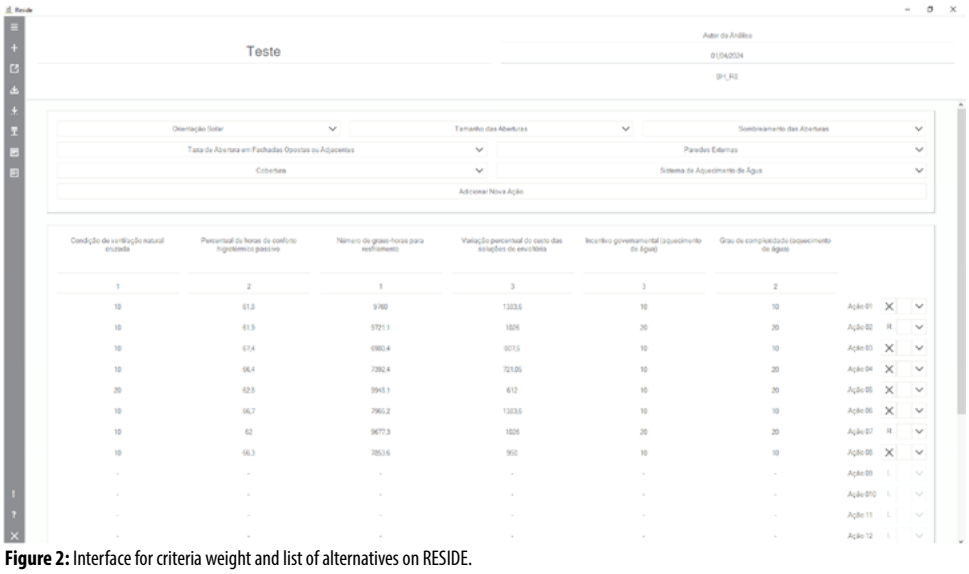

Figure 2: Interface for criteria weight and list of alternatives on RESIDE.

Source: created by the authors.

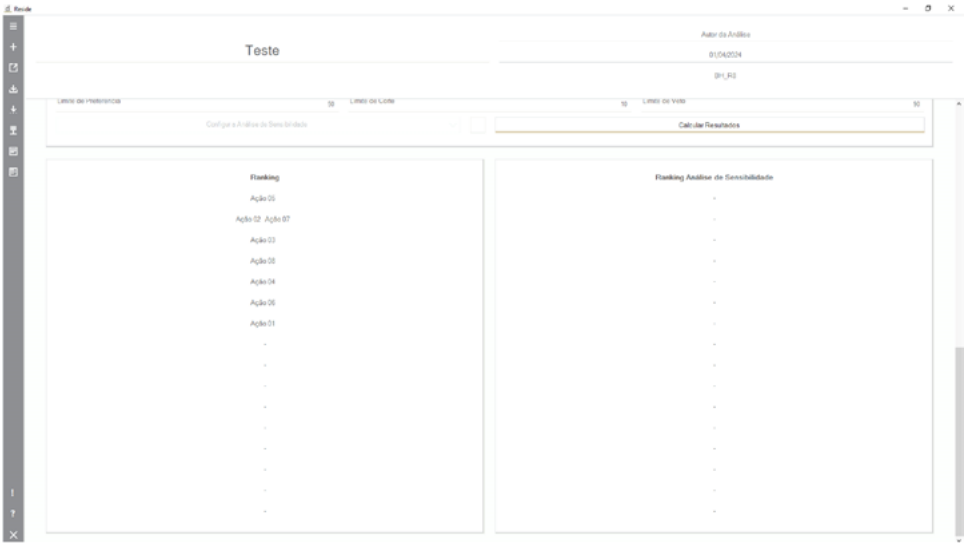

Figure 3: Classification and sensibility analysis interface on RESIDE.
Source: created by the authors.

3. METHODOLOGICAL PROCEDURES FOR REPRESENTATIVE DATABASE DEFINITION

Minas Gerais stands out in Brazil for at least two reasons: its climate diversity and its high number of municipalities. According to IBGE (2017), the state is divided into 13 intermediate geographic regions to organize its territory, considering political, socioeconomic, and cultural aspects for planning, management, and implementation of public policies.

Given the characteristics of RESIDE, it is evident that providing users with a variety of databases to represent different climate and urban contexts is crucial to enhance the accuracy of the analysis and support decision-making in the early stages of project development. However, considering the climate and constructive diversity, as well as the large number of municipalities, it would be unrealistic to expect the development of specific databases for each territory as a basic requirement for using the software.

In the initial effort to make RESIDE available, it was necessary to build databases that represented different regions of the state. Based on the intermediate regions (IBGE, 2017), cities with available TMY (Typical Meteorological Year) files were identified in each area. These cities were then classified according to their climate context, using the classifications established by Nimer (1979) and Köppen (Instituto de Pesquisas e Estudos Florestais, 2024).

According to Nimer (1979), Minas Gerais features eight different climates: hot, super humid climates with an average air temperature greater than 18ºC throughout the year; hot humid climates with 1 to 3 dry months; hot semi-humid climates with 4 to 5 dry months; hot semi-arid climates with 6 to 8 dry months; sub-hot climates with an average temperature between 15ºC and 18ºC in at least one month, humid with 1 to 3 dry months; sub-hot semi-humid climates with 4 to 5 dry months; mild mesothermal climates with an average temperature between 10ºC and 15ºC, humid with 1 to 3 dry months; and mild mesothermal semi-humid climates with 4 to 5 dry months.

Köppen (Instituto de Pesquisas e Estudos Florestais, 2024) classifies the state's climate into several categories: savanna climate with a drier season in summer (As), savanna climate with a drier season in winter (Aw), subtropical humid climate with summer concentrating 70% of precipitation (Cwa), temperate oceanic climate (Cfb), and subtropical highland climate (Cwb).

Based on the climate classification and the availability of TMY files, 13 representative cities were selected—one from each intermediate region—to illustrate the climate diversity described by both Nimer and Köppen. The next step involved studying the urban morphology of each of these 13 cities to identify the construction typologies and patterns cited in NBR 12.721 (ABNT, 2006) and most frequently observed in the area. Using Google Earth and Google Street View, a classification was made considering various typologies according to ABNT (2006). These included single-floor, low standard single-family buildings; single-floor, normal standard single-family buildings; four-story, multi-family low standard affordable buildings; four-story, multi-family normal standard affordable buildings; eight-story, multi-family low standard buildings; eight-story, multi-family normal standard buildings; and 16-story multi-family normal standard buildings.

In the effort to achieve representative databases for the state—understanding that every selection excludes some typologies present in these urban contexts—up to four of the most relevant constructive typologies were defined for each city.

4. REPRESENTATIVE DATABASE FOR MINAS GERAIS

Table 1 presents the 13 cities selected as representative contexts for the state from socioeconomic, cultural, and political perspectives—following the intermediate regions (IBGE, 2017)—and climate classifications adopted.

The software suggests weights for each criterion, but users can specify the weights that are most relevant to their analysis. Each database includes eight reference cases, one for each building orientation relative to geographic north, based on standard envelope solutions (walls and roofs) established by NBR 12.721 (ABNT, 2006) and the most common SAA solution in the analyzed context. For representative cities in Minas Gerais, this is typically the electric shower. This does not imply that this alternative is better or worse than others in that context; rather, it reflects the current market practice in local construction, which is crucial for supporting the decision-making process.

After analyzing the urban morphology of the chosen cities, it was possible to identify up to four predominant typologies in each, as shown in Table 2. This table also provides data such as population, according to IBGE Cities (2024), and the two key economic sectors, according to FJP (2024).

The analysis indicates the need to create 51 databases, a satisfactory and feasible number to produce given the amount of municipalities in the state—852 cities—and their climate and urban morphological diversity.

City	Nimer Classification	Köppen Classification
Belo Horizonte	Sub-warm Semi-humid with 4 to 5 dry months	Cwb
Montes Claros	Warm Semi-arid with 6 to 8 dry months	As
Teófilo Otoni	Warm Humid with 4 to 5 dry months	Aw
Formiga	Sub-Warm Semi-Humid with 4 to 5 dry months	Cwb
Governador Valadares	Warm Semi-humid with 4 to 5 dry months	Aw
Viçosa	Sub-warm Humid with 1 to 3 dry months	Cwa
São João del Rey	Mild mesothermal Semi-humid with 4 to 5 dry months	Cwb
Uberaba	Warm Semi-humid with 4 to 5 dry months	Cwa
Patos de Minas	Sub-warm Semi-humid with 4 to 5 dry months	Cwa
Timóteo	Warm Semi-humid with 4 to 5 dry months	Aw
Capinópolis	Warm Super-humid with 1 to 3 dry months	Aw
Pouso Alegre	Mild mesothermal humid with 1 to 3 dry months	Cfb
Varginha	Mild mesothermal Semi-humid with 4 to 5 dry months	Cwb

Table 1: Selected cities and climate classification.

Source: created by the authors.

5. DATABASE BUILDING PROCEDURE

The construction of the databases involves six steps, using a diverse set of information and tools, as follows:

- Modeling of construction typologies for thermal and energy simulations;
- Thermal and energy simulations;
- Processing of simulation data;
- Cost spreadsheet and comparative analysis;
- Parameters of public policies;
- Construction of the database file.

5.1 Constructive typology modeling for thermal and energy simulation

The work begins with modeling in SketchUp using the Euclid plugin for construction typologies based on the plans and sections present in NBR 12.721 (ABNT, 2006). After modeling the geometry, the process moves to the EnergyPlus, where adjustments are made for natural ventilation parameters, building occupation schedules, shading calculation methods, heat transfer, as well as specifying the location and external conditions of the elements (such as the differentiation between internal and external walls), among other essential parameters to ensure the accuracy of the energy simulations. The importance of groups related to material combinations (Construction and BuildingSurface), which determine the thermal properties of construction elements, and window protection (WindowShadingControl), which directly influences solar heat gain and consequently indoor thermal comfort, is emphasized. These settings generate different simulation files, allowing for a detailed analysis of the energy performance across different scenarios.

Additionally, the groups Building (North Axis), Parametric:SetValueForRun, and Parametric:FileNameSufix are crucial for performing simulations with varying solar orientations. These groups enable the automatic simulations for eight distinct solar orientations (N, NE, E, SE, S, SW, W, NW), providing a comprehensive view of how orientation impacts the thermal performance of a building. All settings in the software are made considering the orientations specified in the Inmetro Normative Instruction Procedure (INI-R) (INMETRO, 2022).

For each city, 144 files must be produced, resulting in 1152 simulations. Each output file contains information about thermal comfort status and degree-hours for long-term stay environments (bedrooms and living room) for each of the 8760 hours of the typical meteorological year. Given the volume of information, it is necessary for the researcher to plan the modeling work in advance by standardizing the nomenclature of the modeled surfaces and creating orientation maps for the modeling. This standardization not only ensures agile traceability for the researcher but also allows for the use of Python codes to reproduce the files.

City	Typologies and Construction Patterns	Population	Key Economic Fields
Belo Horizonte	PPB; R8B; R8N; R16N	2.315.560	Construction; Transportation and Storage
Montes Claros	R1N; PPB; PPN; R8N	414.240	Transportation and Storage; Communication and Information Services
Teófilo Otoni	R1B; R1N; PPB; R8N	137.418	Food Manufacturing; Construction
Formiga	R1B; R1N; PPB; PPN	68.248	Food Manufacturing; Transportation and Storage
Governador Valadares	R1B; R1N; PPB; PPN	257.171	Food Manufacturing; Construction
Viçosa	R1B; R1N; PPB; R8N	76.430	Food Manufacturing; Construction
São João del Rey	R1B; R1N; PPB; PPN	90.225	Transportation and Storage; Extractive Industries
Uberaba	R1B; R1N; PPB; R8N	337.836	Food Manufacturing; Energy

City	Typologies and Construction Patterns	Population	Key Economic Fields
Patos de Minas	R1B; R1N; PPB; R8N	159.235	Food Manufacturing; Agriculture
Timóteo	R1B; R1N; PPB; R8N	81.579	Steel Industry; Construction
Capinópolis	R1B; R1N; PPB	14.655	Energy; Transportation and Storage
Pouso Alegre	R1B; R1N; PPB; R8N	152.271	Food Manufacturing; Transportation and Storage
Varginha	R1B; R1N; PPB; R8N	136.467	Food Manufacturing; Transportation and Storage

Table 2: Typologies and Construction Patterns, Population and Key Economic Fields.
Source: created by the authors.

5.2 Thermal energy simulation

To speed up the process, the simulation is divided into batches according to the size of the openings and the presence or absence of sun shading: Large Window with Protection (JGCP), Large Window without Protection (JGSP), Medium Window with Protection (JMCP), and Medium Window without Protection (JMSP). Using the EnergyPlus Launch, group of Input Files are created for each folder, which consist of IDF (Input Data File) files and EPW (EnergyPlus Weather File) weather files that are specific to the studied city. In addition to organizing the simulation documents and their output, this folder separation prevents data overload, which could cause delays or errors during simulation, especially in cases of unexpected failures. By segmenting the files into smaller groups, it becomes easier to identify and correct potential issues without compromising the entire set of simulations, increasing the reliability and efficiency of the process.

5.3 Data processing of thermal and energy simulation

The simulation output is presented in "comma separated values" (.csv) files compatible with Excel, LibreOffice Calc, and Google Sheets. The output variables include the average air temperature and operative temperature for every hour of the typical year in all long-term stay environments. Using an equation to evaluate thermal comfort based on the neutral temperature calculated for the city, it is possible to determine whether the long-term stay environments are in a state of thermal comfort or not. In order to build the research databases, Humphreys' equation (1978 apud PEREIRA and ASSIS, 2010) was selected due to the climate conditions of Minas Gerais. The equation to be used must be defined for each new database constructed, based on the acclimatization characteristics of the local population. Thermal comfort was considered when the average air temperatures were up to 1ºC above the neutral temperature calculated for the month. The percentage of hours of passive hygrothermal comfort for each environment in a housing unit corresponds to the ratio between the total number of comfort hours throughout the year and the total hours of the year. The average value for each housing unit is calculated using a weighted average based on the area of the environment. Similarly, to calculate the building mean percentage, an average value of the results from each unit was defined, as all of them had the same area. No minimum limit for hygrothermal comfort was set using adaptive comfort indexes because, given the climate conditions of Minas Gerais, it is possible to overcome hygrothermal discomfort caused by cold with slightly heavier-than-usual clothing. The Report on Equipment Ownership and Usage Habits (ELETROBRÁS, 2019) supports this assertion, as it does not list any equipment exclusively for heating buildings.

The result of this process is an average percentage value for each construction alternative in the database, with a directly proportional evaluation, meaning higher values are more satisfactory than lower ones.

The second data processing procedure aims to obtain the cooling degree-hours based on the operative air temperature. The calculation of annual cooling degree-hours followed the INI-R methodology as presented in INMETRO (2022), with the values being weighted by the area of each environment to calculate the value for each housing unit. The average value for the building is then calculated from the averages of the housing units.

The result is expressed in the unit of measurement "degree-hours/year," which is a criterion with an inversely proportional evaluation, meaning higher values indicate a worse condition.

There is a processing spreadsheet for each typology and city. To speed up the data processing, automation using Python codes was chosen, programmed in the Visual Studio Code environment. The automation was implemented using the Pandas library, widely used for data manipulation and analysis, along with the Openpyxl and xlwings commands, which allow manipulation of Excel spreadsheets (.xlsx format). This means that if the data output is in .csv format, it must first be converted to .xlsx. This conversion is performed by a code developed specifically for this research, ensuring that the data is in the correct format for subsequent processing.

Proper organization of the files is essential to ensure the correct functioning of the codes. The research method requires that all source files, obtained from the EnergyPlus simulations, follow a specific naming convention: "'city'_'typology'_'material-combination'_'opening'-'direction'". A practical example for the city of Unaí would be: "unai_R1N_P6C6_JGCP-W". This standardized naming convention simplifies the identification of files during the automated process and ensures that data is logically organized.

Three codes were developed: the first to convert all files from the chosen folders from .csv to .xlsx format, and the second to duplicate and rename the treatment spreadsheet for a specific city to accommodate all 288 possible combinations of material and solar orientation.

A third code is responsible for copying data from the source spreadsheets generated in EnergyPlus and inserting them into the corresponding treatment spreadsheet. This code was designed to interpret the file name and accurately relate the variables between the spreadsheets. For instance, it ensures that data from the file "formiga_R1N_P1C1_JGCP-SE" is correctly inserted into the JGCP tab of the spreadsheet "planilha_de_tratamento_R1N_formiga_SE_P1C1." This process eliminates the risk of human error during data transfer and ensures that the simulations are based on accurately allocated information.

5.4 Costs spreadsheet and comparative analysis

Initially, cost composition tables for budgeting are developed for all constructive solutions of vertical enclosures and roofing, as shown in table 3. Considering the six masonry options and the six roofing options, a total of 36 combinations were evaluated.

The next step is to check the costs in the National System of Construction Cost and Indexes Survey (SINAPI) for December 2013, 2018, and 2023. Following that, the cost of the 36 compositions was calculated. The cost of the reference alternative (External Wall 1, Internal Wall 1, and Roof 2), which is specified by NBR 12.721 (ABNT, 2006) for the typology, was considered in its totality in each year.

Subsequently, the percentage variations in the costs of the other envelope compositions were calculated by the ratio between the cost of each composition and the cost of the reference alternative (for both masonry walls and roofing) for each year analyzed. A comparative temporal analysis of the percentage variation of the values between alternatives was conducted to investigate those whose costs fluctuated significantly over time. It was possible to identify that some solutions experienced an expansion in market share and a relative reduction in cost. The value adopted was the relative cost in December 2023, as shown in Table 4.

5.5 Water heating system complexity and public policies incentive

At this stage of the housing development, it is understood that performing a detailed technical analysis of water heating systems (SAA) to estimate their cost is not appropriate. Instead, three qualitative groupings were established, based on the construction complexity and cost of the SAA: low complexity, medium complexity, and high complexity. Table 5 details the grouping of each system in terms of its construction complexity and the value assigned to it. In this case, the values are inversely proportional.

In the same table 5, the three qualitative groupings are also presented for addressing the incentives for using the SAA provided by public policies. The definition of these groups was based on Brazilian plans MME (2011), (EPE, 2020) and the INI-R (INMETRO, 2022), with values assigned in a directly proportional manner—higher values indicating greater incentives.

Construction Solution	Descriptive
External Wall 1 (EW1)	Snow white paint + Industrialized external mortar(2.5cm) + ceramic block (14 cm) + sprayed gypsum (0.5cm) + Snow white paint - Ceramic Block - "Wall CE extint"
External Wall 2 (EW2)	Snow white paint + industrialized external mortar (2.5cm) + autoclaved aerated concrete block (15 cm) + sprayed gypsum (0.5cm) + snow white paint - autoclaved aerated concrete block - "wall si"
External Wall 3 (EW3)	Snow white paint + Industrialized external mortar(2.5cm) + Structural concrete block (14 cm) + sprayed gypsum (0.5cm) + Snow white paint - Structural Concrete Block - "BC wall"
External Wall 4 (EW4)	Monolayer Industrialized external mortar in snow white color(2.5cm) + Cast-in-place concrete wall (10 cm) + sprayed gypsum (0.5cm) + Snow white paint - Cast-in-Place Concrete Wall - "Wall_ext cm in loco"
External Wall 5 (EW5)	Snow white paint + Coating + Cement board(1cm) + Air chamber (14 cm) + Cement board(-1cm) + sprayed gypsum (0.5cm) + Snow white paint - LSF - "LSF-ext without insulation"
External Wall 6 (EW6)	Snow white paint + Coating + Cement board(1cm) + ROCK WOOL (9 cm) + Air chamber (5 cm) + Cement board(1cm) + sprayed gypsum (0.5cm) + Snow white paint - LSF with insulation - "LSF-ext with insulation"
Internal Wall 1 (IW1)	Snow white paint + sprayed gypsum (0.5cm) + ceramic block (9 cm) + sprayed gypsum (0.5cm) + Snow white paint - Ceramic Block - "Wall CE intint"
Internal Wall 2 (IW2)	Snow white paint + sprayed gypsum (0.5cm) + autoclaved aerated concrete block (10 cm) + sprayed gypsum (0.5cm) + snow white paint - autoclaved aerated concrete block - "wall si"
Internal Wall 3 (IW3)	Snow white paint + sprayed gypsum (0.5cm) + Structural concrete block (14 cm) + sprayed gypsum (0.5cm) + Snow white paint - Structural Concrete Block - "BC wall"
Internal Wall 4 (IW4)	Snow white paint + sprayed gypsum (0.5cm) + Cast-in-place concrete wall (10 cm) + sprayed gypsum (0.5cm) + Snow white paint - Cast-in-Place Concrete Wall - "Wall_int cm in loco"
Internal Wall 5 (IW5)	Snow white paint + sprayed gypsum (0.5cm) + Cement board(-1cm) + Air chamber (14 cm) + Cement board(1cm) + sprayed gypsum (0.5cm) + Snow white paint - LSF - "LSF-int without insulation"
Internal Wall 6 (IW6)	Snow white paint + Sprayed gypsum (0.5cm) + Cement board(1cm) + Air chamber (14 cm) + Cement board(1cm) + Sprayed gypsum (0.5CM) + Snow white paint - LSF with insulation - "LSF-int with insulation"
Roof 1 (R1)	Flat concrete slab (15 cm) + asphalt membrane + mechanical protection mortar (2cm)
Roof 2 (R2)	Flat concrete slab (15 cm) + air chamber (>50 cm) + fiber cement tile
Roof 3 (R3)	Flat concrete slab (15 cm) + air chamber (>50 cm) + aluminum membrane + fiber cement tile
Roof 4 (R4)	Flat concrete slab (15 cm) + air chamber (>50 cm) + ceramic tile
Roof 5 (R5)	Flat concrete slab (15 cm) + air chamber (>50 cm) + thermoacoustic trapezoidal metal sheet (4.5 cm)
Roof 6 (R6)	Flat concrete slab (15 cm) + asphalt membrane + mechanical protection mortar (2cm) + industrialized green roof system (ecoroof)

Table 3: Construction systems for vertical sealing and roofs.

Source: created by the authors.

Composition	Cost	Composition	Cost
EW1+IW1+R1	94.84%	EW4+IW4R1	261.72%
EW1+IW1+R2	100.00%	EW4+PI4+R2	266.88%
EW1+IW1+R3	101.14%	EW4+PI4+R3	268.01%
EW1+IW1+R4	85.48%	EW4+PI4+R4	252.35%
EW1+IW1+R5	98.82%	EW4+PI4+R5	265.70%
EW1+IW1+R6	113.51%	EW4+PI4+R6	280.39%
EW2+IW2+R1	118.14%	EW5+IW5+R1	40.69%
EW2+IW2+R2	123.30%	EW5+IW5+R2	45.85%
EW2+IW2+R3	124.44%	EW5+IW5+R3	46.99%
EW2+IW2+R4	108.78%	EW5+IW5+R4	31.33%
EW2+IW2+R5	122.12%	EW5+IW5+R5	44.67%
EW2+IW2+R6	136.81%	EW5+IW5+R6	59.36%
EW3+IW3+R1	92.32%	EW6+IW6+R1	41.40%
EW3+IW3+R2	97.48%	EW6+IW6+R2	46.56%
EW3+IW3+R3	98.61%	EW6+IW6+R3	47.70%
EW3+IW3+R4	82.95%	EW6+IW6+R4	32.03%
EW3+IW3+R5	96.30%	EW6+IW6+R5	45.38%

Table 4: Compositions and relative cost.
Source: created by the authors.

6. BUILDING THE DATABASE FILE

The database file type received and processed by RESIDE is either .SQL or an SQLite file. It contains 12 columns divided into two sets: parameters destined to define the analysis alternatives and the evaluation criteria. The former includes: (i) the construction solution type for vertical enclosures; (ii) the construction solution type for the roof; (iii) the openings size; (iv) presence of sun shading in the openings; (v) condition of cross ventilation; (vi) solar orientation of the building main axis relative to the sun and (vii) type of water supply system. These are the parameters the user can select to set up their alternatives for analysis. The evaluation criteria are: (i) percentage of comfort hours; (ii) cooling degree hours; (iii) cost of the solutions; (iv) construction complexity of the water heating system; (v) incentives from public policies for the water supply system. These are the data that RESIDE uses to rank the analyzed alternatives.

To accelerate this process and enhance reliability and robustness, a code was developed to construct the database for each city. This code is more complex than those used for handling thermal-energy simulation data. It reads specific cells in the data treatment spreadsheets and inserts the corresponding data for the two variables from the thermal-energy simulation. After this step, the remaining variables required for the database are manually filled in. Simultaneously, a manual verification is conducted to ensure there are no blank fields from the automatic filling. If any blanks are found, an analysis is performed to identify and resolve the issue.

Type	Construction Complexity	Value	Public Political Incentive	Value
Single-Family Solar Accumulation	High	1000	High	1000
Single-Family Natural Gas Instantaneous	Low	1	Medium	100
Single-Family LPG Instantaneous	Low	1	Low	1
Point-of-Use Electric Instantaneous	Low	1	Low	1
Single-Family Electric Instantaneous	Medium	100	Low	1
Point-of-Use Shower Instantaneous	Low	1	Low	1
Single-Family Natural Gas Accumulation	Medium	100	Medium	100
Single-Family LPG Accumulation	Medium	100	Medium	100
Single-Family Electric Accumulation	Medium	100	Medium	100
Multi-Family Solar Accumulation	High	1000	High	1000
Multi-Family Heat Pump Accumulation	High	1000	High	1000
Multi-Family Natural Gas Accumulation	Medium	100	Medium	100
Multi-Family LPG Accumulation	Medium	100	Medium	100
Multi-Family Electric Accumulation	Medium	100	Medium	100

Table 5: Qualitative grouping for construction complexity and public political incentive of SAA (Water Heating System).
Source: created by the authors.

The integration of the database with the RESIDE software is done by converting the .csv file into a .sql format using a free, conventional converter available online. After the conversion, the upload process in RESIDE is intuitive and straightforward, requiring only that the username the project and save the tests performed. This final step ensures that the processed data can be readily utilized within the RESIDE environment, supporting the decision-making process.

7. DISCUSSION

Although there is no official survey on the subject, we can make an educated guess: if suddenly everyone in Brazil intending to build a house sought architectural design accompanied by thermal and energy performance simulations, would they find the number of computational simulation specialists required? Considering the distribution of architects across Brazil and the ratio of architecture professionals to the total population, as reported by the Architecture and Urbanism Yearbook (CAU, 2019), one could assume that the answer to this hypothetical exercise would be no.

In this context, the development and availability of simpler and more accessible tools for the general public, aimed at introducing discussions on thermal-energy performance in the early design stages, considering cost and other construction aspects, could help contribute to increasing the energy efficiency of new buildings. Although these types of tools do not allow for a detailed investigation of the project being analyzed, they offer initial guidance that can be accessed by a significant number of people.

Therefore, it is important to clarify that the use of RESIDE does not compete with the performance of detailed simulations for a given project. Instead, this tool aims to support discussions on energy efficiency in the early stages of residential project development.

Given the intended role of RESIDE, it is necessary for it to be accessible to a large number of users, capable of reproducing various typologies and urban contexts. For this to happen, a significant effort to create diverse database is required.

The construction of these databases, as previously described, involves multiple work stages that are intensive in two key demands. The first is the need for specialized labor in thermal and energy simulation and Python programming. The second is a robust computational infrastructure to speed up the simulations. In this research project, it can be said that the time spent on training and the limited infrastructure for simulations were significant drawbacks that limited the number of databases produced thus far. However, the results achieved may eventually support a significant number of users in Minas Gerais.

8. FINAL CONSIDERATIONS

The use of multicriteria decision-making (MCDM) tools represents an important step towards achieving sustainable development goals. Through these methods, it is possible to conduct an integrated analysis that considers the interdependencies and trade-offs between different criteria, providing a more comprehensive overview of design and construction choices that impact the entire lifecycle of a building. In other words, MCDM tools allow decision-makers to address the sustainability challenges inherent in projects with the necessary complexity.

The RESIDE software emerges as an instrument that supports designers and decision-makers who are willing to face increasing complexity with sustainable practices, starting from the early stages of architectural design. However, the use of RESIDE is conditioned on the prior existence of databases for various urban contexts, which are not currently available. The proposed procedure for identifying representative databases is a step forward in enabling the large-scale use of this software. It is understood that the overlap of socioeconomic, cultural, and political classifications, established for the entire Brazilian territory, and climate classifications allows for the identification of reference cities for intermediate regions. Identifying the most common construction typologies in these cities leads to databases that can be used in neighboring cities with similar climate conditions. This type of database simplification becomes feasible because ELECTRE-III is a method that responds well to situations where full confidence in the accuracy of the values assigned to the criteria cannot be relied upon, due to the process of overclassification, concordance, and discordance it performs to classify alternatives.

The procedure for developing the databases has so far resulted in databases for three construction typologies in 13 representative cities. The research will continue on two fronts: the ongoing construction of databases for other construction typologies and the development of a website to make both RESIDE and its databases available to the general public.

REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR12721: Avaliação de custos unitários de construção para incorporação imobiliária e outras disposições para condomínios edilícios - Procedimento, Rio de Janeiro, 2006. 91 p

BATTISTI, Fabrizio. ELECTRE III for strategic environmental assessment: a "Phantom" approach. **Sustainability**, v. 14, n. 10, p. 6221, 2022. https://doi.org/10.3390/su14106221.

CAU - Conselho de Arquitetura e Urbanismo. **Anuário de Arquitetura e Urbanismo 2019**. volume 3. CAU, Brasília, 2019. Available at https://www.caubr.gov.br/wp-content/uploads/2019/06/ANU%C3%81RIO-FINAL-WEB.pdf

EBADI TORKAYESH, Ali; FATHIPOIR, Fariba; SAIDI-MEHRABD, Mohammad. Entropy-based multi-criteria analysis of thermochemical conversions for energy recovery from municipal solid waste using fuzzy VIKOR

and ELECTRE III: case of Azerbaijan region, Iran. **Journal of Energy Management and Technology**, v. 3, n. 1, p. 17-29, 2019. doi: 10.22109/jemt.2018.134505.1098.

ELETROBRAS. Pesquisa de posse e hábitos de uso de equipamentos elétricos na classe residencial. Brasil, 2019. **Eletrobras, Procel, 2019**. Available at https://eletrobras.com/pt/AreasdeAtuacao/BRASIL.pdf. Accessed on Nov 10, 2023.

EPE. NOTA TÉCNICA EPE 030/2018 **Uso de Ar-Condicionado no Setor Residencial Brasileiro:** Perspectivas e contribuições para o avanço em eficiência energética. Brasília, EPE, 2018. 43 p. Available at https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-341/NT%20EPE%20030_2018_18Dez2018.pdf Accessed on Out 03, 2023.

EPE. **Nota Técnica:** Ações para promoção da eficiência energética nas edificações brasileiras: no caminho da transição energética. Brasília, EPE, 2020. Available at https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/Documents/NT%20DEA-SEE-007-2020.pdf/. Accessed on Nov 17, 2022.

FJP. **Regiões Geográficas Intermediárias de Minas Gerais**. Available at https://fjp.mg.gov.br/regioes-geograficas-intermediarias-de-minas-gerais/. Accessed on March 24, 2024.

HUMPHREYS, M. Outdoor Temperatures and Comfort Indoors. **Building Research & Information**, v. 6, n. 2, p. 92, 1978.

IBGE. **Divisão regional do Brasil em regiões geográficas imediatas e regiões geográficas intermediárias:** 2017, Rio de Janeiro: IBGE, 2017. 82p. ISBN 978-85-240-4418-2

IBGE. IBGE **Cidades**. Available at https://cidades.ibge.gov.br/. Accessed on March 24, 2024.

INMETRO. Portaria nº 309, de 6 de setembro de 2022. Brasília, **INMETRO 2022**. Available at https://pbeedifica.com.br/inirmanuais#:~:text=Os%20manuais%20de%20aplica%C3%A7%C3%A3o%20da,Anexos%20II%20e%20III%2C%20respectivamente. Accessed on Set 24, 2023.

INSTITUTO DE PESQUISAS E ESTUDOS FLORESTAIS. **Mapa Köppen Brasil Detalhado**. Available at https://www2.ipef.br/geodatabase/. Accessed on March 25, 2024.

KOSOVA, Robert; QENDRAJ, Daniela Halidini; XHAFAJ, Evgjeni. Meta-analysis ELECTRE III and AHP in evaluating and ranking urban resilience. **Journal of Environmental Management & Tourism**, v. 13, n. 3, p. 756-768, 2022. Online-ISSN: 2068-7729.

LABED, Kaouter; HAMDADOU, Djamila; TRIFA, Mohamed. Towards a Spatial Decision Support System for Territory Planning. **The Journal of Contemporary Issues in Business and Government**, v. 30, n. 1, p. 25-36, 2024.

LOURA, Rejane Magiag, RAMOS, Bruno S., MAIRINK, Ana J. M., ASSIS, Eleonora S.; BASTOS, Leopoldo E. G. Multicriteria decision tool to assist in decision-making of housing envelope solutions and heating water systems. **INTERNATIONAL JOURNAL OF DEVELOPMENT RESEARCH**, v. 09, p. 27445-27452, 2019. ISSN: 2230-9926.

MITCHELL, Melanie. **Complexity: A Guided Tour, New York, Oxford University Press, 2009**. ISBN 978-0-19-979810-0. 349 p.

MINISTÉRIO DE MINAS E ENERGIA (MME). **Plano Nacional de Eficiência Energética:** Premissas e Diretrizes Básicas. Brasília, MME, 2011. Available at https://bibliotecadigital.economia.gov.br/handle/123456789/183. Accessed on Ago 18, 2015.

NIMER, E. Um modelo metodológico de classificação de climas. **Revista Brasileira de Geografia**, Rio de Janeiro, v. 41, n. 4, p. 59-89, out./dez. 1979.

ROY, B. Electre-III, an algorithm for ranking based on a fuzzy representation of multiple criteria preferences. **Sema, Research Report n.81**, Paris, 1977.

SALVADOR, Guilherme et al. ELECTRE applied in supplier selection – a literature review. **Procedia Computer Science**, v. 232, p. 1759-1768, 2024. ISSN 1877-0509, https://doi.org/10.1016/j.procs.2024.01.174.

TERVONEN, T.; FIGUEIRA, J.; LAHDELMA, R.; SALMINEN, P. An inverse approach for ELECTRE III. **Internal Report. Coimbra, INESC, 2005.**

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THE INFLUENCE OF SAND AND CEMENT ON THE LATERITIC SOIL COMPACTION WITH IRON ORE TAILINGS

INFLUÊNCIA DA AREIA E DO CIMENTO NA COMPACTAÇÃO DE SOLO LATERÍTICO COM REJEITO DE MINÉRIO DE FERRO

INFLUENCIA DE LA ARENA Y DEL CEMENTO EN LA COMPACTACIÓN DE SUELO LATERÍTICO CON RESIDUOS DE MINERAL DE HIERRO

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ABSTRACT

The characteristics of lateritic soils vary significantly, depending on the laterization process they have undergone. Due to this diversity, physicochemical and mechanical tests may be necessary to assess the feasibility of using it. This research aimed to characterize the soil and sedimented iron ore tailings (IOT) and analyze, through compaction tests, the influence of the Portland cement and the sand in the mixtures used for rammed earth (RE) construction. Three groups were proposed for compaction tests: Group 1 (reference – only soil), Group 2 (40% sand + soil), and Group 3 (40% sand + 2.5% Portland cement). Each group consisted of five mixtures with varying content of soil replacement by IOT. The results showed that, although Groups 2 and 3 increased the maximum dry density values in the mixtures without IOT compared to Group 1, the mixtures did not reach the minimum requirements specified by the Brazilian standard for RE. Additionally, the mixtures without IOT presented high optimal moisture content. The use of IOT in mixtures positively reduced the optimum water content and increased the dry density values, which are important parameters to RE production.

KEYWORDS

Compaction test; Lateritic soil; Iron ore tailings; Rammed earth.

RESUMO

As características dos solos lateríticos variam significativamente, dependendo do processo de laterização a que foram submetidos. Devido a essa diversidade, análises físico-químicas e mecânicas podem ser necessários para avaliar a viabilidade. Esta pesquisa teve como objetivo caracterizar o solo e os rejeitos de minério de ferro sedimentados (RMF) e analisar, por meio de testes de compactação, a influência do cimento Portland e da areia nas misturas usadas para a taipa de pilão. Três grupos foram propostos para os testes de compactação: Grupo 1 (referência), grupo 2 (40% de areia) e grupo 3 (40% de areia e 2,5% de cimento Portland). Cada grupo consistia em cinco misturas com conteúdo variável da substituição do solo pelo RMF. Os resultados mostraram que, embora os Grupos 2 e 3 tenham aumentado os valores máximos de densidade seca nas misturas sem RMF em comparação ao Grupo 1, as misturas não atingiram os requisitos

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mínimos especificados pela norma brasileira de taipa de pilão. Além disso, as misturas sem RMF apresentaram elevado teor de umidade. O uso do RMF em misturas reduziu a quantidade de água ótima para compactação e aumentou os valores de densidade seca, que são parâmetros importantes para a produção da taipa de pilão.

PALAVRAS-CHAVE

Ensaio de compactação; solo laterítico; rejeito de minério de ferro; taipa de pilão.

RESUMEN

Las características de los suelos lateríticos varían significativamente, dependiendo del proceso de laterización al que hayan sido sometidos. Debido a esta diversidad, pueden ser necesarios análisis físico-químicos y mecánicos para evaluar la viabilidad. Esta investigación tuvo como objetivo caracterizar el suelo y los residuos de mineral de hierro sedimentados (RMF) y analizar, a través de pruebas de compactación, la influencia del cemento Portland y de la arena en las mezclas utilizadas para la tierra apisonada. Se propusieron tres grupos para las pruebas de compactación: Grupo 1 (referencia), Grupo 2 (40% de arena) y Grupo 3 (40% de arena y 2,5% de cemento Portland). Cada grupo consistía en cinco mezclas con contenido variable de sustitución del suelo por RMF. Los resultados mostraron que, aunque los Grupos 2 y 3 aumentaron los valores máximos de densidad seca en las mezclas sin RMF en comparación con el Grupo 1, las mezclas no cumplieron con los requisitos mínimos especificados por la norma brasileña de tierra apisonada. Además, las mezclas sin RMF presentaron un alto contenido de humedad. El uso de RMF en las mezclas redujo la cantidad de agua óptima para la compactación y aumentó los valores de densidad seca, que son parámetros importantes para la producción de tierra apisonada.

1. INTRODUCTION

Laterization is a natural process of rock degradation caused by atmospheric and geological conditions (KUMAR *et al*., 2022). Lateritic soils are the product of this weathering process, originating from composed rocks essentially by iron, aluminum, and quartz oxides, being common in tropical and subtropical regions (CASTRO *et al*., 2020). About 8% of the earth's surface is covered by lateritic soils, with Brazil presenting its occurrence in almost all regions.

Although laterization is a natural process, climate change and soil desertification have intensified this phenomenon, intensifying the natural process. The fine particles of lateritic soil have caused air pollution around the world (KUMAR *et al*., 2022). Thus, it becomes essential to investigate in detail the behavior of lateritic soils in various applications, especially in lower environmental impact solutions.

Lateritic soils may have different characteristics and behaviors due to the diversity of their original rocks and the process of weathering. This process can result in variations in the structure, chemical composition, and granulometry. Consequently, the structural, chemical, and mineralogical properties are modified (CAMAPUM, 2004).

Lateritic soil structure can change their void rates and the size and volume of the pores. Concerning granulometry and mineralogical properties, lateritic soils, because they have high fine content, are strongly influenced by the clay fraction.

The clay fraction of these soils is predominantly composed of the kaolinite group (Luciano *et al*., 2012) and has a high concentration of iron and aluminum oxides (Pinto, 1998). Among the main three clay minerals, kaolinite has the largest surface area, but the lowest clay activity (DAS, 2007). Its structure consists of the repetition of layers of elementary gibbsite and silica blades in a 1:1 crystalline network. The presence of poorly expansive clay is frequent in lateritic soils in tropical climate regions, such as the Minas Gerais region, in which the laterization is conditioned by soil leaching (VALE, 2020).

Because of its heterogeneity, lateritic soils present changes in geotechnical characteristics such as Atterberg limits, specific density, and humidity (KUMAR *et al*., 2022), and it isn't easy to estimate their behavior when submitted to climate change (CAMAPUM, 2004). Therefore, it may be necessary to conduct physicochemical and mechanical tests to evaluate the feasibility of using lateritic soil (Araújo and Farias, Araújo, Rodrigues, 2023).

The compaction test is a common practice used for soil study. In a natural state, the soil has a high void ratio that is filled with air. During compaction, mechanical energy application removes air, increasing soil density and reducing its empty spaces (BARROS *et al*., 2021). Through compaction tests, it is possible to determine the maximum dry density (MDD) and optimum moisture content (OMC).

In addition to that, the rammed earth (RE) technique also benefits from the knowledge that can be acquired in the compaction test because it is one of the parameters required by NBR 17014 (ABNT, 2022), reinforcing its importance.

Rammed earth is a low environmental impact constructive technique in which the wall is performed with compacted soil within removable formwork, resulting in a monolithic element. Thus, proper compaction can increase the wall resistance. However, some authors attest that the RE vulnerability increases when lateritic soils are used because these soils change their properties by interacting with the atmosphere (Wahab *et al*., 2021).

The use of stabilizers can improve the physical and mechanical characteristics of lateritic soils. Several research works have been carried out on the use of cement and lime for lateritic soil stabilization. However, cement production has a high environmental impact, and its use should be reduced whenever possible.

Wahab et al. (2021) studied the influence of 3, 6, 9, and 12% of cement addition on lateritic soil on compaction, durability, and compressive strength. Soil compaction increased as cement was added. Caro et al. (2018) analyzed that between 2% and 6% of cement may be sufficient to stabilize lateritic soils.

Some research has used industrial waste for lateritic soil stabilization. Obianyo et al. (2021) studied Nigerian lateritic soil stabilization with 2% bone ash and 2% palm ash for adobes production. The authors concluded that the bone ash and palm ash addition contributed to a relevant increase in compressive strength.

Oluremi and Ishola (2024) investigated the efficacy of the Arabic gum biopolymer as an additive to increase the mechanical resistance of Nigerian lateritic soil, as used for paving. The authors attested that using 10% biopolymer increased the MDD and decreased the OMC.

Another study used contaminated sand with oil for lateritic soil stabilization. The authors concluded that using up to 20% of contaminated sand could be adequate for soil stabilization (ABDELIMALI *et al*., 2021).

Lage *et al*. (2022) used sedimented iron ore tailings (IOT) by soil replacement for lateritic soil stabilization,

in southeastern Brazil, for RE production. The authors demonstrated that compaction increased and OMC decreased as the IOT was added.

Thus, different stabilizers have been discussed in the literature, and the use of industrial waste is a viable alternative to mitigate the environmental impact of soil stabilization.

Iron ore tailings are by-products originating from the iron ore process, mainly in Brazil, China, and Australia. Despite high profits, one of the main environmental issues associated with iron extraction is the amount of tailings generated during the process and their environmental consequences.

In 2015, the Fundão dam collapsed in Bento Rodrigues, a little community belonging to the municipality of Mariana, Minas Gerais. The dam's storage was 55 million cubic meters of iron ore tailings (IOT) resulting in the IOT displacement through the rivers, where it was sedimented at the bottom (SEMAD, 2016). Sedimented IOT samples were dredged and are available for proper use.

Considering the wide availability of lateritic soils in Brazil and the need to use them in low environmental impact constructive solutions, especially in response to the growing demand for the urgent destination of IOT, this paper aimed to analyze the lateritic soil stabilization by compaction tests with IOT incorporation. Sand and Portland cement were added to the mixtures to make them suitable for the RE technique.

This research aimed to provide adequate use for sedimented IOT, which is currently stored without the correct destination. In addition, it can expand knowledge about lateritic soil stabilization for RE production, which is necessary for its dissemination and application.

2. MATERIALS AND METHODS

The materials used in this study were: the lateritic soil, IOT samples, Portland cement, and natural sand. The soil used was collected from the central region of the state of Minas Gerais, the Southeast region of Brazil (Figure 1). The IOT collection was carried out in the municipality of Barra Longa, at Alta Floresta Farm, which became a surplus deposition and management area five years after the failure of the Fundão dam (Mariana, Minas Gerais).

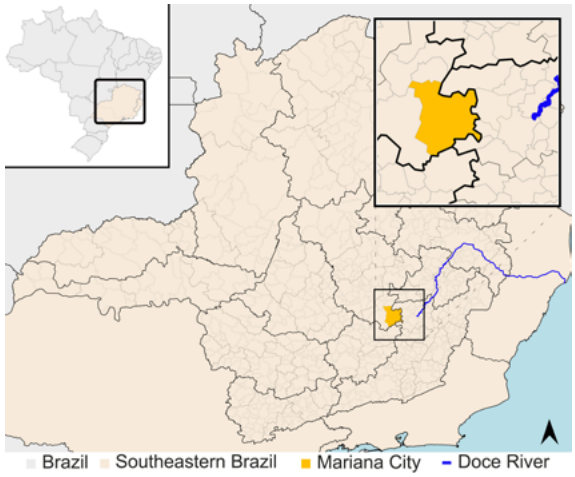


Figure 1: Map - Location of Mariana City and Doce River.
Source: Authors.

Soil and IOT were analyzed by the following tests: i) mineralogical characterization was performed by X-ray diffraction (XRD); ii) chemical characterization was performed by X-ray fluorescence spectrometry (XRF); and physical characterization was carried out by granulometry (NBR 7181, 2016a), and Atterberg limits (NBR 6459, 2016b and NBR 7180, 2016c). Table 01 presents the tests and results obtained.

Clay activity influences soil plasticity. It was observed that the soil used in the mixtures has a high clay content but has low plasticity due to the type of clay, the kaolinite (HOFFMANN, MINTO, HEISE, 2011).

Soil Plasticity Index (PI) was equal to 2% and clay fraction was equal to 35%, so the Clay Activity (CA) of the soil was calculated at 0.06%. The clays are considered inactive when the CA is less than 0.75%, which confirms the XRD and XRF results, which presented a predominance of kaolinite which is a low-activity clay (SKEMPTOON, 1953).

Low clay activity indicates greater soil stability, lower variations in water content, fewer volume changes when damp, and lesser shrinkage when dry, compared to materials that have the highest clay activity (KOUTOUS, HILALI, 2019).

Properties	Soil	IOT
Clay (%)	35.0	9.0
Silt (%)	19.0	35.0
Sand (%)	45.8	52.0
Gravel (%)	0.2	4.0
Liquidity Limit (%)	41.0	20.0
Plasticity Limit (%)	39.0	NP
Plasticity Index – PI (%)	2.0	-

Table 1: Soil and IOT characterisation and classification.
Source: Authors.

XRD analysis showed a predominance of the kaolinite, quartz, and goethite minerals in the soil. The sample of IOT presented quartz and hematite as predominant minerals. It suggests that the sedimented IOT maintained characteristics like the IOT found in dams, even after the tailings have spread and have mixed in the environment. In the chemical analysis by XRF, both in the soil and in the IOT sample, significant proportions of the alumina (Al_2O_3), silica (SiO_2), and hematite (Fe_2O_3) minerals were identified. The latter was also observed in the XRD test.

Additionally, IOT samples were subjected to leaching and solubilization tests, according to NBR 10005 and 10006 (ABNT, 2004b,c) to classify them by hazardousness, according to NBR 10004 (ABNT, 2004a). IOT collected in Barra Longa was classified as Class II A - not dangerous and not inert, as it contains iron, aluminum, and manganese in content above the upper established limit.

The sand sample used in this research is the commercial-washed medium type. The maximum characteristic dimension value of the sand was 2.36 mm, and the fineness modulus was 2.44 mm. Sand and IOT were added to the mixtures to achieve the granulometric guidelines defined by the Brazilian rammed earth standard, NBR 17014 (ABNT, 2022).

Cement was added to analyze the impact on mechanical strength, durability, and the effect of raising the pH value. The cement used was type CPII-F 32 (Portland composite cement) with clinker + calcium sulfate partially replaced by limestone filler - clinker + calcium sulfate = 75-89%; and filler = 11-25% (ABNT, 2018), as it is one of the most common cement in Brazil. CP II – F is equivalent to ASTM limestone cement (IL) and, depending on the composition proportion and material quality, can be equivalent to BSI CEM II A-L, ALL, B-L, or B-LL (NATALLI *et al*., 2021).

2.1 Samples preparation

The mixtures produced with IOT as a soil replacement were defined based on the results obtained in the characterization of materials, to reach the requirements of NBR 17014 (ABNT, 2022). Then, the mixtures must follow a) 50% to 80% of retained material between sieves with mesh openings of 0.075 mm and 2.0 mm; b) 20% to 35% of material that passes in the sieve with a mesh opening of 0.075 mm.

Based on these requirements, NBR 17014 (ABNT, 2022) classifies clay and silt fractions below 0.075 mm grain size and sand fractions between 0.075 mm to 2.0 mm. For a definition, the clay is classified as all particles with Ø ≤ 0.002 mm; the silt is between 0.002 mm and 0.075 mm; and the sand is between 0.075 mm and 2 mm.

So, Group 1 was composed of five mixtures, with two reference samples (100% soil and 100% IOT), while the other three consisted of soil and IOT mixtures. The mixtures were named according to the soil replacement by IOT. Even with high soil replacement by IOT, it was observed that it was not possible to reach the "clay + silt" values specified in NBR 17014, as shown in Table 2.

Group 2 was defined with the addition of natural sand aiming for the granulometric correction of Group 1. The sand addition is a recommended practice by NBR 17014 (ABNT, 2022). The letter 'S' was added to nominate the Group 2. Table 3 shows the mixtures and proportions of Group 2.

Mixtures	Soil (%)	IOT (%)	Clay+ Silt (%)	Sand (%)
0	100	0	74.05	25.72
70	30	70	57.87	39.00
80	20	80	50.01	46.18
90	10	90	46.82	49.01
100	0	100	44.0	52.00

Table 2: Mixtures and proportions of materials - Group 1.
Source: Authors.

In addition to the granulometric correction with sand, 2.5% of cement was added to the mixtures, in Group 3, to analyze the cement's impact on the durability and mechanical behavior of the mixtures.

The cement content was chosen to seek the benefits of stabilization with the lowest cement content, due to the high environmental impact of the material. This content was defined after literature analysis (ARRIGONI *et al*., 2017; TOUFIGH, KIANFAR, 2019; ZAMI *et al*., 2022). The letters "SC" were added to nominate the Group 3.

Mix-tures	Soil (%)	IOT (%)	Sand (%)	Clay+ Silt (%)	Total Sand (%)
0-S	100	0	40	52.89	46.94
70-S	30	70	40	37.87	60.28
80-S	20	80	40	35.72	61.96
90-S	10	90	40	33.58	63.84
100-S	0	100	40	31.43	65.71

Table 3: Mixtures and proportions of materials - Group 2.
Source: Authors.

Table 04 presents a summary of the groups, the nomenclatures used, and the proportion of materials.

Group	Mix-tures	Soil (%)	IOT (%)	Sand (%)	Ce-ment (%)
1	0	100	0	-	-
	70	30	70	-	
	80	20	80	-	
	90	10	90	-	
	100	0	100	-	
2	0-S	100	0	40	-
	70-S	30	70	40	
	80-S	20	80	40	
	90-S	10	90	40	
	100-S	0	100	40	
3	0-SC	100	0	40	2.5
	70-SC	30	70	40	
	80-SC	20	80	40	
	90-SC	10	90	40	
	100-SC	0	100	40	

Table 4: Description of mixtures and material contents.
Source: Authors.

2.2 Compaction test

The compaction test, as established by NBR 7182 (ABNT, 2016d), was carried out to determine the moisture content necessary to compact the soil until reaching the maximum dry density, considering the compaction energy.

The small Proctor Hammer (2.5 kg) was used, with three layers of 26 blows per layer, as required on technical standard (NBR 7182), for normal compaction energy. To prevent the wet mixture from adhering to the bottom of the proctor, a filter paper has been positioned inside the mold.

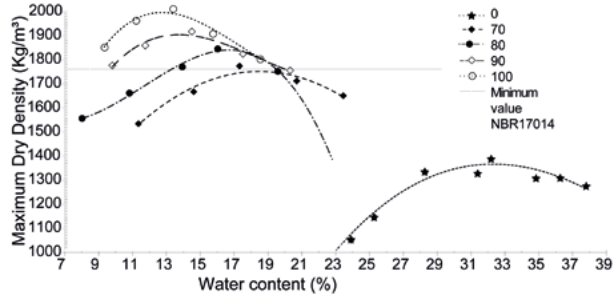
After compaction, the specimen was extracted with the help of the extractor. A little sample was removed from the center of the specimen to determine the moisture to obtain the compaction curve. According to NBR 17014 (ABNT, 2022), the mixture must reach a dry density value greater than or equal to 1750 kg/m^3, similar to those established in other countries (ÁVILA, PUERTAS, GALLEGO, 2021; LOSINI *et al*., 2022).

3. RESULTS AND DISCUSSION

Graphic 1 shows the results of the compaction test in Group 1. It is possible to observe that the mixtures 0 and 70 did not reach the MDD and presented high values of OMC.

The high moisture of soil compaction can be partially attributed to the high content of alumina (Al_2O_3) present in the soil. Alumina acts as a natural adsorbent owned by retaining liquids on its surface (PHAM *et al*., 2019).

If the RE mixtures show a high optimum moisture content (OMC) it is possible to observe four main disadvantages: i) contemporary, due to the limited water resources in many countries (ZAMI *et al*., 2022); II) The high water content may lead to retraction and deformation in RE during the drying process and evaporation of water (KOUTOUS, HILALI, 2019); iii) Excessive soil moisture may result in adherence to it to forms and other work equipment during RE molding (HOFFMANN, MINTO, HEISE, 2011); and iv) mechanical resistance tends to increase with the reduction in the OMC (Chauhan *et al*., 2019; JAQUIN *et al*., 2009).



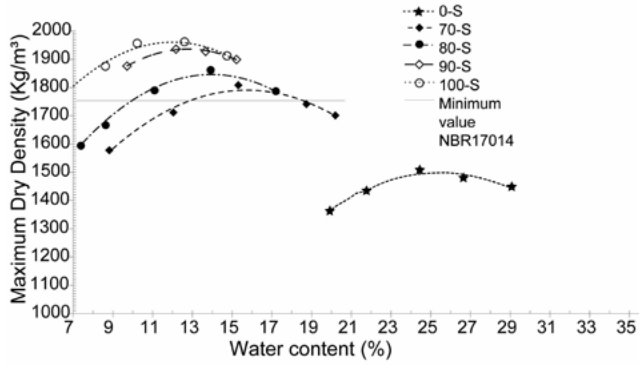
Graphic 1: Dry density versus water content - Group 1.
Source: Authors.

Figure 2 shows the adherence of the mixture into the molds during the RE samples production. However, it is

important to understand that the proctor compaction test does not apply the same energy as the mechanical compactor equipment used on the construction site. This means that the OMC, determined by the compaction test, can be excessively high (MESBAH, MOREL, OLIVER, 1999).

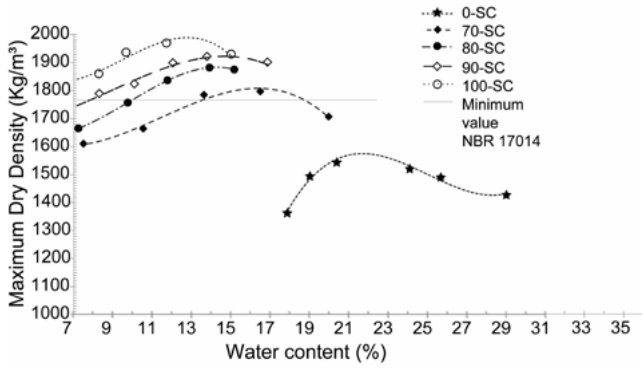
Figure 2: Adherence of the mixture (0% - Group 1) to the mold.
Source: Authors.

Graphic 2 shows the compaction test of Group 2. In mixtures 80-S, 90-S, and 100-S, it is possible to observe an increase in MDD as it increased the IOT content in the mixture, similar to Group 1.

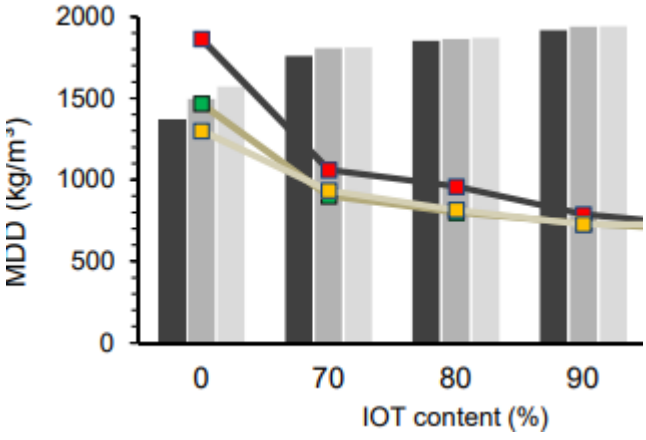


Graphic 2: Dry density versus water content - Group 2.
Source: Authors.

The sand addition has resulted in the reduction of OMC in all mixtures. The 0-S mixture was the most affected by the impact of the sand addition, with a 22% decrease in the OMC compared to Group 3 mixtures (Graphic 3). For a better comparative analysis and a better understanding of the impact of additions on mixtures, Graphic 4 was prepared.



Graphic 3: Dry density versus water content - Group 3.
Source: Authors.



Graphic 4: Dry density versus optimum water content.
Source: Authors.

It is noteworthy that correction with sand has a significantly greater and positive impact on mixtures produced without IOT or with a low content of IOT. This fact occurred because both sand and IOT act similarly in the mixture but considering that IOT is thinner than sand used.

Thus, in IOT-only mixtures, the sand and the cement do not affect the OMC and the MDD. The increase in dry density in mixtures with sand and cement addition can be explained by the contribution of sand to a uniform granulometric distribution, resulting in a more appropriate grain packaging and, consequently, a higher dry density (HOFFMANN, MINTO, HEISE, 2011).

There is also a tendency for the dry density of mixtures to increase as IOT content increases.

4. CONCLUSIONS

After the analysis, it was possible to conclude:

1. The lateritic soil studied did not reach the MDD required by NBR 17014. In addition, it presented a high humidity of compaction, resulting in soil adherence to the mold.
2. The sand addition for granulometric correction in the mixtures has reduced the OMC for compaction without significantly affecting the MDD of mixtures with higher IOT content.
3. In IOT mixtures, the cement did not significantly influence the OMC or the MDD.
4. The use of IOT in mixtures positively reduced the OMC and increased the dry density values, which are important parameters to RE production.

REFERENCES

ABDELHALIM, R. A.; RAMLI, H.; SELAMAT, M. R. Cone penetration measurements in oil-contaminated sand stabilized by lateritic soil and potencial usage in concrete mix. **Case Studies in Construction Materials**, v. 15, 2021. Disponível em: https://doi.org/10.1016/j.cscm.2021.e00580. Acesso em: 24 ago. 2024.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 6459**: solo: determinação do limite de liquidez. Rio de Janeiro, 2016b.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 7180:** solo: determinação do limite de plasticidade. Rio de Janeiro, 2016c.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 7181:** solo: análise granulométrica. Rio de Janeiro, 2016a.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 7182:** solo: ensaio de compactação. Rio de Janeiro, 2016d.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 10004:** resíduos sólidos: classificação. Rio de Janeiro, 2004a.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 10005:** procedimento para obtenção de extrato lixiviado de resíduos sólidos. Rio de Janeiro, 2004b.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 10006:** procedimento para obtenção de extrato solubilizado de resíduos sólidos. Rio de Janeiro, 2004c.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 16697:** cimento portland: requisitos. Rio de Janeiro, 2018.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 17014:** taipa de pilão: requisitos, procedimentos e controle. Rio de Janeiro, 2022.

ARAÚJO E FARIAS, M. L.; ARAÚJO, H. A.; RODRIGUES, J. K. Análise da aplicabilidade de sistema de classificação universal para solos lateríticos utilizados em camadas de pavimentos. **Transportes**, v. 31, n. 1, p. 2750, 2023. Disponível em: https://doi.org/10.58922/transportes.v31i1.2750. Acesso em: 20 jul. 2024.

ARRIGONI, A.; BECKETT, C.; CIANCIO, D.; DOTTELI, G. Life cycle analysis of environmental impact vs. durability of stabilised rammed earth. **Construction and Building Materials**, v. 142, p. 128–136, 1 jul. 2017. Disponível em: http://dx.doi.org/10.1016/j.conbuildmat.2017.03.066. Acesso em: 20 jul. 2024.

AVILA, F.; PUERTAS, E.; GALLEGO, R. Characterization of the mechanical and physical properties of unstabilized rammed earth: a review. **Construction and Building Materials**, v. 270, p. 121435-121446, 2021. Disponível em: https://doi.org/10.1016/j.conbuildmat.2020.121435. Acesso em: 20 jul. 2024.

Barros, D. do S., Pereira, P. H. dos S., Motter, H., Santos, A. dos. Compactação de solo: indíces físicos necessários para determinação dos fatores de compactação. **Pesquisa e Ação**, v.7, n.1, p, 51–64. 2021.

CAMAPUM, J. C. Propriedades e comportamento de solos tropicais não-saturados. In: 5º Simpósio Brasileiro de Solos Não Saturados, São Carlos, **Solos Não Saturados.** Vilar, O. M., EESC-USP, v. 2, p. 1-2, 2004.

Advanced characterisation of cement-stabilised lateritic soils to be used as road materials. **International Journal of Pavement Engineering**, v. 20, p. 1425–1434. 2018. Disponível em: https://doi.org/10.1016/j.rcradv.2022.200120. Acesso em 22 mar. 2024.

CASTRO, Marcus D.; OLIVEIRA, Vinícius N.; MASCARENHA, Márcia M.A.; GITIRANA JUNIOR, Gilson de F.N.; LUZ, Marta P. Análise das curvas características solo-água de amostras remoldada e indeformada de um solo laterítico não saturado. In: XX Congresso Brasileiro de Mecânica dos Solos e Engenharia Geotécnica, 2020. **Anais** [...]. Campinas, 2020.Disponível em: https://www.researchgate.net/publication/362144568_Analise_das_curvas_caracteristicas_solo-agua_de_amostras_remoldada_e_indeformada_de_um_solo_lateritico_nao_saturado. Acesso em: 20 jul. 2024.

DAS, Braja M.; SOBHAN, Khaled. **Fundamentos de engenharia geotécnica**. 6. ed. São Paulo: Thompson, 2007.

HOFFMANN, M.; MINTO, F.; HEISE, A. Taipa de pilão. In: NEVES, Célia; FARIA, Obede Borges (org.). **Técnicas de construção com terra.** Bauru, SP: FEB-UNESP/ PROTERRA, 2011. p. 1–79. E-book. Disponível em: www.redproterra.org. Acesso em: 22 ago. 2024.

JAQUIN, P. A.; AUGARD, C. E.; GALLIPOLI, D.; TOLL, D. G. The strenght of unstabilised rammed earth materials. **Geotecnique**, v.59, p. 487-490. Disponível em: http://dx.doi.org/10.1680/geot.2007.00129. Acesso em 24 de jul. 2024.

KOUTOUS, A.; HILALI, E. M. A Proposed Experimental Method for the Preparation of Rammed Earth Material. **International Journal of Engineering Research & Technology**, 2019. Disponível em: http://dx.doi.org/10.17577/IJERTV8IS070140. Acesso em: 20 jul. 2024.

KUMAR, S. G.; SAINI, P. K.; DEOLIYA, R. MISHRA, K. Characterization of laterite soil and its use in construction applications: A review. **Resources, Conservation and Recycling Advances**, v. 16, n. 200120, 2022. Disponível em: https://doi.org/10.1016/j.rcradv.2022.200120. Acesso em: 20 jul. 2024.

LAGE, Gabriela T. de L.; BESSA, Sofia, A. L.; SANTOS, Beatriz F. A. dos; MATIAS, L. M. GALERY, Roberto. **Potencial de estabilização da taipa de pilão com rejeitos de mineração e cal**. 11 nov. 2023, [S.l.]: ANTAC, p. 1–6, 2023. Disponível em: https://www.researchgate.net/publication/375578606. Acesso em: 20 jul. 2024.

LOSINI, Alessia E.; GRILLET, Anne-Cecile; WOLOSZYN, Monika; LAVRIK, Liudmila; MOLETTI, Chiara; DOTELLI, Giovanni; CARUSO, Marco. Mechanical and microstructural characterization of rammed earth stabilized with five biopolymers. **Materials**, v. 15, n. 9, 1 maio 2022. Disponível em: https://doi.org/10.3390/ma15093136. Acesso em: 20 jul. 2024.

Natalli, J.F.; Thomaz, E.C.S.; Mendes, J.C.; and Peixoto, R.A.F., 2021. A review on the evolution of Portland cement and chemical admixtures in Brazil. **IBRACON Estrut. Mater**., 14 (2021), e14603.

MESBAH, A. A. M.; MOREL, J. C.; OLIVER, M. Clayey soil behaviour under static compaction test. **Material and Structures**, v. 32, n.9, p. 687- 694, 1999. Disponível em: https://link.springer.com/content/pdf/10.1007/BF02481707.pdf . Acesso em 24 ago. 2024.

OBIANYO, I. O.; MAHAMAT, A. A.; ANOSIKE-FRANCIS, E. N.; STANISLAS, T. T.; GENG, Y.;ONYELOWE, K. C.; ODUSANYA,S.; ONWUALU, A. P.; SOBOYEJO, A. B. O. Perormance of lateritic soil stabilized with combination of bone and palm bunch ash for sustainable building applications. **Cogent Engineering**, v. 8, n.1921673. 2021. Diponível em: https://doi.org/10.1080/23311916.2021.192167. Acesso em 24 jul. 2024.

OLUREMI, J. R.; ISHOLA, K. Compaction and strength characteristics of lead contaminated lateritic soil treated with eco-friendly biopolymer for use as road foundation material. **Hybrid advances**, v. 5, n. 100158. 2024. Disponível em: https://doi.org/10.1016/j.hybadv.2024.100158. Acesso em: 24 ago. 2024.

PANAGIOTOU, R.; KYRIAKIDES, M.A.; ILLAMPAS, R.; LOANNOU, I. An experimental approach for the investigation of the performance of non-stabilized Compressed Earth Blocks (CEBs) against water-mediated weathering. **Journal of Cultural Heritage**, v. 57, p. 184–193, 1 set. 2022. Disponível em: https://doi.org/10.1016/j.culher.2022.08.009. Acesso em: 20 jul. 2024.

PINTO, C. de S. Propriedades dos solos. In: FALCONI, F.; CORRÊA, C. N.; ORLANDO, C.; SCHIDT, C.; ANTUNES, W. R.; ALBUQUERQUE, P. J. HACHICH, W.; NIYAMA, S. (org.). **Fundações: teoria e prática.** 3. ed. São Paulo: Oficina de textos, 2019. Disponível em: Acesso em Artmed, 2014. p. 25-72. Disponível em: http://ofitexto.

arquivos.s3.amazonaws.com/degustacao/fundacoes-teoria-e-pratica_deg.pdf. Acesso em: 24 ago. 2024.

PHAM, Tien Duc; TRAN, Thi T.; LE, Van, A.; PHAM, Thu T.; DAO, Thi H.; LE Thanh S.L. Adsorption characteristics of molecular oxytetracycline onto alumina particles: The role of surface modification with an anionic surfactant. **Journal of Molecular Liquids**, v. 287, 1 ago. 2019. Disponível em: https://doi.org/10.1016/j.molliq.2019.110900. Acesso em: 20 jul. 2024.

SEMAD. **Desastre Ambiental em Mariana e Recuperação do Rio Doce**. Disponível em: https://www.meioambiente.mg.gov.br/component/content/article/13-informativo/2879-desastre-ambiental-em-mariana-e-recuperacao-da-bacia-do-rio-doce. Acesso em: 20 jul. 2024.

SKEMPTON, A. W. The Colloidal "Activity" of Clays: l'activité colloïdale des argiles. 3RD **International conference on soil mechanics and foundation engineering**, 3., 1953, Suíça. International society for soil mechanics and geotechnical engineering, 1953. p. 57–61. Disponível em: https://www.issmge.org/publications/online-library. Acesso em: 20 jul. 2024.

TOUFIGH, Vahab; KIANFAR, Ehsan. The effects of stabilizers on the thermal and the mechanical properties of rammed earth at various humidities and their environmental impacts. **Construction and Building Materials**, v. 200, p. 616- 629. 2019. Disponível em: https://doi.org/10.1016/j.conbuildmat.2018.12.050. Acesso em: 20 jul. 2024.

WAHAB, Norshakila A. ROSHAN, Mohammad J.; RASHID. Ahmad S.A.; HEZMI, Muhammad A.; JUSOH, Siti N.; NORSYAHARIATI, Nik D.; TAMASSOKI, Sakina. Strength and durability of cement-treated lateritic soil. **Sustainability** (Switzerland), v. 13, n. 11, 2021. Disponível em: https://doi.org/10.3390/su13116430. Acesso em: 20 jul. 2024.

ZAMI, Mohammed S.; EWEBAJO, Adeoluwa O.; AL-AMOUDI, Omar S.B.; AL-OSTA, Mohammed A.; MUSTAFA, Yassir M.H. Compressive strength and wetting–drying cycles of Al-Hofuf "Hamrah" soil stabilized with cement and lime. **Arabian Journal for Science and Engineering**, v. 47, p. 13249- 13264, 2022. Disponível em: https://doi.org/10.1007/s13369-022-06576-0. Acesso em: 20 jul. 2024.

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JICV: conceptualization, formal analysis, investigation, methodology, visualization, data curation, writing - original draft and writing - review & editing.

SALB: conceptualization, formal analysis, methodology, visualization, data curation, writing - original draft, writing - review & editing, validation, funding acquisition, project administration.

TCM: methodology.

LAFS: investigation.

ACSA: investigation.

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