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A taxonomy of design practices for Sustainability towards Planetary Health

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Abstract. This contribution is part of the research that aspires to investigate how scientific design research is involved in determining a new balance between human beings and nature to improve the living conditions of our species on Earth.
First, the paper investigates the different paradigms of Health based on the relationship between human beings and nature, presenting the levels of consistency in the concept of Sustainable Development.
Subsequently, the research dwells on the analysis of the main design practices approaches, i.e. Planet-Centric Design, Human-Centered Design, Non-Human Centered Design, and Humanity-Centered Design, that investigate the relationship between our species and nature, classifying them according to definition, keywords, approach to Health paradigms, and adherence to the concept of Sustainability within Sustainable Development. The aim is to take a position on which of the above-mentioned approaches offers a perspective that allows humankind to perceive itself as a community as well as to be "in nature with nature", without conflict and matricide, accepting our finiteness and not denying death. Hence, design practices must be able to develop good practices for Sustainable Development towards Industry 5.0, respecting the planetary and social boundaries of the "Doughnut".
Finally, the paper dwells on the sustainability assessment methods of industrial practices to highlight the consistency between the criteria selected by the different tools, and the concepts of Sustainability and Health inherent in the methodological approach of design. It converges to identify under-researched aspects of implemented practices on which design can focus to develop Industry 5.0.

Keywords. Planetary-Centric Design; Human-Centered Design;
Humanity-Centered design; Non-Human Centered Design; Planetary Health

1 Preamble on the need to reposition the focus of Design research and practice

Design is about creating and mediating meanings within societal transitions [1]. Design research is now more committed than ever to determining a new balance of the human-nature relationship, underlying the Health paradigm, to improve the living conditions of our species on Earth. Today, Planetary Health has rapidly gained relevance and credibility in both scientific and public debate since its values seem consistent with the Sustainability and Sustainable Development vision promoted by the Brundtland report in 1987 [2]. The report set out the values and principles that still frame the Sustainable Development debate about the challenge of the coexistence of continued economic and population growth and a healthy planet [3]. Valenturf and Prunell reported that the Sustainable Development concept of Sustainability, typified by the triple bottom line - defined as the "weak" Sustainability paradigm -, is currently shifting to a concept of economics as a tool to maintain or improve social well-being, environmental health quality and economic prosperity - defined as the "strong" Sustainability paradigm. This ongoing development of the concepts of Sustainability and Health toward a more humanity-centered paradigm, embodying the explicitly anthropocentric view of the Brundtland report, is also confirmed by the emergence of a new industrial paradigm that places operational emphasis on humans. The emerging new paradigm of Industry 5.0 has added new principles to the industrial revolution, as stated by Adel [4], moving towards the smart social factory that is based on:

- Sustainability. Improvement of iterative procedure of reuse, recycle, and recover – i.e., Circular Economy;
- Human-centeredness. Emphasis on human needs over the production process;
- Resilience. Ability to cope with crises.

Design, as a primary meaning, traces back to the Latin verb "proiectare" (throwing forward) and function for systems innovation, manifests human projection into the future and has been involved in various aspects of Sustainability discourse and practice with systematic engagement since the 1980s, as well detailed in the review by Ceschin & Gaziulusoy [5]. Given the new emerging industrial paradigm, designing for Sustainable Development within the planetary and social boundaries of the "Doughnut" [6], presupposes the need to reposition design practice and research toward the human-nature relationship, consistent with the most current Health and Sustainability paradigms.

Hence, this chapter aims to answer the following research questions:

- RQ1. Which design approach best offers a more accurate perspective on the relationship between man and nature and towards which to converge to reposition the focus of design research and practices toward Industry 5.0?
- RQ2. To what extent do most common and established Circular Economy assessment methods of industrial practices best consider the evolving

Sustainability paradigm within Industry 5.0 to achieve Sustainable Development Goals (SDGs)?

1.1 Methodology overview

Our exploration follows a consequential iterative methodology illustrated in Fig. 1.1 and reflected in the following sections of the chapter, where the methods are explored in more detail, and the results presented.

Step 1 (section 1.2) investigates the adherence of three main Health paradigms in sustainability-related fields, i.e. One Health, EcoHealth, and Planetary Health, to Sustainable Development based on the principles governing the human-nature relationship. Identifying the demarcation of the different paradigms of Health and Sustainability proved to be a challenge. In this study, which is a praxeology design study, we focused on the consequences that the scientific and policy components of the two paradigms' evolution have in defining the framework of the principles of the design discipline for Sustainable Development.

Following a selective bibliometric approach, a Systematic Literature Review (SLR) of articles, books, and proceeding that address the three Health paradigms are performed: theoretical aspects; definitions; distinguishing elements of the concept from its predecessors; and applications and implications in different scientific fields applied to the study and definition of socio-technical systems. The analysis is based on active searches in the SCOPUS database and reading of key publications selected according to principles of open access and selected thematic categories. Within a detailed and deep review based on the key publications within the three Health paradigms, we (i) outline the definitions, (ii) describe how they conceptualise the human-nature relationship, and (iii) identify the main areas of scientific application and (iv) points of contact with the Sustainable Development debate. Subsequently, the adherence of the Health paradigms to the emerging Sustainability paradigm is evaluated using an unstructured deductive approach.

Step 2 (section 1.3) narrates the four main approaches to design - Planetary-Centric Design (PCD), Human-Centered Design (HCD), Non-Human Centered Design (NHCD), and Humanity-Centered Design (HYCD) - to reposition the discipline toward Sustainability and Health paradigm shifts. The demarcation of each of the four methodological design approaches, yet to be clearly defined, is based on the underlying values, theories, and design practices. To analyse this, a selective approach was adopted based on (i) active searches of various databases and reading of key publications, (ii) in-depth reading of reference lists, (iii) web pages and newsletters dedicated to approaches dealing with the theoretical aspects of this discipline, and (iv) the way in which the approaches are defined. Finally, we propose a scientific demarcation based on (a) definitions; (b) adherence to the main Health and Sustainability paradigm, according to how they conceptualise the human-nature relationship; (c) and application in industrial innovation.

Step 3 (section 1.4) analyses the most common methods of assessing the Sustainability of industrial practices to evaluate the adherence of indicators to Planetary Health principles toward Sustainable Development. As a non-exhaustive

list, based on previous taxonomies, of indicators of sustainability assessment methods from Industrial Ecology and Complex Systems Science are analysed according to the level of adherence to the current Sustainability paradigm. Finally, under-researched aspects that design research should focus on to develop sustainability indicators suitable for new industrial paradigms are proposed within a methodological conceptual framework.

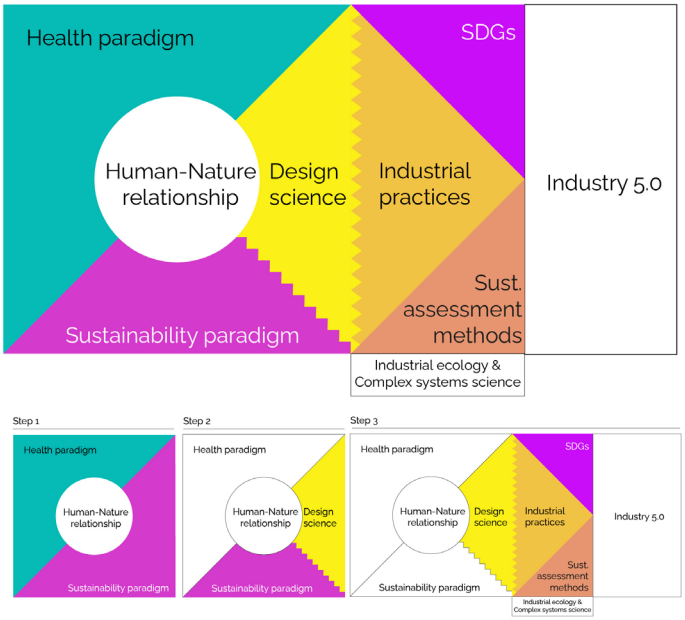


Fig. 1.1. Research methodology.

2 Sustainability toward Health paradigm shift

2.1 Planetary Health: a new paradigm for the human-nature relationship

In 1993 Per Fugelli wrote “The patient Earth is sick” [7]. This led to the concept of Planetary Health, launched in 2015 by the Rockefeller Foundation-Lancet Commission. Planetary Health stands as a solution-oriented transdisciplinary field focused on analyzing the impacts of human alterations on the Earth's natural systems to achieve the highest attainable standard of wellbeing and equity worldwide, moving beyond the previous paradigms of One Health and EcoHealth [8].

Methodology. To assess the levels of consistency of the three Health paradigms with the concept of Sustainable Development, a bibliometric analysis is performed using the following search terms: ("One Health" OR "EcoHealth" OR "Planetary Health") AND ("Sustainable Development")). Research is limited to the sustainability-related fields of Social Sciences; Environmental Sciences; Agricultural and Biological

Sciences; Energy; Engineering; Earth and Planetary Sciences; Economics; Econometrics and Finance; Multidisciplinary; and Business, Management and Accounting. Findings related to areas of healthcare were excluded to highlight complex human interactions with the environment and sociopolitical and economic processes, as opposed to the focus of the older paradigm centered on specific mechanisms of disease and treatment [9]. SCOPUS provides complete publication data, with a total of 185 articles identified. Non-Open Access (n= 59), articles not written in English (n = 1) and were excluded; articles limited to exact keywords of “Planetary Health”, “One Health”, “Ecosystems Health”, “Environmental Health”, “Sustainable Development”, “Sustainable Development Goal”, “Design”, in the end, a total of 111 articles were included in the final bibliometric analysis. The objective of the following quantitative observation is the shifting among the three different paradigms to describe the complex human-nature relationship toward Sustainable Development from the following aspects:

- annually publication trends;
- citation analysis of the research output.

From these recorded documents, SLR is conducted through a consequential process of screening titles and abstracts to select articles to be included in the analysis according to relevance related to the debate on:

- theoretical aspects and definition of paradigms;
- elements distinguishing the concept from its predecessors;
- applications and implications in different scientific fields.

In the end, 80 articles are included in the final qualitative analysis.

Results. The temporal distribution of contributions shows an exponential trend since 2015, with a local maximum in 2017 (7 papers) and a global maximum reached in 2022 (36 papers).

This trend can be traced back to two main events in the history of the Health paradigm that has favuored scientific production on these topics in subject areas other than the traditional healthcare field, leading the discussion to define a new relationship between humans and nature:

- in 2015, the Lancet Commission on Health and Climate Change concluded that the issue of climate change is "the greatest opportunity to redefine the social and environmental determinants of health” [10] within the Paris Agreement and the Agenda 2030;
- in mid-2017, the second signing of the "Notice to Humanity” scientific call to action defined steps to be taken for the Sustainability of humanity, other species, and the surrounding environment [11].

Following the screening of the titles and abstracts of the collected articles, the Health paradigm shift for the achievement of SDG2 'Zero Hunger' appears to be very

relevant; most of the most cited articles address the consequence of the topic on this thematic area (Table 1.1).

Table 1.1. List of most cited documents indexed by SCOPUS (Date of SCOPUS search: 19 January 2023).

Title	Cited by	Reference
Food security and the 2015-2030 sustainable development goals: From human to planetary health.	129	[12]
Sustainability science: An ecohealth perspective.	77	[13]
One health contributions towards more effective and equitable approaches to health in low- and middle-income countries.	76	[14]
Linking sustainability to the healthy eating patterns of the Dietary Guidelines for Americans: a modelling study.	75	[15]
Environmental and nutritional impacts of dietary changes in Spain during the COVID-19 lockdown.	66	[16]
AMEE Consensus Statement: Planetary health and education for sustainable healthcare.	63	[17]
A One Health approach to managing the applications and implications of nanotechnologies in agriculture.	57	[18]
Disease ecology, health and the environment: A framework to account for ecological and socio-economic drivers in the control of neglected tropical diseases.	56	[19]

However, these contributions result from the implication of this paradigm shift in a particular area of Sustainable Development, but they add little or nothing to the debate on the three paradigms in terms of: theoretical aspects; definitions; elements distinguishing the concept from its predecessors; and applications and implications in different scientific fields; hence 31 documents were excluded from the SLR.

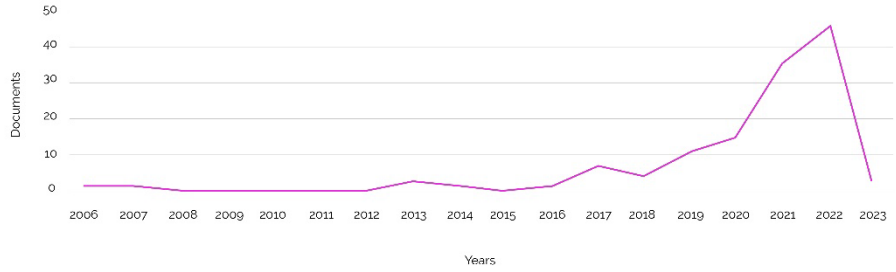


Fig. 1.2. Number of published articles per year indexed by SCOPUS shown by year of publication (2006-2023) (Date of SCOPUS search: 19 January 2023).

80 articles were identified as the most relevant to frame the evolution of the debate and the conceptualization of the paradigms. Table 1.2 shows the base year for the first theorization of the paradigms; definitions selected to be the most up-to-date and scientifically significant following the number of citations in scientific publications; the underlying human-nature relationship; and subject areas. While Fig. 1.2 shows a timeline of the evolution of the Sustainable Development debate and the Health paradigm.

Table 1.2. Assessment of the Health paradigm consistency within Sustainable Development definition [2].

Health paradigm; Theorization start date and scope	Definition	Human-nature relationship	Consistent to Brundtland sustainable development
One Health 1980s Veterinary and Conservation Medicine.	"Is the collaborative effort of multiple health science professions, together with their related disciplines, and institutions—working locally, nationally, and globally—to attain optimal health for people, domestic animals, wildlife, plants, and our environment." [8]	Prioritizing the health of both humans and animals protecting them from infectious diseases and disease spread.	No.
EcoHealth 1990s Biodiversity Conservation.	"Is committed to fostering the health of humans, animals, and ecosystems and to conducting research which recognises the inextricable linkages	Promoting health and wellbeing with a focus on social and ecological interactions.	Yes. It has been shaped by Brundtland's Sustainable Development

	between the health of all species and their environments." [8]		concept.
Planetary Health 2015 Multidisciplinary. Social and ecological science.	"Is the achievement of the highest attainable standard of health, well-being, and equity worldwide through attention to the human systems—political, economic, and social—and the Earth's natural systems that define the safe environmental limits." [10]	Safeguarding human health focusing on human effects on the environment and development factors such as consumption, population growth, technology, and urbanization.	Yes. The concept of health is closely linked to the concept of sustainable development as defined in the report.

The literature notes a long and detailed chronological evolution of the three not always uniquely defined concepts [8], often criticised for being so similar as to be indistinguishable, characterised by evolutionary stages consistent with the progressive debate on Sustainable Development (Fig. 1.3).

The scientific paradigm debate on One Health dates to the 1980s, although the concept was already known to Hippocrates. Historically, One Health has been more concerned with health science, and World Health Organisation has adopted this model to "design and implement programs, policies, legislation, and research in which multiple sectors communicate and work together to achieve better public health outcomes" [20] since the "One World -One Health Framework" publication in 2008. Therefore, One Health plays a marginal role in the debate about repositioning the design focus to define a Sustainable and healthy human-nature relationship within Sustainable Development.

EcoHealth, on the other hand, can be defined as an "ecosystem approach to health": in the field of Biodiversity Conservation, it links public health to natural resource management and ecosystem services [21,22]. Since the early 1990s, the debate on EcoHealth has focused on the need to provide a clear definition; however, due to criticism of the concept and its theoretical framework, there is still no unambiguous definition of EcoHealth. For this study, it is useful to point out that the concept of EcoHealth has developed as the most appropriate method through which to achieve the Millennium Development Goals (MDGs) and is an implication of Brundtland's concept of Sustainability: improving ecosystem services to improve human welfare [11,23].

Planetary Health is the most recent concept, which is why it has been criticised for being underdeveloped, but at the same time, the most cited in the literature included in the study: 26 published papers containing the keyword "Planetary Health" matching the search query (One Health, n=18; EcoHealth, n=19). Planetary Health was proposed as an alternative to the previous two paradigms by The Rockefeller Foundation-Lancet Commission on planetary health in 2015 [10] as an approach to human health in the context of the Anthropocene, often criticised for its excessive

anthropocentrism. However, it can be argued that Planetary Health embraces a new emphasis in the history of Conservation Ecology, which has shifted from an overly utilitarian perspective to one that recognises the two-way dynamic relationship between humans and nature [24]. Also, it is consistent with Raworth's image of the "Doughnut" and Brundtland's vision of Sustainability, which is to mitigate and respond to threats to the sustainability of human civilization establishing a dynamic balance in the human-nature relationship to meet everyone's needs within the planet's resources, preserving humanity without altering the natural evolution of ecosystems and supporting the regeneration ecosystems compromised by human activity.

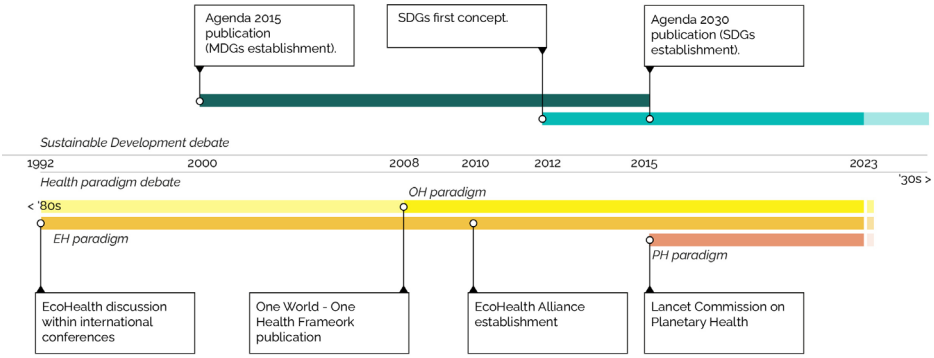


Fig. 1.3. Timeline of the evolution of the debate on Sustainable Development and Health paradigms.

2.2 Understanding the evolving concept of Sustainability practices within Planetary Health

Although specific definitions vary, Sustainable Development embraces the so-called "triple bottom line" paradigm and is rooted within Sustainability science, which deals with the interactions between natural and social systems. However, the literature recently shows a shift in the Sustainability paradigm, which makes a participatory discussion on this new human-nature interaction emerging paradigm urgent. This evolution is consistent with the ongoing evolution of the Sustainable Development debate well described by Sachs [25]. While in 2000, the MDGs helped to promote global awareness and political and social responsibility for problems such as poverty, hunger, and disease, focusing mainly on poor countries; in 2015, the urgency of implementing Sustainable Development across the planet with a shared focus on the triple bottom line has gained momentum. Perspectives on Sustainability have evolved from this paradigm where economy, society and environment are on the same level, leading to no consensus on which is more important; to considering the economy as a tool for organizing and enhancing natural capital and social well-being [3]. This shift is coherent with the opposing paradigms of dualism and monism, i.e., a concept of homogeneity between man and nature [26].

Given the above reflections, we propose the new following integrated definition of Sustainable Development. It can be argued that Sustainable Development safeguards human and nature conservation by using economics as a tool to improve human-nature interaction as a state of active exchange between two entities towards mutual improvement and respect achieving Planetary Health toward the monism paradigm.

Given this, design discipline as a practice must reposition itself with respect to this dynamic human-nature interaction to manifest humanity's projection into the future. To do this, in addition to the discipline's historical focus on lowering environmental impacts through redesign [5], a way of designing for making a positive impact is needed, going beyond the rhetorical level, developing products and systems consistent with the given definition of Sustainable Development toward mutual improvement, reestablishing the human-nature interaction that begun to severely break away since the rise of Industry 1.0 [27].

3 Design practices for an integrated and widespread Planetary Health

3.1 Repositioning the approach of Design practices

Developments in the Science of Conservation [24], in addition to providing hints for possible interpretations of the evolutionary dynamics of design strategies [28], can also provide useful hints for a repositioning of design in the continuum of the Sustainability paradigm: from placing man at the center of design action, within nature conservation for human to placing the human-nature relationship at the center, within a human and nature conservation. Four main and emerging approaches of the design discipline -Planetary-Centric Design (PCD), Human-Centered Design (HCD), Non-Human Centered Design (NHCD), and Humanity-Centered Design (HYCD)- are analysed to assess which among them best offers a more accurate perspective of investigation of the relationship between man and nature and towards which to converge for a repositioning.

Methodology. Since design is an integrative discipline [29], the scientific demarcation of these four approaches, which is the issue at hand, is based on the underlying values, theories of science and scientific fields included. To analyse this, it is not enough to carry out a bibliometric exercise via the SCOPUS database based on the keywords: ("Human-centered" OR "Non-human-centered" OR "Planetary-centric" OR "Humanity-centred") AND ("design" OR "approach")). The search is limited to:

- the exact keyword “Design”, “Design Methodology and “Design Research” due to the overall goal of the repositioning of the discipline;
- and the subject areas of Engineering; Social Sciences; Arts and Humanities; Economics, Management and Accounting; Environmental Sciences; Earth and Planetary Sciences; and Multidisciplinary. This is due to the integrative nature of the discipline within the ecosystem of the artificial [28] between the Social Sciences and the Environmental Sciences.

SCOPUS provides complete publication data, with a total of 205 articles identified. Non-Open Access (n= 115) were excluded; in the end, 90 articles were included in the final bibliometric analysis. The objective of the following quantitative observation is to define the focus of publications among the four approaches based on the following aspects:

- annual publication trends;
- analysis of the distribution of relevant author keywords.

The 328 keywords of the authors of the 90 articles identified were analysed:

- qualitatively, the keywords related to the individual design approaches and methods were highlighted as most relevant to be analysed in relation to the macro approaches under investigation. Non-subthematic keywords such as "design methodology", "design research", and "design science" are not taken into account;
- quantitatively, to assess the occurrences of the most relevant keywords via VOSviewer software.

Indeed, a qualitative data-analysis of the SLR is performed integrated into a selective approach to Multivocal Literature Review (MLR) [30]:

- both additional records, through an in-depth reading of reference lists of previous records identified;
- web pages and newsletters dedicated to approaches dealing with the theoretical aspects, assessed as reliable according to the reliability parameter of the individual author and the institution.

Hence, from the identified papers, the MLR was conducted through a consequential process of screening the titles and abstracts to select literature for inclusion in the analysis based on their relevance to the debate on:

- theoretical aspects and definition of approaches;
- elements distinguishing the approaches;
- design research transformation and evolution.

As a taxonomic exercise to the creation of a glossary of the four main approaches derived from the study from the interpretation of the literature, we provide a demarcation among them based on: (i) definition; (ii) research scope; (iii) perspective of investigation of the human-nature relationship; (iv) adherence to Sustainability and Health paradigms; and (v) application for industrial innovation.

The research scope (ii) is defined through a logic-deductive approach of the definition and the analysed literature, highlighting the perspective of the approach towards an [31, 32]:

- axiological, as dealing with material and non-material human values (what is inside);
- ontological, as dealing with "being-in-the-world" (relational);

research paradigm to better appreciate and compare different design research approaches.

Regarding the man-nature relationship (iii), those approaches that have the man himself and his needs as the main element of inquiry are relied on the concept of Cartesian dualism, whereas approaches that move towards the opposite paradigm of monism refer to “being-in-the-world” [32].

From the definition, the research scope, and the type of human-nature relationship, we deduce through a critical approach the relationship and adherence to the concept of Sustainable Development and to the most relevant Health paradigm (iv). The actual and/or possible application of these approaches to develop industrial innovations (v) is demonstrated in the literature through specific case studies, by proof, or by argument.

Results. The temporal distribution of contributions (Fig 1.4) shows an exponential trend since 2012, with a local maximum in 2016 (6 papers) and a global maximum reached in 2021 and 2022 (20 papers). The progressive interest of design research in broadening its scope is consistent with the overview of the evolution of the Design for Sustainability (DfS) field provided by Ceschin and Gaziulusoy [5]. The focus of DfS on human-centred aspects characterises much of current research and practice since 2005. This is also evident from the iterative analysis of the author's distribution of relevant keywords (Table 1.3). Although “Human-Centred Design” seems to have an average occurrence among the most cited keywords, most of the other keywords can be traced back to this approach from the individual definition.

Table 1.3. The author’s keywords most relevant to describe the approach used and associated occurrence score within records indexed by SCOPUS. (Date of SCOPUS search: 25 January 2023).

Author keywords	Occurrences	Relevance to the four approaches investigate
Participatory Design	8	Human-Centered Design
Speculative Design	5	Non-Human Centered Design
Interaction Design	5	Human-Centered Design
Action Design research	5	Human-Centered Design
User Centered Design	4	Human-Centered Design
Human-Centered Design	4	Human-Centered Design
Design Fiction	4	Non-Human Centered Design
More-than-human Design	3	Non-Human Centered Design
Value-sensitive Design	2	Human-Centered Design

Indeed, when we speak of Participatory Design and action research, we place ourselves within a general class of approaches that involve community members as participants in the design process, as a people-centered approach to tackling real-world problems [33].

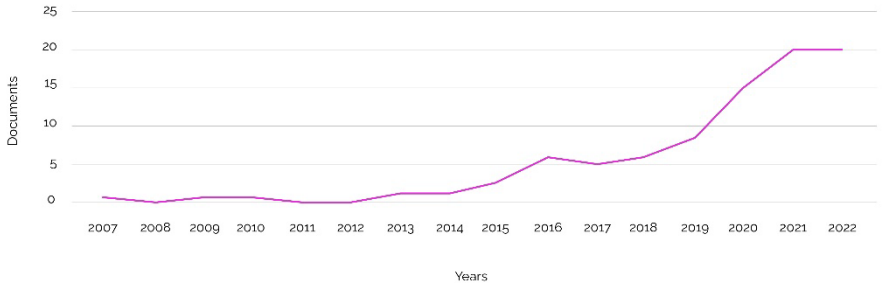


Fig. 1.4. Timeline of the evolution of the debate on Sustainable Development and Health paradigms.

While User-Centered Design and Interaction Design are multi-method experimental research approaches centered on humans and their surroundings, often technological, which fall under human-centered approaches [34]; next in line is Value-sensitive Design, a theoretically grounded approach to the design of technology that takes human values into account, which can usually be traced back to Interaction Design [35].

Speculative Design and Fiction Design exceed the limits of reality as it is; they are design approaches for how things could be, for possible futures. Whereas Speculative Design and Narrative Design push the limits of reality as it is, as design approaches for how things could be, they are closer to the Non-Human Centered Design paradigm, understood as more-than-human Design, providing an alternative context to Human-Centered Design [36].

This analysis, although not exhaustive due to its limitations in focusing mainly on author keywords, shows that the approach most frequently addressed by design research is Human-Centered Design, followed by Non-Human Centered Design as the opposite paradigm.

As a result of the taxonomic exercise, we propose the following glossary to typify and demarcate the four approaches according to the method described above.

Human-Centered Design (HCD). (i) It aims to provide the best solution which meets the human needs. It is based on interaction with people involved to understand their tacit and explicit needs and desires [37]:

- (ii) the axiological perspective of its scope is rooted in the Social Sciences;
- (iii) the perspective of investigation of the human-nature relationship is dualistic;
- (iv) it adheres to the previous triple bottom line paradigm: an anthropocentric view of Sustainability is one that manages and sustains natural resources for humans. It does not fit the Planetary Health paradigm because of the strong dualism of the human-nature relationship;
- (v) this design approach is currently applied in industrial innovation.

Non-Human Centered Design (NHCD). (i) It is about designing for the "more-than-human worlds" and the interrelatedness of the human and non-human domains.

All entities have legitimacy in the pluralism consisting of objects and things, humans, and others [38, 39]:

- (ii) the ontological perspective of its scope is rooted in Ecology;
- (iii) the perspective of investigation of the human-nature relationship is interactivity;
- (iv) this approach is related to both the EcoHealth and Planetary Health paradigms. Human activity is valued by its responsibility to minimise its environmental footprint [40]. While some more radical approaches reject the concept of Sustainability as intrinsically human-centered;
- (v) this design approach is meant to be applied in industrial innovation.

Humanity-Centered Design (HYCD). (i) It can be argued that this emerging participatory approach aims to design "with care" within naturalistic monism [26, 41]:

- (ii) the ontological perspective of its scope is rooted in multidisciplinary;
- (iii) the perspective of investigation of the human-nature relationship is interactivity;
- (iv) this approach is related to Planetary Health and the "strong" Sustainability paradigm. Its goal is to solve the problems of humanity and its livelihood, through a dynamic human-nature interaction, which implies having compassion and empathy with your fellow humans and more-than-human beings. While some approaches referring as humanity-centered, do not conceive of humanity within a naturalistic monistic value framework;
- (v) this design approach is meant to be applied in industrial innovation.

Planetary Centered Design (PCD). (i) It is an emerging approach within Design for business and management scholarly research and practice to help businesses design better products and services without sacrificing their responsibility to the environment [42]:

- (ii) the ontological perspective of its scope is rooted in Business and Economics Science;
- (iii) the perspective of investigation of the human-nature relationship is dualistic;
- (iv) it adheres to the former triple-bottom-line paradigm: typified by an anthropocentric view of DfS as a profit-driven activity that must also consider responsibility for the environment;
- (v) this design approach is meant to be applied in industrial innovation.

From this framework, it can therefore be concluded that these approaches are positioned on a continuum of the Sustainability paradigm and differ in the focus of their research.

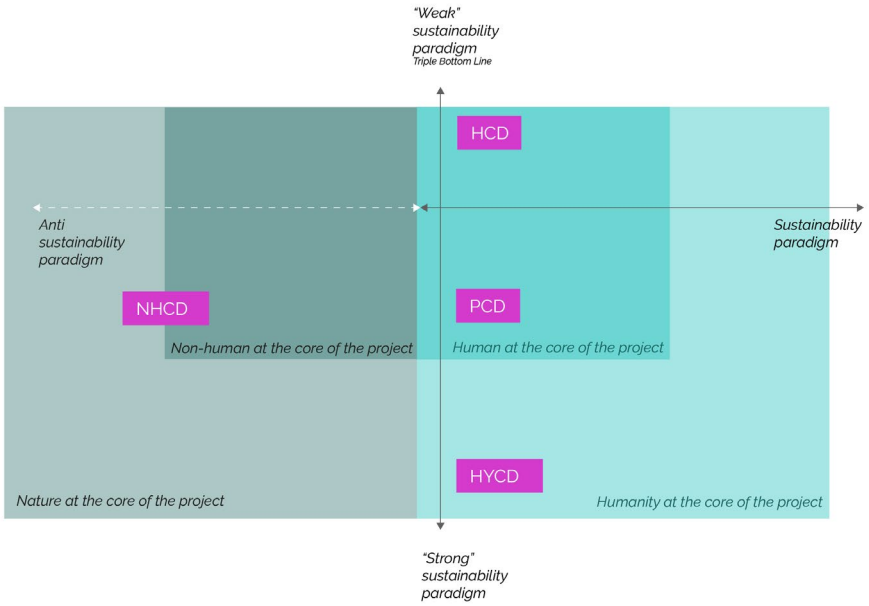


Fig. 1.5. Design approaches embedded in the continuum of the Sustainability paradigm.

Through visualization (Fig. 1.5), this positioning can be conveyed:

- Non-Human Centered Design (NHCD) is the only approach that, in some cases, rejects the very concept of Sustainability; its research focus is the non-human and/or nature itself;
- Human-Centered Design (HCD) embraces the "weak" paradigm of Sustainability; its research focus is on humans as users;
- Planetary-Centric Design (PCD) lies between the two paradigms of Sustainability, with an imbalance towards the triple bottom line; its research focus is humans and their processes;
- Humanity-Centered Design (HYCD) embraces the "strong" Sustainability paradigm; its research focus is on solving complex problems related to mankind in the context of naturalistic monism.

Therefore, Humanity-Centered Design emerges as having a more accurate perspective for investigating the relationship between man and nature and towards which to converge to reposition the discipline. The topic of care, which emerged in the praxiological discourse on Humanity-Centered Design, refers explicitly to the paradigm of Health, the evolution of which is discussed above. Here, it is implicitly emphasised that care is addressed to the dynamic interaction between man-nature.

3.2 Systemic Design for an Ethic of Care

Systemic Design (SD) is a nature-inspired approach that addresses socio-technical system development [43]. This methodology was developed around five key principles [44]; of particular interest for the subject matter is the last one [45]: “Human beings, in relation to their context, are the center of the project”.

Although “humanity” does not yet emerge in this definition to replace “human”, it can be inferred that this is not a Human-Centered Design approach but rather a Humanity-Centered Design one. Indeed, since the research is focused on humans, it can be argued to be anthropocentric; however, the reasons for this thesis are to be found in Anne-Marie Willis's discourse on Ontological Designing [46] and Heidegger's monistic concept of "being-in-the-world" [32]. From the study of their contributions, it can be said that the human being is always in a reciprocal shaping relationship with the more-than-human, designed or natural. Crucially, to provide the best solution that meets human needs, it is necessary to take care of the interrelation of human-being and non-human domains by generating positive feedback loops for the sake of livelihood and conservation - as indeed occurs in the practice and research of SD -, having compassion and empathy with your fellow human and more-than-human beings.

To this, a participatory Humanity-Centered Design is needed, dealing with instruments of the feminist and indigenous principle of the 'ethic of care' to guide monism decision-making within policy, academia, industry, and society. Further studies and insights are needed to define how, in what way, and to what extent the instruments of feminist theory and Indigenous ethics are assimilated by SD research and practice or can be.

4 Assessing the adherence of industry 5.0 toward Planetary Health

The concept of Industry 5.0 emphasises the importance of research to support industry in its long-term role for humanity within planetary boundaries to promote Sustainable Development; highly consistent with the Planetary Health paradigm as discussed above. However, it is unclear how Industry 5.0 can realise the Sustainable Development values it aims for. Design processes can support industrial transition from the use of vocabularies to mediate meanings, all the way up to developing and implementing tools and methods [47]. This entails a necessary reflection on how to develop methods to measure the effective adherence of industrial practices to the three pillars of Industry 5.0 [48]. The next section conducts an analysis that integrates current criticisms of Circular Economy assessment methods and tools, highlighting their inadequacy in assessing adherence to the evolving Sustainability paradigm within Planetary Health. Finally, it emphasises the need for the design discipline to contribute to the debate by promoting a more holistic assessment of adherence to all three Industry 5.0 principles contextualised as: Circular Economy, Resilience, Human-centeredness.

4.1 Sustainability assessment toward Industry 5.0

Circular Economy presents itself as a production and consumption model rich in perspectives and ideas for solving the main sustainability issues within SDGs. Therefore, the research interest in identifying proper ways to support, implement and measure Circular Economy before, during, and after implementation, contributions to Sustainable Development is continuously growing and has produced an increasing number of different indicators and methods [3,49]. Through the integration of the critical review by Walzberg et al. [50], this section will briefly contribute to providing a more holistic critique of Circular Economy strategies based on their adherence to the five principles of SD, as a Humanity-Centered Design methodology. This will help to converge for an Industry 5.0 that cares for the dynamic human-nature relationship. To this end, we advocate a humanity-centered Industry 5.0, catalysed by design, which places the human-nature relationship above human desires, overriding the emphasis on human needs over the production process. The goal is to begin a discussion of what criteria from the previous methods are consistent or inconsistent for Circular Economy assessment in Industry 5.0 and how they might be integrated into a mixed-oriented assessment methodology.

Methodology. A deductive and analytical approach is employed to critique the quantitative sustainability assessment methods identified by a previous review [50] within Circular Economy. Seven methods from Industrial Ecology (Life Cycle Assessment, Environmentally Extended Input-Output Analysis, Material Flow Analysis, Emergy and Exergy), Complex Systems Science (System Dynamics, Discrete Event Simulation, Agent-Based Modeling, Operational Research) are analysed according to adherence to the “strong” Sustainability paradigm.

Qualitative methods are not considered in this analysis as they are by their nature holistic and already widely used in SD research [44,45,51].

Results. The analysis shows that these models and indicators adhere to the “weak” rather than the “strong” Sustainability paradigm:

- economic benefits, in fact, are estimated regardless of whether they contribute to maintaining or improving social welfare and Planetary Health;
- the multiple environmental indicators focus on reducing inputs used, reducing waste, and focusing excessively narrowly on carbon emissions. This suffers from the so-called "carbon tunnel vision" coined by Jan Konietzko, omitting important indicators related to environmental impacts such as biodiversity loss, ecotoxicity, and water crisis;
- absence of indicators regarding social impacts, beyond indicators such as cost reductions and premium prices that benefit consumers.

It can be argued that such methods of evaluating Circular Economy are no longer consistent in the context of Industry 5.0 for Planetary Health. These need to be overcome in order to build an integrated reporting model that gets over the dualistic view by evaluating adherence to the principles of Industry 5.0 in an integrated way,

defining analytically measurable indicators of humanity and environmental benefits or hybrids that capture the different dimensions of impacts in a holistic but systematic way. This analysis is not meant to be exhaustive but is intended to provoke a discussion in the field of design research on its contribution to defining analytically measurable indicators and assessment methods for the new industrial paradigm and its pillars, crosschecking all aspects of the “Doughnut”.

4.2 Sustainability assessment toward Industry 5.0

What emerges from the above discussions is the tendency of design to shift the focus towards a “strong” Sustainability paradigm embedded in Industry 5.0. However, for design to drive the implementation of more sustainable solutions towards Industry 5.0, more practical holistic tools are needed to achieve tangible results. This section outlines a methodological framework to guide the development of the assessment tools needed within academia and industry to evaluate industrial practices in compliance with the three pillars of Industry 5.0.

In 2017, Arodudu and colleagues argued that sustainability assessment, as a process to guide decision-making towards sustainability, requires answering specific questions about impact (what), space (where), time (when), and stakeholders (who) [52]. However, the proposed assessment process is a limited framework for developing holistic methods since it is based on the "weak" Sustainability paradigm. Therefore, an update of the mentioned framework is proposed here (Fig. 1.6), structuring, and integrating the relevant aspects to question the development of assessment methods for Industry 5.0. First, the objective of this updated framework is to review the spatial, temporal, stakeholder, and impact aspects in relation to the concepts of Sustainability and Planetary Health.

The four original elements and the related questions (what, where, when, who) are associated with one of the three pillars as follows:

- the questions "where", "when", and "who" are traced back to crisis resilience as a concept closely related to the ability of one or more subjects to profitably manage time and resources in a setting;
- the question "what" is reconceived outside the impact concept of the triple bottom line paradigm. Instead, it relates to the core analysis element of the evaluation method, leading back to the pillar of human-centredness.

A fifth question is added to these four questions, the "how." This question refers to the ways in which the “waste hierarchy” embedded in the Circular Economy is conceived by the assessment method. Based on this framework and basic questions, holistic assessment processes, methods, and indicators that can capture the nuances of Industry 5.0 implementation should be developed and classified according to the following logic. Following the divergent and convergent structure proposed, an evaluation method should aim for more comprehensiveness in assessing and considering the five elements/questions. When evaluating crisis resilience, it is crucial to take a comprehensive approach. This entails considering the long-term effects of decision-making processes, including both medium- and short-term perspectives, on

local industrial practices within the context of the regional and global setting. In evaluating the coherence of industrial practice to Circular Economy, an assessment method should draw on the 'waste hierarchy' concept by recognising practices that prioritise resource reduction over recycling and reuse. Finally, in assessing the human-centeredness of industrial practice, an evaluation method should broaden its focus beyond the production system itself and map and assess how it engages the relationship between natural and social systems.

This framework, as the key methodological contribution of this paper, aims to direct design research in defining indicators and analytical evaluation methods for research and industry toward the implementation of the new industrial paradigm and its pillars.

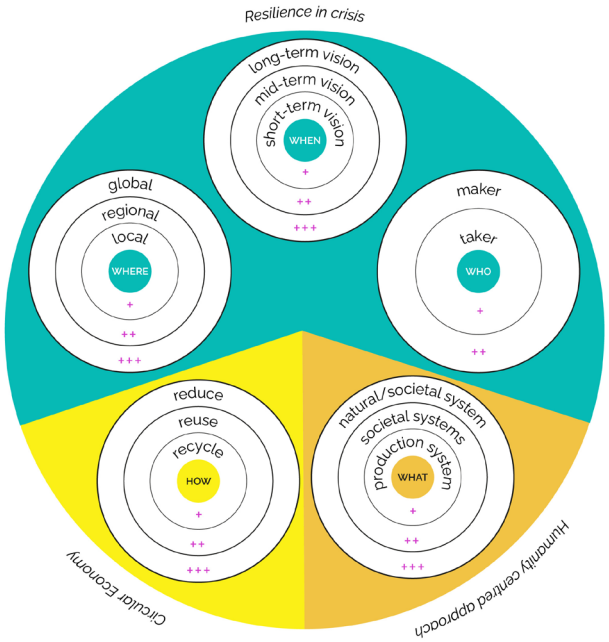


Fig. 1.6. The five basic elements and questions of holistic assessment processes for Industry 5.0.

5 Conclusion and final remarks

This chapter explores the human-nature relationship under the different lenses of the evolving paradigms of Health and Sustainability within sustainability-related fields for a repositioning of design research and practice for an Industry 5.0 that takes care of the dynamic human-nature relationship.

Section 1.2 investigates the evolution of the main paradigms of Health and Sustainability in the context of the sustainability-related scientific and political debate on Sustainable Development. Starting from the principles governing the human-

nature relationship, this section establishes which one offers a more holistic perspective that allows building on a design approach to enable humankind to perceive himself as a community and to be “in nature with nature”. Therefore, we propose an integrated definition of Sustainable Development, linked to the human-nature relationship perspective within Planetary Health. Section 1.3, building on the previous section, argues for the need to reposition the discipline of design among four main emerging and/or established approaches to place the human-nature relationship at the center of design research and practice, according to a monistic perspective. Finally, Section 1.4 critiques the relevance of current sustainability assessment methods considering the new industrial paradigm, pointing out their inadequacy. Furthermore, by positing a framework for developing congruous assessment processes and methods for industrial practices, the need for design to conduct research to define integrated methods within the proposed framework for holistic assessment processes that overcome the human-nature dualism typical of current methods is stressed.

This chapter initiates a latent and necessary discussion on the repositioning of design for Industry 5.0 takes care of the dynamic human-nature relationship, building on the discussions of Conservation Ecology, arguing for a humanity-centered approach that cares about generating positive feedback loops among human-being and non-human domains.

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