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SUSTAINABILITY IN CIVIL CONSTRUCTION: POSSIBILITIES AND DIFFICULTIES

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ABSTRACT

This article investigates the feasibility of civil construction based on principles of sustainability. The objective is to present, in a synthetic way, concepts, opinions and analyses that address possibilities, challenges and obstacles related to sustainability in the civil construction sector. The research was conducted through a literature review, selecting scientific studies that deal with sustainability in this context. The main causes of environmental imbalance resulting from the construction activity were identified and actions were suggested to promote sustainability in the built environment. It is expected that this study will contribute to the promotion of new research and to the involvement of different sectors of society in the implementation of sustainable practices in civil construction.

Keywords: Civil construction. Sustainability. Environment. Sustainable development.

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INTRODUCTION

Knowing about the origin and diffusion of the concept of sustainability makes us better understand the relationship between man's actions and nature, as well as its economic, social and cultural implications. Sustainability or "sustainable development" is a much broader concept than environmental protection, implying the improvement of the healthiness and integrity of the environment in the long term (SILVA; SARDEIRO, 2017).

By knowing aspects of sustainability or sustainable development and their actions in the most diverse areas of activity, it allows them to draw up plans and look for solutions that are really effective. With regard to sustainable civil construction, it is important to seek a balance between the real need to build and harmony with the environment.

With population growth and the evolution of technologies, social, political and technological transformations came, causing the environment to be degraded with the depletion of natural resources (BAPTISTA, 2010). According to Castanho and Teixeira (2017), the "Green Revolution" provided seed improvement, use of agricultural inputs (pesticides, fertilizers, fertilizers) and use of mechanization, forming Agroindustrial Complexes (CAI's) and obtaining greater productivity, but bringing degradation to the environment.

Pereira and Calgaro (2021) consider that man destroys biodiversity by commercializing resources extracted from it, concerned with economic power, as a consumer being, without any concern for the preservation of natural resources. Problems arise such as: climate change and global warming, melting glaciers, destruction of flora and fauna with species that maintain the balance of the planet, social exclusion, misery and hunger.

> Man has appropriated nature in various ways, without due concern for preservation and sustainability. The supposed modernity, carved in the economistic vision, in which some own everything and others nothing, has led to the plundering of nature and of man himself, in all its spheres. [...] Solidarity, social equity, fraternity, education, morals, knowledge, all this summarizes and sculpts a synergy between man, society and nature. Understanding and understanding oneself are man's greatest challenges. Understanding its relationship with society, with new technologies and with nature is on the list of the most complex searches towards development (PEREIRA; CALGARO, 2021, p. 270 and 280).

Since 1960, Rachel Carson has already mentioned reflections on the degradation of soil, air, water and on human, animal and plant life, with the use of insecticides and pesticides, publishing her book "*Silent Spring*", translated as "Silent Spring" (CARSON,

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1962). In 1972, there was the Stockholm Declaration at the United Nations (UN) Conference on the Human Environment - Stockholm Conference. This conference led to the publication of the report "The Limits to Growth", organized by researchers from the *Massachusetts Institute of Technology*, proposing "zero growth", not well accepted in the international community, a book published by Meadows (MEADOWS, 1978; KRUSE; CUNHA, 2022).

The Brundtland Report, entitled Our Common Future, prepared by the *World Commission on Environment and Development*, and presented to the UN General Assembly in 1987, defined Sustainable Development as "Development that satisfies current needs without compromising the ability of future generations to meet their own needs". The definition arises from the understanding that natural resources can be depleted (EDWARDS, 2005; MATEUS, 2004; GOMES; LACERDA, 2014; BOZZ, 2011; AGOPYAN; JOHN, 2011; QUONIAN; SOUZA-LIMA; MOSER, 2019; SUGAHARA; RODRIGUES, 2019).

Sustainability in civil construction implies constructive measures and procedures that seek to increase the efficiency of an enterprise in the use of natural resources, aiming to reduce environmental, economic and social impacts, throughout its life cycle (ARBACHE, 2010; LARA, 2021).

This work seeks to present a concise overview of sustainability and/or sustainable development in general, as well as the main causes and effects caused by the carelessness of the application of sustainability in civil construction.

It is understood that civil construction has to change the way it is executed. It is worth remembering that in recent years it has been suffering pressures and tensions, caused by floods and fires, with the destruction of existing buildings and demand for new constructions in record time, which leads it to think about priority treatment and, therefore, improvement in the use of resources, execution time of works and waste management. Climate change also requires a construction with greater care regarding the thermal comfort of the built environment, as well as the elimination or reduction of CO2 that causes these changes.

METHODOLOGY

This is a descriptive research with a qualitative approach. It is descriptive, as it aims to identify the main aspects that interfere with sustainability, either by promoting it or by

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restricting it. It is qualitative, as it tends to analyze, understand and present results that are not statistically measurable. The methodological resource is fundamentally the bibliographic research in technical/academic publications.

The bibliographic review, according to Noronha and Ferreira (2000), consists of a non-critical approach, in which works of greater interest are selected, merging their main focuses on the subject; interpreting recent works from different areas, bringing them to the case under study; extracting specific concepts applicable to the case. We sought to consult scientific articles in national and international journals, searching for keywords around "sustainability", "sustainability in civil construction", as well as "sustainability problems in civil construction" and "sustainable solutions in civil construction", "forms of sustainable civil construction", "possibility of sustainable construction", in the Capes Periodicals databases (which hosts main and well-known databases, such as: ACM Digital Libray; Library, Information Science & Technology Abstracts; Nature; Oxford Journals; Science (AAAS) and Google Scholar.

THEORETICAL FOUNDATION

SUSTAINABILITY OR SUSTAINABLE DEVELOPMENT

According to Correio (2021), there were four industrial revolutions: the first, between 1760-1830, a period that was marked by the great technological leap and society was never the same again; the second, called the technological revolution, in which there was growth in the means of transport, expansion of markets, speed in trade and also new forms of propulsion of production machines such as diesel and electricity; the third, records contributions by Alan Turing, in the 1930s, whose studies began the conception of the computer; the fourth, which began in 1970, is called the Age of Knowledge or the Age of Information.

According to Quonian, Souza-Lima and Moser (2019), in modern society, called "consumer society", there has been an expansion of consumption, making it excessive, most of the time unnecessary, due to the interference of new practices linked to capitalism, such as planned obsolescence and the feeling of social inclusion, which generates a negative effect both for the consumer (unnecessary expenditure of resources) and for ecology (depletion of natural resources). They understand fundamental and of paramount importance the change in paradigm and values of society, companies, producers.

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At the UN Conference on Environment and Development, better known as Rio92, the term "sustainability" gained global prominence and prominence. Agenda 21 was then generated, creating several agreements and programs to sensitize countries, with sharing, to put into practice the assumptions of sustainability (AGOPYAN; JOHN, 2011). Related to Agenda 21, the Millennium Development Goals (MDGs), which were in force from 1990 to 2015, emerged in the 2000s at another UN General Assembly, composed of senior representatives from 191 countries, called the "United Nations Millennium Summit", in New York, United States. At the time, 8 objectives, 21 goals and 60 indicators were listed. In particular, MDG 7 dealt with the guarantee of environmental sustainability, which aimed at a significant improvement in the lives of at least 100 million inhabitants of environmentally degraded neighborhoods (UN, 2000; ROME, 2019).

From then on, there was a reassessment in the understanding of sustainable development, not restricted only to environmental protection, but encompassing three dimensions: economic, social and environmental. Therefore, after this period, the term Sustainability was defined as all activities and actions aimed at meeting the current needs of human beings related to quality of life, without compromising future generations. Furthermore, Sustainability links economic and social development without significant aggression from the environment, minimizing the consumption of primary natural resources, replacing them with renewable resources (FURUKAWA; CARVALHO, 2011; SILVA, MACHADO, LEOPOLDINO, FARIAS, 2018).

Later, the Rio+10 conference, held in Johannesburg (South Africa), in 2002, reaffirmed that sustainable development has three essential pillars (*Triple Bottom Line*): environmental, social and economic (RIBEIRO, 2002; UNSCD, 2012). This was followed by the Rio+20 conference in 2012, renewing the commitment to sustainable development formalized in previous conferences in several countries, resulting in the document entitled "*The future we want*", translated as "The future we want", still remaining the focus on the use of natural resources and issues related to homelessness (ROMA, 2019).

In 2015, the United Nations General Assembly (UNGA), composed of 193 UN member countries, defined global goals known as the Sustainable Development Goals (SDGs), which must meet four main dimensions: social, environmental, economic and institutional. There are 17 goals and 169 interconnected global goals, to be achieved by 2030, being known as the "2030 Agenda" (ROMA, 2019).

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Even knowing that, directly and/or indirectly, all the SDGs proposed at the 2015 UNGA are interrelated, in this work SDGs 11 and 12 stand out, in particular, on sustainability in civil construction. SDG 11 is about making cities and human settlements inclusive, safe, resilient and sustainable, with the goal of promoting sustainable urbanization, prioritizing slum areas (UN, 2015). SDG 12 aims to "ensure sustainable production and consumption patterns", with changes in production and a greener and more inclusive global economy (PEREIRA ET AL., 2019).

Sustainable development combines three types of important basic elements: economic efficiency, social justice, and ecological prudence. It aims at people's quality of life and the preservation of the environment in which they are inserted. Therefore, there is talk of recycling matter and not depleting natural resources. Therefore, thinking about recycling is thinking about sustainable development (KRAEMER, 2023).

There is no conceptual agreement, only a conceptual approximation in a comprehensive way, regarding the terms sustainability and sustainable development. Paulista, Varvakis, Montibelle-Filho (2008) have already said that the definitions seek to integrate the constant growth of human conditions, preservation of natural resources and economic efficiency. In turn, Iaquinto (2018) presents the dimensions of sustainability by addressing ten areas in which it exerts its influence: ecological or environmental dimension, economic dimension, social dimension, spatial or territorial dimension, cultural dimension, political dimension (national and international), legal-political dimension, ethical dimension, psychological dimension and technological dimension.

Therefore, the term sustainability is complex and has several definitions. It can be said that it is a multidimensional concept, which addresses economic development, environmental preservation, social and psychological issues, and requires both preventive and corrective measures and control of present and future activities, with the aspiration of preserving and improving the quality of life of current and future generations (YEMAL; TEIXEIRA; NÄÄS, 2011)

From what people know and understand by sustainability, the meaning of sustainability, it becomes possible to understand the logic that follows sustainable practices and at what level individuals are considering and identifying sustainability (TECHIO; GATES; COSTA, 2016, p. 194).

Figure 1 presents a simplified way of visualizing the three pillars of sustainability, known as the "*triple button-line*", as the foundation of the concept of sustainability.

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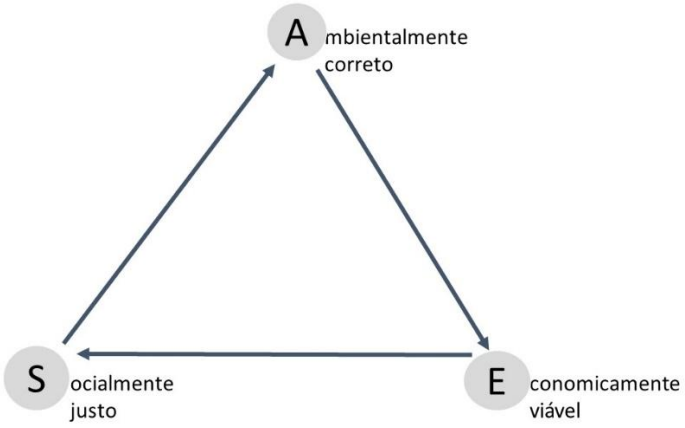
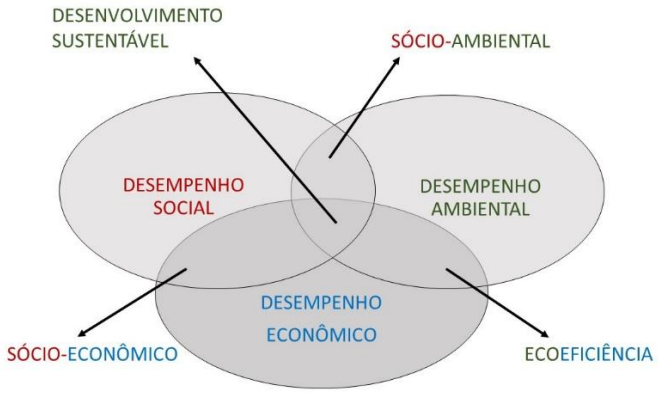
Figure 1 – The pillars that make up the concept of sustainability



Source: maisustentavel.blogspot.com/p/consultoria-ambiental.html

In order for Sustainable Development to exist, it is necessary to be present the economic, social and environmental aspects of the "*TBL – Triple Bottom Line*", and that there is an integration of these aspects (Figure 2).

Figure 2 – The tripod of sustainability



Source: Adapted from Furukawa and Carvalho (2011, p.9)

Figure 3 presents a diagram that shows sustainable development as a consequence of the union of the social (People), environmental (Planet) and economic (Profit) spheres. In it it can be understood that only with the intersection of the three spheres (or three pillars) can sustainability be obtained.

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Figure 3: Pillars of sustainability

Source: Adapted from Giovanelli (2019)

The relationship between population increase and waste generation is direct: the more prosperous and the more people live in the country, the more urban solid waste (MSW) is generated (DIAS, 2012). It is true that there has already been an increase in the population's awareness of the intense process of environmental degradation and the social problems resulting from unbridled development and accumulation of waste, but this awareness needs to be increased. It is up to the government to adopt measures such as the elaboration and implementation of legislation that disciplines waste management, and brings management instruments (DOLPHINE; MORAES, 2019).

THE PROBLEM OF CIVIL CONSTRUCTION IN THE CURRENT CONTEXT

In civil construction, sustainable works are focused on developing buildings that continue to meet the needs of users, but with alternatives for solutions to the main environmental problems of our time (BIOCONSTRUÇÃO, 2010; VAGHETTI; SAINTS; ULIANA, 2021). Sustainable construction is closely linked to sustainability and the interdisciplinarity of knowledge among professionals involved in the project.

Civil construction is one of the strategic sectors of the economy of any country. It is one of the pillars to maintain good results in the Gross Domestic Product (GDP) of a country. However, it is necessary to look carefully at the effects of the growth and the magnitude of the works, as the sector has great potential for impact on the environment. The sector is polluting, generating waste in construction, maintenance and demolition processes;

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environmental problems begin from the extraction of raw materials for construction to the final disposal of waste (ISHIKAWA, 2013; BARROS, 2017).

The environmental impact of civil construction is great, with contamination of nearby water reserves, intense disposal of debris and many other inconveniences. The sector is considered the most impactful among all human activities exploratory of the environment. In Brazil, between 40 and 50% of natural resources are used, 25% of solid waste is generated, 25% of water consumes and occupies 12% of land, being an activity that causes the most damage to the environment (MACIEL ET AL, 2018).

According to Amaral (2024), civil construction is currently more aggressive than in the past, as industries and materials have evolved, cities expand disorderly, with deforestation, construction on slopes and near rivers and streams. "More than 100 million people around the world do not have a place to live and more than 1 billion are living in inadequate places" (p.5). But, it can be said that today there are materials, machinery and technologies to build in a more sustainable way.

According to the *International Council for Research and Innovation in Building* and Construction, civil construction has a less efficient management model. For example, for the production of each ton of cement, between six hundred and one thousand kilograms of carbon dioxide (CO2) are released into the atmosphere. Cement manufacturing is responsible for 5 to 8% of global carbon dioxide emissions (SELLA, 2022).

The extraction of inputs for the production of construction materials, in addition to emitting a large amount of CO2, deforests forests, consumes 40% of all energy, 25% of water, 30% of materials in the natural environment (including about 66% of wood, without proper forest management) and generates 25% of solid waste, occupying 12% of the land (BENITE, 2011; CONSTRUCTION, 2008; SPIGNARDI, 2016).

No society will achieve sustainable development without profound transformations in civil construction, which exerts a considerable weight in the national and international macroeconomy, responsible for about 40% of its gross capital formation and a large mass of workers, both in industrialized and third world countries (BEZERRA; PASCHOALIN FILHO, 2017).

It is easy to detect the existence of the generation of a large amount of rubble in buildings in all cities, with considerable waste of materials that could be reused, processed and recycled. The generation of Solid Waste has increased, both in quantity and in diversity and hazardousness (GOUVEIA, 2012 apud MAROTTI; PEAR TREE; PUGLIESI, 2017). It is

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important to consider that the generation of debris in Brazil is directly linked to the workforce, since the lack of qualification and awareness of the latter regarding the environment, causes accumulation or waste of materials, often even involuntarily, without any concern.

According to a 2022 report by the Brazilian Association of Public Cleaning and Special Waste Companies – ABRELPE, more than 48 million tons of construction and demolition waste (CDW) were collected in 2021 (ABRELPE, 2022). In 2020, this association recorded that this waste can represent 50% to 70% by mass of the total generated, an increase since the National Solid Waste Policy (PNRS) enacted in 2010, when the number of waste was equivalent to 33 million tons (ABRELPE, 2020). Only a small part is designated for recycling and about 50% of Brazilian municipalities still dispose of waste in irregular places and do not recycle it to use it in civil construction works. Therefore, the main focus for sustainability in the construction sector should be the sustainable consumption of environmental resources, which implies reducing waste generation (ABRECON, 2018; HAWK; EL-DEIR; NETHERLANDS, 2022).

In turn, Paiva et al. (2021), record that construction and demolition (C&D) waste represents 30% to 40% of total urban waste, is one of the most significant waste streams in the city, and produces a series of impacts on society and the environment, such as illegal landfills or dumps, emission of harmful gases, and water pollution.

The composition of construction and demolition waste is varied, such as ceramics, concrete, mortars, natural rocks, wood, steel and other metals, plastic, plaster, cement, glass, asphalt, among others. It has inert materials, such as bricks, rocks and glass, but it can also be made of non-inert and even dangerous materials (class I), such as asbestos (LARUCCIA, 2014d). After construction is completed, the built environment continues to have an impact on a continuous basis (use of water, electricity, for example), considered eternal impacts (LARUCCIA, 2014; SAUCEDO, 2022).

As an example, the work of Barros (2017, p. 146), exemplifies (Chart 1) the sources of generation of civil construction waste, ascertained in the visitation of a construction site of a residential condominium in the city of Curitiba.

Table 1 – Sources of civil construction waste generation and their scope

Primary Source	Scope
Demolition	Remains of building materials
General Services/Administration	Paper, Plastic
Construction Site Installation	Wood, plastic
Foundation	Earthmoving
Structure	Wood, nail, paper

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Masonry Enclosure	Grout, blocks
Coating	Plaster, ceramic tiles, wood
Facilities	Plastic, Copper, Aluminum
Painting	Paints

Source: Barros (2017, p. 146)

In addition to the impacts generated by the building, there are still aggravating factors in the Brazilian scenario: unqualified labor; public sector omission; lack of planning of the works and little or no application of innovations. It is necessary to develop techniques for the industrialization of the sector and different forms of construction that respect the construction worker and the environment (ARAUJO, 2020). For Souza and Pires (2022), the impacts generated by construction occur at different times: in the extraction and production of a material; during the execution of the work; and in the irregular disposal of Civil Construction Waste - RCC.

To reduce waste production, the policy of the 5 R's was developed – reduce, reuse or reuse, recycle, rethink and refuse. For each of the 5 points there are attitudes that enable the individual to follow his "commandments". According to Silva et al. (2017) and Brasil (2007) would be:

- Rethink: check *a priori* if there is a real need for the product, then if the product has an ecological production, without great expenses for the environment, from the initial stages to its final disposal;
- To refuse: it would be to refuse those unnecessary and non-ecological products;
- Reduce: this is the point that best applies to civil construction; reduce waste and waste production, as there is a direct impact on natural resources;
- Reuse: products that would otherwise be discarded can be reused with little or no manufacturing, which reduces waste production;
- Recycling: the act of recycling consists of applying more manufacturing processes to the waste, thus being the last resort, favoring the reduction of production. It is possible to transform materials to their natural state or another product.

Figure 4 illustrates each point that makes up the concept of the 5R's.

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Figure 4 – 5R's

Source: https://www.bing.com/imagens/

Considering the 5Rs in civil construction, it would be interesting to reflect that Repensar would cover the entire chain (raw material industry, builder, bricklayer, architect, engineer, technicians, construction materials sellers, property owners), each reflecting on their responsibility towards each basic component of sustainability; Refusing reminds us of asbestos that has been used for long, long years, even though it is known of its potential negative effect on human health; Reduce, applies to the research of new materials with less use of natural resources and adaptation of current materials; Reuse is reflected in the construction costs, what is the reuse process, what is the gain of reuse; Recycling, also linked to costs, what is the process used, what is the cost of recycling, what is the positive reflection.

APPROACH TO SUSTAINABILITY OR SUSTAINABLE DEVELOPMENT IN CIVIL CONSTRUCTION

Writing about sustainable construction is to present a new mentality in the construction industry, with a commitment to the principles of a "green economy" and the adoption of practices that improve socio-environmental performance. This starts with the project and continues until the actual construction, with a careful selection of materials and alternatives that have less impact on the environment and human health (CNI, CBIC, 2012).

For civil construction, the concept of "sustainability" began to be incorporated only in the 1990s, even though it is known that this activity has a strong environmental impact, and it is estimated that about one third of the consumption of all natural resources spent in the

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world is the responsibility of civil construction (TAIPALE, 2012; TECHIO; GATES; COSTA, 2016).

The concept of "sustainable construction" or "sustainable building" is defined by the Technical Committee of the International Organization for Standardization (ISO/TC 59/ SC3 N 459), as:

> Sustainable building is one that can moderately maintain or improve the quality of life and harmonize with the climate, tradition, culture and environment in the region, while conserving energy and resources, recycling materials and reducing hazardous substances within the capacity of local and global ecosystems, throughout the life cycle of the building (ARAUJO, 2002, p.2; LEE; SANTOS, 2018, p. 12).

Thinking about sustainability, it is necessary to identify the impacts generated and present solutions to eradicate or minimize them.

> Engineering brings surprising technological evolutions. These are techniques and equipment launched that make it possible to make an environment environmentally friendly. One of the possible alternatives is the use of solar energy for lighting the environment and heating water. The capture of solar energy and its subsequent transformation into electrical or mechanical energy is a clean and renewable energy, which does not pollute the environment and is an inexhaustible and free source of energy. (LARUCCIA, 2014, p. 78).

According to Ihlenfeld and Mattioda (2022), sustainability must involve social aspects where *Stakholders* are considered, as it must include people and institutions and their competencies and skills, relationships and social values. Thus, the *Stakholders* involved would be: society, employees, customers, shareholders, creditors, suppliers, local community, government, competitors and NGOs.

In turn, Kraemer (2023) mentions that companies are transforming agents that influence human resources and seek to collaborate with ethical postures, transparency, and social justice. Larrosa and Bueno (2017, p. 156) talk about "the social aspect and the cultural challenge of sustainable interventions in urban spaces" and regarding the social role of properties and that sustainable buildings should fulfill the social character, thinking about cities responsibly, building in an integrated way with the surroundings, thinking about urban mobility and the environment. And, Techio, Gonçalves and Costa (2016, p. 191/192), already spoke about the need for "fundamental changes in the social sphere, especially in the 'way of thinking and in the way of living, producing and consuming' and that the result of sustainability "depends on social insertions, values and social beliefs that influence the way of perceiving, feeling and positioning oneself in the world".

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In recent years, the understanding of the sustainability of buildings has also turned attention to non-technical issues, such as social, economic and, more recently, cultural aspects (BARATELLA, 2011; GOMES; SILVA; SOUZA, 2021). It is considered sustainable when it presents an increase in positive criteria and reductions in negative effects. Therefore, it is important to study sustainability in civil construction, as there is no housing for everyone and the search for this service through construction through popular housing, within the current parameters or standards, will imply unprecedented environmental problems.

Sustainable performance in civil construction has requirements for the promotion of environmental and socioeconomic benefits. In addition to the economic and environmental benefits arising from the reduction of waste of resources, there are social benefits from overcoming housing deficits (FALCÃO; EL-DEIR; NETHERLANDS, 2022).

More recently, the concept of "smart cities" has been introduced, which aims to optimize urban sustainability through technologies, in order to increase the efficiency of infrastructures (AHVENNIEMI ET AL., 2017).

The term "green construction" arises from the collective concern of the market with the preservation of the environment. "Green construction" emphasizes a marketing strategy in the social field, with an appeal to the preservation and concern for the environment and the guarantee of more sustainable economic progress (TECHIO; GATES; COSTA, 2016)."Green building*" is all* initiatives to create buildings that use resources efficiently, with a focus on energy use; comfort, longevity, allowing disassembly at the end of the building's life cycle, and can increase the useful life of the components by reusing or recycling them (GOMES, 2003; LARA, 2021).

However, it is good to consider that "green construction" or "*green building*" must be strengthened both by the government and by operational practice in civil construction, so as not to remain or not simply fall into fashion. It should be noted that projects launched with the *slogan* of sustainability are not always in fact considered sustainable. They only use the concept of "green construction" as a strategy to raise consumer awareness and bring a positive image of the company (TECHIO; GATES; COSTA, 2016).

The CIB (International Council for Research and Innovation in Building and Construction) released Seven Principles for Sustainable Construction, repeated in the fourth edition of Kibert's book (2008):

- Reduce resource consumption;

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- Reuse resources (maximize reuse);
- Use recycled products and send unwanted products from the process for recycling (recycle materials at the end of the building's life);
- Protect nature (environment and ecosystems);
- Eliminate the use of toxic waste (eliminate harmful materials at all stages of the life cycle);
- Analyze the costs of the complete product life cycle (manage resources in a balanced way);
- Ensure product quality.

The Brazilian Chamber of the Construction Industry (CBIC), through the "Sustainable Construction" Program, has several partners to subsidize the elaboration of public policies that make Sustainable Construction a reality and works with seven main objectives:

- Reduction of emissions in the production chain;
- Energy efficiency of buildings;
- Rational use of water;
- Use of sustainable materials and systems;
- Solid waste management;
- Enabling sustainable development in urban space;
- Valuing the human being (CBIC, 2017).

In order to define or even identify a sustainable construction, it is necessary to compare the traditional construction (conventional system) with the new criteria proposed in the discussions of sustainable development, with the integration of socioeconomic and environmental issues being present.

The differences in the analyses can be outlined in Figure 5. On the left side, the triangle shows the factors traditionally considered in civil construction in competitive terms: quality (at the level required by the project), time (optimization of productivity and reduction of construction period) and cost (maintenance/cost reduction). On the right side, the general factors involved in an eco-efficient construction are: economic conditions, social equity and/or cultural legacy, and environmental quality. In this tripod, the more specific factors that involve the maintenance of biodiversity through the minimization of

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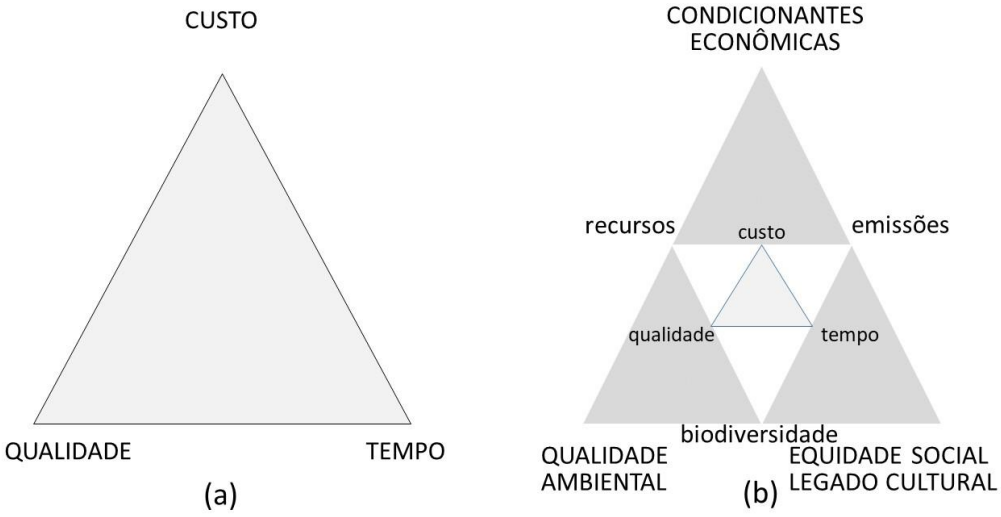
environmental impact, reducing the depletion of natural resources, low production of waste and the minimum emission of polluting gases or even repair for the environment, minimal, integrating ecosystems for biodiversity conservation. With the balance between general and specific factors, it is possible to structure the (traditional) cost, quality and time factors.

Thus, concomitantly with the factors already considered (quality, time, cost), the principles of eco-efficiency are introduced into the economic conditions; The concept of time is expanded with the guarantee of social equity and cultural legacy, and biodiversity is respected with environmental quality.

Figure 5 – Comparison of Methodologies (a) Traditional; (b) Sustainable Construction



Source: Adapted from Matthew (2004)

Consider the need of sectors of society, especially the academic through its researchers, to draw the attention of the civil construction industry to the effective production, in fact, of more sustainable constructions. Also, to draw the attention of consumers by removing from them the false idea that sustainable construction is one that preserves the environment, without including other sustainability indicators. There must be, therefore, structural and cultural changes both in consumers, in construction professionals, in industry, in financiers and in political actions. By broadening the debate and inserting practices according to the principles of sustainability, changes in people's social representations and behaviors may occur. This is the challenge (LARROSA; BUENO, 2017)

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According to Leff (2001) and Pederzoli, Silva and Martins (2021), it is impossible to solve the growing environmental problems and reverse their causes, without a change in behavior and knowledge systems regarding the values generated by the existing society.

The work of Marques, Simões and Braga Junior (2024), makes a study of Environmental Certification Seals as a practical way to assist and monitor sustainable construction. To obtain the certification (ecological seal), the construction process is subjected to strict criteria and constant evaluations, with benefits to all parties involved. There are several agencies that issue sustainable construction seals, with different possibilities for certifications. The main agencies related to civil construction activities applied in Brazil are: BREEAM, LEED, AQUA, CASA AZUL DA CAIXA, CASBREE, EDGE, CBC BRASIL, PROCEL, SUSTENTA X, DGNB and SUSHI.

RESULTS

From the synthetic approach above, one can extract causes of the imbalance of the environment and consequently of non-sustainability; the consequences generated, both in generic terms and specifically the consequences of the non-sustainability of civil construction and what must be done and/or thought about to reestablish sustainability, especially in the construction industry. These are challenges or problems that need to be overcome.

Thus, Chart 2 was elaborated, which shows, in a broad way, these considerations and, in a way, cooperates so that the problems and probable solutions in civil construction can be known.

Table 2 – Causes, consequences and contributions to sustainable construction

CAUSES	CONSEQUENCES OF NON-SUSTAINABILITY QUALITY	CONSEQUENCES OF UNSUSTAINABLE CONSTRUCTION	CONTRIBUTIONS TO SUSTAINABLE CONSTRUCTION	SUPPORTING REFERENCES
Green Revolution	Destruction of biodiversity	Agglomeration in cities	Applying principles of the "green economy"	Pereira and Calgaro (2021); Pear tree; Nadalin; Gates; Nascimento (2019); CNI, CBIC (2012)
Industrial/technological revolution	Destruction of biodiversity, social exclusion, misery, hunger (unbridled consumption)	Contamination of water reserves, rubble, carbon dioxide emissions (acceleration of material consumption)	Employ new technologies (ecotechnics). The materials can be reused, processed and recycled (reduction of waste generation).	Pereira and Calgaro (2021); Sella (2022); Mateus (2004); Marotti; Pear tree; Publiesi (2017)

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Revolution by the computer	Harm or damage to the economic, social and environmental dimensions	Acceleration of projects and, consequently, growth of constructions.	3D printing, material saving	Iaquinto (2018); Rome (2019); Gomes; Silva; Souza (2021); CNI, CBIC, 2012; Taparello (2016)
Age of knowledge	Harm or damage to the economic, social and environmental dimensions	Unqualified labor; generation of construction, maintenance and demolition waste; increase in waste in diversity and hazardousness.	Increase the efficiency of an enterprise; apply principles of the green economy; good use of material, economic and social resources, such as: energy efficiency, rational use of water, use of sustainable materials, solid waste management, valorization of the human being.	Correio (2021); Rome (2019); Araújo (2020); Barros (2017); Arbache (2010); Lara (2021); (CNI, CBIC (2012)
Consumer society	Excessive consumption	Indiscriminate consumption of ceramics, concrete, mortar, natural rocks, wood, steel and other metals, plastic, plaster, cement, glass, asphalt	Seek improvements in social, economic and cultural aspects. Draw the attention of consumers; to provoke cultural changes in professionals, in industry, in funders, in political actions.	Quonian; Souza-Lima; Moser (2019); Laruccia (2014); Larrosa; Bueno (2017)

Source: the authors (2024)

DISCUSSION

It is convenient to note that the causes of non-sustainability are the same, both looking at the generic panorama and at the sole focus of civil construction. The consequences of human performance below sustainability in civil construction are the same as those present in all sectors of society, added to the unbridled accumulation of debris, with labor unprepared to deal with the problem, outlining a panorama that is difficult to control.

The rural exodus in Brazil is almost double the world average and challenges the sustainability of the countryside and city. Making a comparison between the year 2000 and the year 2022, the article informs that over 22 years the rural population decreased by 34%, according to data tabulated by Gerson Teixeira, agronomist and director of the Brazilian Association of Agrarian Reform (ABRA), who explains: "the strong migration without the necessary reception in public housing, health and education policies has created urban catastrophes in the country" (MST, 2024; PTA. 2024). According to the Brazilian Institute of Geography and Statistics (IBGE), from 2010 to 2022 the Brazilian

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population grew by 6.5%, which represents an increase of 12.3 million people in the period (MST, 2024; PTA. 2024; IBGE NEWS AGENCY, 2024). Thus, the agglomeration of people in cities, the acceleration of buildings without trained labor and aware of environmental problems, the indiscriminate consumption of contaminating materials, from their extraction to their final use, all this increases the amount of debris and, consequently, collaborates in contaminating aquifer reserves, polluting the environment with carbon dioxide emissions and making human life in cities less and less healthy.

On the other hand, it is known that there is the possibility of using new technologies, reuse and/or processing of recycled materials for use in the construction itself, awareness of civil construction actors, in view of the search to minimize the effects of environmental contamination.

The research presents, in Chart 2, what was developed in the literature overview, a reflection that the possible causes of the imbalance of the environment require an increase in the adoption of sustainable constructions: the industrial and technological revolution; the revolution and diffusion of information technology; the age of knowledge; the growth of the consumer society.

The table presents the consequences arising from these causes, which cause the non-occurrence of sustainability in general, as well as the consequences that conventional civil construction has been bringing: the agglomeration of the population in cities; the contamination of aquifer reserves by rubble; CO2 emissions; the presence of unqualified labor that does not "think" or care about the rubble; the indiscriminate consumption of raw materials: ceramics, cement, concrete, mortar, wood, steel, plastic, plaster, glass and other materials.

Finally, the table presents, as a recommendation, some contributions that sustainable construction can bring: application of principles of the "green economy"; the use of new technologies with reuse/recycling of materials; the use of 3D printing with savings in materials; energy efficiency; the rational use of water; the rational management of waste; human valorization; the cultural and professional changes in those involved/participants in civil construction and the political actions that can ensure and encourage this new sustainable construction system.

It should be borne in mind that, if there is commitment and cooperation from the construction industry, the professionals involved in it, the financiers, the government actions and the consumers of the constructions, it is possible to restrict this waste and

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mitigate the problem with the application of the principles of sustainable construction, improving the social, economic and cultural aspects.

CONCLUSION

The importance of understanding what "sustainability" is perceived, emphasizing that all human actions must move towards satisfying their current needs, but without compromising natural resources for future generations, without aggression to the environment, so that the development of society can be sustainable. In this context, sustainability in civil construction must also be addressed, at least eliminating impacts from the extraction of natural resources and the generation of contaminating waste.

Likewise, this research showed that the consequences of non-sustainability are similar both in general human actions and in the actions of conventional civil construction, but it is possible to apply principles, technologies and materials that contribute to sustainability, and thus increase the efficiency of an enterprise with the rational use of natural resources.

It is seen that the use of forces (practices or actions) in order to promote sustainable construction is not in vain. There are possibilities to make civil construction sustainable. The study or diagnosis of the reasons for the non-adoption of sustainable construction in its entirety will certainly bring light and contribute so that its implementation can, indeed, mitigate the environmental, economic and social impacts of civil construction.

This work presents only a spark for the interest in studying this problem, notably focusing on the increase in the process of implementation of sustainable constructions.

Future studies could be developed in order to improve techniques for sustainable construction, such as the implementation of the use of 3D printing, which is an engineering revolution with the possibility of new *designs* and faster construction time.

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