

Deep products; a multi-dimensional taxonomy of subtraction-by-design approaches

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This paper represents a continuation of research by the authors introducing Deep Products. Building from a survey specifically collected to address the rising concerns of the impact of design in ecological futures, this paper will present a multi-dimensional taxonomy of subtraction-by-design approaches. Based on our research findings, the authors underline a range of dimensions; Process (biological- mechanical-digital), enablers (independent-companies-governments), output (objects-services- initiatives), scale (person-house-city), rawness (biomass-carbon-plastic), achievements (negative zero- net zero-partial removal). In addition, we present two quadrants; one showcasing location— where the waste removal is placed in terms of the four fundamental earth elements (air, water, land, and social), and another quadrant placing interventions along two dominant interventional axes (social- technological, and pragmatic-speculative). Present and future work will be dedicated to implement subtraction-by-design in educational modules at the Royal college of Art, as well as testing and validating the multi-level taxonomy presented by expanding its database.

Keywords: Pedagogy, ecology, deep products, subtractionism, extractionism.

1. Introduction

Donella Meadows book *Limits to Growth* (1972) warned us that population and industrial growth were pushing humanity and the environment towards collapse 50 years ago. Now, 50 years after, the planet has crossed multiple planetary boundaries. Recent studies have pointed to the possibility of human activity overcoming its planetary boundaries. For instance, the latest International Plant Protection Convention (IPCC) synthesis report published in March 2023 emphasises the urgency of taking more ambitious action (AR6 Synthesis Report: Climate Change 2023). This report (2023, p.3) recognises the “interdependence of climate, ecosystems and biodiversity, and human societies; the value of diverse forms of knowledge; and the close linkages between climate change adaptation, mitigation, ecosystem health, human well-being and sustainable development, and reflects the increasing diversity of actors involved in climate action”. IPCC’s Chair Hoesung Lee points out that we are in the verge of reaching 1.5 temperature rise and stressed the need to act now to secure a liveable sustainable future.

These insights have become a major concern and other studies are highlighting the fundamental threats to supporting biophysical sub-systems affecting the resilience of ecological processes (Leach et al., 2013; Steffen et al., 2015; Lade et al., 2020). The importance of these planetary boundaries emerged recently as a quintessential space for policies such as the ‘EU Green Deal’ — which aims to make Europe carbon neutral by 2050 — and provide society with a clear framework to operationalise a more sustainable planet (EU, 2019). Or the UNESCO’s #ESDfor2030 agenda, which provides a roadmap seeking to strengthen the role of education in securing a sustain-able future (UNESCO, 2020). The Sustainable Development Goals (SDGs) proposed in the SDG’s framework places education as capital to their achievement. In this context, Petrina has critically analysed our current design practices. In his



view current models are not sustainable and when we teach design and technological problem solving, we “invariably neglect the interconnectedness of products” with our cultural and natural ecologies (Petrina, 2020, pp. 208).

In this context, as products are becoming more ubiquitous, persuasive and polluting, papers are calling for the development of reparative strategies (e.g., The Right to Repair regulations, Chapman 2021, Berger, & Irvin 2022). These strategies are becoming fundamental, not only to address sustainability, but to maintain trust in systems and design practices. Building from these perspectives designers are envisioning new typologies of products aiming for instance to extract CO₂ from the environment or creating products from landfill waste. In this context a fundamental question arises; what could be a philosophical framework for a subtractive practice in design?

This question led the authors to a preliminary investigation into a range of emerging design frameworks addressing circularity in the UK (Galdon & Hall, 2022). In this study, the IDEO/EMF Circular Design Guide, RSA’ Great Recovery and design for regeneration reports, the Design Council’s Beyond Net Zero report, and the Textiles Circularity Centre (TCC) at the RCA were investigated. Then a comparative study was implemented to underpin gaps and opportunities. From this research, a paper developing the notion of Deep Products by building from notions of Deep Ecology, Deep Design, and stewardship was published (Galdon & Hall, 2022). This theoretical proposition addressed the design of products from a life-cycle perspective through contemporary notions of subtraction-by-design. The model presented transitioned design orthodoxies from extractionism to subtractionism, demanding extended design projects considering every aspect of the life-cycle of products, from inception to deployment, while addressing issues of impact and reuse with the characteristic of subtraction-by- design. This subtractive

model presented a radical new approach to design products which marked a transition from an object-subject relationship (Latour, 2005), to the impact of this relationship on the system/environment (Ingold, 2008) with a specificity of care (Rogers & Bremner, 2011).

This paper was part of a specific track at the Design Research Society 2023 in Bilbao, Spain and was led by two of the authors of this paper. It aimed at proposals for Design Dematerialisation: opportunities through reduction. As defined by the researchers;

A subtractive future is not really concerned with finding efficiencies of current norms but with the strategies, experiences, interactions, shifts, behaviour changes, re-connections and new economies of degrowth. This track seeks to interrogate the interconnection of philosophical, moral and existential arguments with the concrete and tangible realities of taking and coordinating action in, and through the field and practices of design. (Hall et al., 2022)

Is within this context that we are further expanding and grounding Deep products via this taxonomical research. We are presenting this investigation as a follow-up research intervention.

Building from a survey specifically designed to address the rising concerns aforementioned, this paper will present a multi-dimensional taxonomy of subtraction-by-design approaches to underpin a preliminary categorisation of practises and dimensions. Based on our research findings, the authors underline a range of emerging dimensions; Achievements (negative zero-net zero-partial removal), Process (biological-mechanical-digital), Enablers (independent-companies-governments), Output (objects-services-initiatives), Scale (person-house-city), and Rawness (biomass-carbon-plastic). In addition, we present two quadrants; one showcasing location —from where the waste removal is placed in terms of four fundamental earth elements (air, water, land, and social), and another quadrant showcasing design interventions along two



dominant interventional axes (social- technological, and pragmatic-speculative).

Through this taxonomy the authors explore the state of the art of subtractive practices to build an operational framework to facilitate a transition towards more design-led ecological practices.

2. Methodology

This study aims for a preliminary estimation to understand what is happening in the field of design in the context of regenerative and subtractive practices. Here we are investigating how practice, in this case subtraction-through-design, emerges and adapts through time and circumstances to address readiness, appropriateness and preparedness in the context of sustainable practices.

The increasing amount of information available in the info-sphere enabled us to collect the interventions dealing with subtraction and regeneration as they emerged from a variety of online sources. In this context, the infinite array of digital tools allowed us to collect the design interventions efficiently. As such, we implemented a diary-type form of data collection. We decided this was the best possible method to gather the collected experience of the material culture, body of experience, skills and understanding embodied in the arts of planning, inventing, making and doing related to regenerative and subtractive emerging practises.

Diary studies were introduced in 1913 by George Bevens as a recording mechanism for daily life. In this paper we are using what could be characterised as an elicitation perspective (Carter, 2005) in the context of diary studies. We enable these notions with an 'in the moment' approach, which was introduced to diaries studies by Wickham (2013).

The diary-type of entries process implemented consists of capturing emerging cases as soon as they are found in the digital landscape to record examples of subtractive design and its ongoing evolution/s. In other

words, we have documented subtractive practises as they are evolving.

2.1. Data collection

In order to frame the intended outcome, a progressive and systematic integrative review was conducted. It was decided to use this approach to insert flexibility into the cataloguing of the cases. The search criteria was based on their relevance to the subject. Design blog Dezeen was searched daily. This online source creates collections of design interventions in the context of climate change. This sourcing was preferred to papers due to their immediacy and relevance. Papers tend to showcase a specific method, technique or process, whereas a specialist blog offers an extended and holistic view of cases in almost real-time. We also included reports from news platforms to complement and expand the data collection to insert a broader and more inclusive and representative perspective.

The criteria to choose examples was based on the characteristics of subtraction-trough-design presented in the conclusions of our previous paper (Galdon & Hall, 2022). These are interventions characterised by landfill waste activation, use of mono-material to facilitate full recycling, or products assembly/disassembly systems/mechanisms to facilitate its reuse/recyclability when using multi- materials. The selection was conditioned by our searches; therefore, it was somewhat arbitrary. The cases collected in this paper represent a sample of data. In this investigation we were not interested in documenting everything that has happened in the past with exactitude (knowledge of), as this task belongs to other disciplines, but aimed to understand what is happening in real-time to foresee where design interventions and strategies should or could be implemented. In effect, we were interested in documenting a sample of data in real-time to extract high patterns of knowledge to build “knowledge for future actions” (Glanville, 2015).



2.2. Data analysis

In this context, we collected 50 cases (See appendix 1), which we used as a foundation to build a set of preliminary categories and subcategories (gradients) to provide a preliminary understanding of the field and practises around subtraction.

In this scenario, we have selected the cases from the point of view of design practise. Accounting for 50 cases in total, these interventions are a record of places, dates, embodiments and strategies and the proposed categorical structure operates as a type of indexical system, which we have enabled by articulating several graphic organisational frameworks enabling projects to be cross-referenced and compared. We have accepted all design interventions as valid and gave them the same role and status by representing each of them equally.

The classification of the interventions into categories and subcategories emerged in the process of collecting following an elicitation approach. However, this classificatory system presented challenges. The classification process was executed in the moment, therefore was influenced by contextual elements and personal interpretations and judgements. Different variables were assigned to each case as they were collected. This aspect may provide variability in the assessment. However, as stated earlier, we are not so much concerned with exactitude, but recollection to underpin emerging patterns for future actions. This kind of complexity led to a broader categorisation of prospective initiatives.

Once we classified the cases and organised them into subsets, we could implement a categorical analysis to underpin evolutive traces in specific categories and/or subcategories. This process enables a preliminary understanding to generalise data patterns. The examples represented in this paper illustrate how we operated these categories. We can observe how specific subcategories dominate in some of the categories. From this point we were able to organise graphic material

in a categorical way to further analyse its evolution. By using categories and subcategories, we uncovered evolutive traces. This process presents a design-led, graphical and visual alternative or complement to pure statistical and mathematical models.

This model of diary-type entries with cases collected from the infosphere via elicitation was previously implemented by the main author (Rodgers, Galdon, & Bremner, 2020) in the context of pandemic design, in which we could anticipate design trajectories (Rodgers, Galdon, & Bremner, 2023).

Our approach follows the pioneering work of Nigel Cross, in which as design researchers we must be concerned with extracting and identifying higher patterns of activity emerging from the collected experience of the material culture, and the collected body of experience, skill and understanding embodied in the arts of planning, inventing, making and doing in the artificial world, to infer knowledge for future actions in the context of appropriateness, readiness, and preparedness (Cross, 1982).

3. Results

3.1. Achievement

Achievement - This category refers in this taxonomy to the impact of a design intervention in the context of subtraction-by-design.

The achievement category is structured in three main subcategories; negative zero, net zero, and partial removal. With these subcategories we were able to include all the cases.

Achievement		
Negative zero	Net zero partial	Removal

This category proved the most difficult category to operate due to the lack of a benchmark tool or methodology to establish, with some accuracy, the real impact of a design intervention. This is true in interior

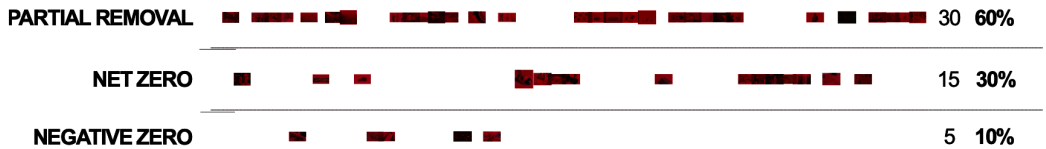


design, furniture, and specially in fashion. These fields provide no reference or statements such as 100% recyclable or 100% biodegradable. However, in the field of architecture and construction is the opposite; In these areas the impact is clearly identified on whether the output presented is net zero or negative. This reality may be due to the regulated operationability of architectural practise around standards and certifications. This insight opens a space to develop some procedure to identify the true impact of a design intervention. Further research will be needed to develop this tool/framework.

In order to build an evolutive trace to get a preliminary sense of the area, we placed projects that clearly define negative impact, or net zero in its subsequent categories. We also integrated projects with 100 per cent biodegradable, and 100 per cent circular proposals with the net zero category, as they seem to imply a balanced impact by means of dissolution or re-usability. Everything other project has been placed under the partial removal category.

As a result, negative zero was the least intervene subcategory accounting to 5 cases representing 10% overall. Net zero was second subcategory accounting to 15 cases representing 30% overall. Partial removal was the dominant subcategory with 30 cases representing 60% overall.

↓ Fig. 1. Evolutive traces: Achievement category. Fernando Galdon, 2023.



3.2. Process

Process refers in this taxonomy to the main process used in a design intervention in the context of subtraction-by-design.

The process category is structured in three main

subcategories; biological, mechanical, and digital. With these subcategories we were able to include all the cases.

Process		
Biological	Mechanical	Digital

This dimension proved easy to operate due to our acknowledgement of traditional and current sets of transformational processes. The mechanical links to the industrial designer; the digital operates in the recent digital/social design practises; and the biological is an emerging field that is already being implemented in design schools (e.g., Biodesign at Central Saint Martins, Symbiotica in Australia, or a MA in Bio-integrated Design at the Bartlett school of architecture, UCL). In this area, unless a new radical process emerges, the proposed subcategories are capable of addressing any possible output.

In order to build an evolutive trace to get a preliminary sense of the area, we placed projects in its subsequent subcategory based on the process that is predominantly defined in the text. However, we acknowledge that some of the project combine processes. This is especially true in projects operating in the biological subcategory, which normally incorporate mechanical elements. The mechanical and digital tend to operate in its own domain.

As a result, Digital was the least intervened subcategory accounting to 4 cases representing 8% overall. Biological processes were the second subcategory accounting to 18 cases representing 36% overall. Finally, mechanical processes were the dominant subcategory with 26 cases representing 56% overall.



↑ Fig. 2. Evolutive traces: Process category.

3.3. Enablers

Enablers refers in this taxonomy to the type of enabler implementing a design intervention in the context of subtraction-by-design. The enablers category is structured in three main subcategories; individual, company, and government. With these subcategories we were able to include all the cases.

Enablers		
Individual	Company	Government

As with the previous dimension, enablers proved easy to operate due to our acknowledgement of traditional and current sets of enabling processes. The individual links to the independent designer, student or scientist operating in an experimental setting; the company operates in the design studio, or established company, small or large, commercialising its development; and the governmental subcategory is operating in the context of supporting initiatives. In this area, an alternative subcategory may be expanded to NGOs.

In order to build an evolutive trace to get a preliminary sense of the area, we placed projects in its subsequent subcategory based on the criteria established above.

As a result, Government was the least intervened subcategory accounting to 4 cases representing 8% overall. Individuals (independent designer, student or scientist operating in an experimental setting) were the second most popular subcategory accounting to 15 cases representing 30% overall. Finally, companies (small or large) were the dominant subcategory with 31 cases representing 62% overall.



3.4. Output

Output refers in this taxonomy to the type of output emerging from a design intervention in the context of subtraction-by-design.

The output category is structured in three main subcategories; service, initiatives, and objects. With these subcategories we were able to include all the cases.

↑ Fig. 3. Evulsive traces: Enablers category. Fernando Galdón, 2023.

Output		
Service	Initiatives	Objects

This dimension also proved easy to operate due to our acknowledgement of types of outputs in the context of design. Objects are the most traditional typology, yet in more contemporary design practises services have been dominating the type of outputs in the context of design practise. (The (Institution) announced its MA Service Design back in 2011). Currently services account for 80% of UK’s GDP (House of commons, 2022). Finally, initiatives are an emerging field in design and a small representation can be found in this category. They tend to be dominated by political bodies or independent organisations aiming to generate impact via engagement. In this area, unless a new radical typology emerges, the proposed subcategories are capable of addressing any possible output.

In order to build an evulsive trace to get a preliminary sense of the area, we placed projects in its subsequent subcategory based on the type of output that is predominantly defined in the text.

However, we acknowledge that some of the project combine outputs. This is especially true in projects



operating in the initiatives' subcategory, which sometimes presents objects as their output. The objects and services tend to operate in its own domain.

As a result, service was the least intervene subcategory accounting to 7 cases representing 14% overall. Initiatives were the second most popular subcategory accounting to 16 cases representing 32% overall. Finally, objects were the dominant subcategory with 27 cases representing 54% of the cases overall.

↓ Fig. 4. Evolutive traces: Output category. Fernando Galdon, 2023.



3.5. Scale

Scale refers in this taxonomy to the size and use of outputs emerging from a design intervention in the context of subtraction-by-design.

The output category is structured in three main subcategories; person/human, home, and city. With these subcategories we were able to include all the cases.

Scale		
Person	Home	City

As with the previous dimension, this dimension proved easy to operate due to our acknowledgement of different scales operating in the context of design. The person subcategory refers to human scale; the home subcategory refers to habitat-related interventions; and the city subcategory refers to a scale beyond the human, and the house, but contextualised in a specific context, therefore, not planetary in scale. In this area, an alternative subcategory may be expanded to planetary-scale interventions.

In order to build an evolutive trace to get a preliminary sense of the area, we placed projects in its subsequent subcategory based on the criteria established above. In this context fashion interventions dominated the person/human scale subcategory, and furniture related interventions and construction related interventions dominated the home scale subcategory. The city scale subcategory was dominated by decarbonisation initiatives.

As a result, the person/human subcategory was the least intervene subcategory accounting to 13 cases representing 26% overall. City related interventions were the second most popular subcategory accounting to 16 cases representing 32% overall. Finally, home related interventions were the dominant subcategory with 21 cases representing 42% of the cases overall. This category of scale was the most distributed from the six variants presented.

↓ Fig. 5. Evolutive traces: Scale category. Fernando Galdón, 2023.



3.6. Rawness

Rawness refers in this taxonomy to what type of material or substance we are subtracting from a design intervention in the context of subtraction-by-design.

The rawness category is structured in three main subcategories; biowaste, carbon, and plastic. With these subcategories we were able to include all the cases.

Rawness		
Biowaste	Carbon	Plastic

This category proved very difficult category to operate due to the specificity and broadness of some of



the projects. Some of them are specifically targeting plastics, and other are broadly targeting emissions or circularity/sustainability. As with the case before, this is true in interior design, furniture, and specially in fashion. Some projects in these fields provide broad statements such as recyclable, biodegradable, circularity, or sustainability. In this area, the proposed subcategories are capable of addressing any possible output, however, we acknowledge the more cases emerge, the more likely to expand into additional subcategories for addressing all possible outputs.

In order to build an evolutive trace to get a preliminary sense of the area, we placed projects in its subsequent subcategory based on the rawness they were primarily subtracting as defined in the text. However, we acknowledge that some of the project combine processes. This is especially true in projects operating in the biowaste subcategory, which sometimes incorporate decarbonisation initiatives in them. The carbon, and plastic tend to operate in its own domain.

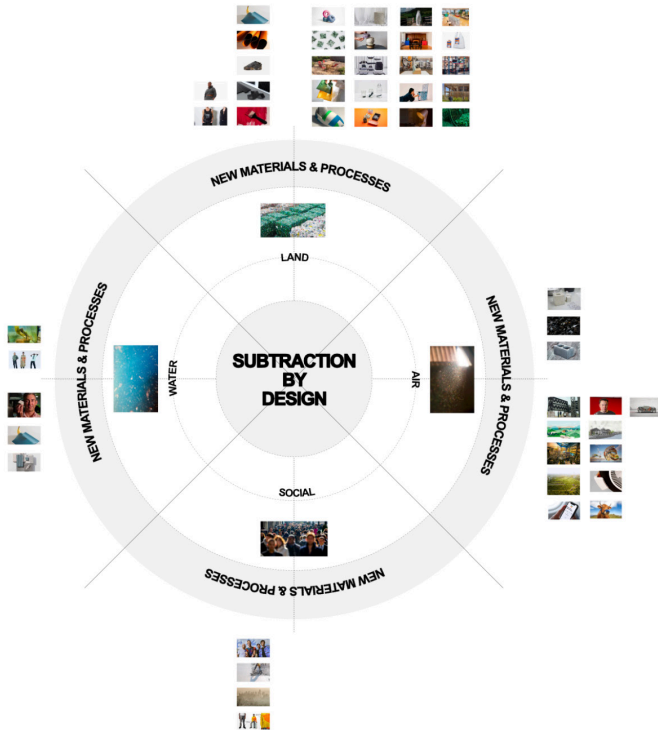
As a result, the plastic subcategory was the least intervene subcategory accounting to 11 cases representing 22% overall. Carbon related interventions were the second most popular subcategory accounting to 17 cases representing 34% overall. Finally, biowaste related interventions were the dominant subcategory with 22 cases representing 44% of the cases overall. This category of scale was also very distributed.

↓ Fig. 6. Evolutive traces:
Rawness category.



3.7. Quadrant 1 – Subtractive location

This quadrant addresses from where the waste removal is placed in terms of the four fundamental earth elements (air, water, land, and social).



← Fig. 7. Quadrants: case distribution by subtraction areas.

As results show, the social category was the least intervene category accounting to 4 cases representing 8% of overall cases. The water category related interventions were the second least popular category accounting to 5 cases representing 10% of overall cases. Cases related to the Air category were the second most dominant category with 14 cases representing 28% of the cases overall. Finally, Land removal interventions were the most dominant category from the four variants presented with 27 cases representing 54% overall.

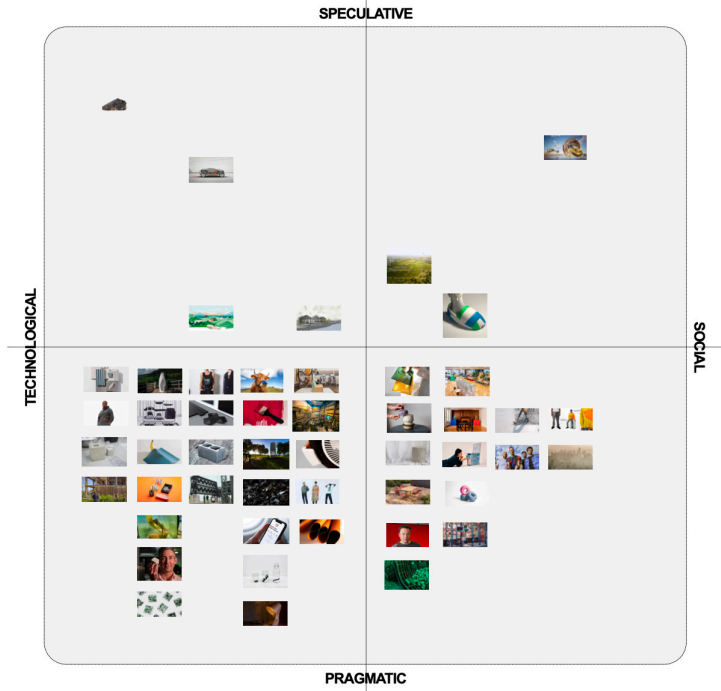
This preliminary estimation is helping us to locate in which areas are designers are implementing removing waste via subtraction-by-design.



3.8. Quadrant 2 - Interventions

This quadrant addresses where the design interventions sit along two dominant interventional axes (social-technological, and pragmatic-speculative).

→ Fig. 8. Quadrants: case distribution by interventional approaches.



As results show, the speculative-pragmatic spectrum resulted in 4 interventions representing the speculative spectrum, whereas the pragmatic spectrum represented 43 interventions. With 3 cases operating at the intersection of them.

In term of the social-technological spectrum resulted in 11 interventions representing the social spectrum, whereas the technological spectrum represented 32 interventions. With 7 cases operating at the intersection of them.

In term of quadrants, the technology-pragmatic was the area representing more cases. It was followed by the social-pragmatic. The speculative-technological and

speculative-social were the least representing areas.

This preliminary estimation is helping us to locate which design strategies are being implemented by designers to address subtraction-by-design.

4. Discussion

In this work, 50 design interventions have been documented in a brief period of time to estimate where and how designers are subtracting-by-design. In this paper we illustrate the ingenuity, resourcefulness and willingness of designers to make a more liveable world, yet this impetus also generated a range of dilemmas and paradoxes for designers and other stakeholders to resolve how to progress design practise in order to address the greatest challenge we face; climate change, liveable futures and the scale of our interventions.

As designers, we are constantly reminded of the potential of turning our future visions into real products and implement systemic changes. The vast technological developments in computing and manufacturing combined with low production costs and rapid execution cycles mean it is relatively simple to turn ideas into finished objects ready to be distributed worldwide. However, the explosion of home manufactured products has the potential to result in negative environmental impact.

One of the fundamental insights from this study was the lack of certifications in the area of design. This aspect differs from architecture in which a set of certifications underpins the real impact of design interventions. This missing tool complicates analyses focused on measuring the real impact of design interventions. This fact opens a space for the development of systems of accountability in design.

Another insight was the explosion of interventions in removing waste from land and air, and the lack of interventions focusing on oceans and involving social participation. This area opens a space for the development of partnerships to address waste removal



from our environment. Recent strategies like the decade partnership between the Royal College of Art (RCA) and UNESCO may be a model to address this challenge (2023). However, this area also lacks environmental and economic impact studies and processes addressing subtraction, management, and traceability to understand the real impact of removal. This fact opens a space for the development of systems of management in design.

Home and city-based scales are currently the main target for designers. As argued, they will need to be complemented with larger interventions at a bioregional and planetary scale through multi-stakeholder partnerships hand in hand with interconnected impact and traceability studies.

In terms of data analysis, estimation emerged as a fundamental ontology to collect and monitor emerging practises and methods to convey directionalities and potential strategies. In future-oriented and impact-led design research we trade some degree of accuracy in order to estimate knowledge for future actions. Therefore, our output, as an estimation, is probabilistic, and research is always preliminary in its nature (Galdon & Hall, 2019). Moreover, in exchange we provide guiding knowledge for prospective developments – as Glanville proposed, “knowledge for” future action and possibilities rather than “knowledge of” past actions and events (Glanville, 2005). Consequently, Design research is directional and transformational at its core.

4.1. Evaluation

From this research in subtractive design, we translated the fundamentals insights of this paper into an educational unit we call Supergreen: regenerative materials, structures and aesthetics (RMS&A). The unit is an intense creative and practical psychomotor exploration of materials, structures and aesthetics leading to creation of artifacts exemplifying a well-structured process together with evidence of developing

functional, aesthetic and scientific understanding of ecological approaches, materials and related manufacturing and production systems.

Students are introduced to a creatively inspirational project context which, through a programme of introductory talks from designers and artists, encourages a strongly experimental and intuitively inspired exploration of materials and structures as well as related defining elements for physical embodiment such as form, line and detail. Subjects for focused exploration include product archetypes such as furniture, footwear, fashion, or food utensils. This physical and practical work was coupled with an introduction to and in-depth consideration of the environmental, socio-cultural and scientific factors involved with the use of materials, manufacturing systems and related engineering performance factors. The work will result in artefacts reflecting the creative and analytical process and decisions made in the context of regenerative + subtractive design.

The Regenerative Structures module implements an experiment-centric approach. This module aims at nurturing students' explorative spirit by experimenting with various methods of conceiving and handling forms while developing new modalities. The outcomes usually are grounded in design archetypes, but resulting in products with innovative features associated with novel forms beyond the boundaries of art, engineering, ergonomics, and function. The creative potentials emerge when designing with such an experimental approach.

We aim for the outcomes of this module to achieve iconic status in the portfolios of designers through their unique qualities of supporting the human form and function whilst providing a testing ground for new manufacturing processes, structures, aesthetics, and experiments that are planet positive. The world is full of design archetypes, and yet every year we continue to see new forms and functions. It's this close relationship



to our changing lives that continues to drive the possibilities for innovations in how we exist.

4.1.1. Brief

Amidst the environmental collapse it is imperative that higher education reflects on how future designers need to unlearn and shift the industrial design mindset to proactively and responsibly design to remediate the present, creating a more ecological and just future(s). The state of environmental degradation requires a reformulation of the ethos and principles of design. The next generation of designers must catalyse a shift in design reflecting ecological and social values into their professional outputs.

As a response to the challenges emerging from dealing with the climate crisis, one of the government advisors on design, The Design Council, released the report *Beyond Net Zero: A Systemic Design Approach*. This institution describes the relevance of systems thinking as “a comprehensive approach that considers not only the individual elements involved in a project but also how these elements interrelate, how the system changes over time, and how it relates to its wider environment” (2021, p.27). In this context, designers are envisioning new regenerative / subtractive typologies of products aiming for instance to extract CO₂ from the environment or creating products from landfill waste.

In this context we have envisioned four main areas of intervention; furniture, fashion, footwear, and food utensils. They represent the main categories used by humans in their everyday lives. The main reason to have products with a manageable scale is to maximize workshop interaction and extend time for deep experimentation with regenerative materiality and subtractive processes, while considering its emerging aesthetics and impact. Students will have to select an archetype from the categories presented and will develop a manifesto as a starting point to frame their intended position.

The main focus will be on material use/impact and processes to enable regenerative + subtractive products. Students will consider both old and new manufacturing techniques. They will explore how we, as designers, can positively influence the balance between the environment vs the harmful manufacturing forces embedded in the implementation of the industrial process. Special emphasis will be given to new local production paradigms and reimagining local micro-factories. The final presentation of the unit will be in the form of an exhibition focused on students' work, development, reflection and execution. It will include a printed booklet/portfolio with a maximum of 15 pages excluding a cover page and a references page (e.g., with links to additional materials) and will be compiled to include the following elements:

- Manifiesto (ideals and values)
- Material exploration (self-initiated experimentation)
- Structures analysis, testing and reflection (from material experimentation)
- Ideation (sketching and lo-fi prototyping)
- Product development phase (e.g., including reflection points)
- Finishing (e.g., including itinerary points)
- Exhibition elements (100 words description, name of object)

4.1.2. Results

We selected the top 40 projects from the module spanning furniture, fashion, utensils, and shoes (See appendix 2). As a result, the 40 projects operated within the established dimension except the Rawness category that needed one extra subcategory to address all cases (Fig. 9).

In terms of the Achievements category, the subcategories presented (partial removal-net zero-negative zero) covered the full spectrum of possibilities. As a result, negative zero was the least intervene subcategory accounting to 0 cases representing 0%



overall. Net zero was second subcategory accounting to 13 cases representing 32% overall. Partial removal was the dominant subcategory with 27 cases representing 68% overall. These results align with the preliminary analysis conducted.

In terms of the Process category, the subcategories presented (biological-mechanical-digital) covered the full spectrum of possibilities. We placed projects in its subsequent subcategory based on the process that is predominantly defined in the text. However, as happened with the initial analysis some of the project combine processes. This is especially true in projects operating in the biological subcategory, which normally incorporate mechanical elements. The mechanical and digital tend to operate in its own domain. As a result, Digital was the least intervened subcategory accounting to 3 cases representing 7% overall. Biological processes were the second subcategory accounting to 18 cases representing 45% overall. Finally, mechanical processes were the dominant subcategory with 19 cases representing 48% overall. These results also align with the preliminary analysis conducted.

In terms of the Enablers category, the subcategories presented (government-company-individual) covered the full spectrum of possibilities. However, as the analysis was conducted in the context of an individual project in higher education, all projects belong to the individual category, therefore, this category becomes redundant in this context.

In terms of the Output category, the subcategories presented (object-initiatives-service) covered the full spectrum of possibilities. As with the preliminary study, we placed projects in its subsequent subcategory based on the type of output that is predominantly defined in the text. However, we also acknowledge here that some of the project combine outputs. This is especially true in projects operating in the initiatives' subcategory, which sometimes presents objects as their output. The objects

and services tend to operate in its own domain.

As a result, service and initiatives were the least intervene subcategories accounting to 5 cases representing 12% overall each of them. Finally, objects were the dominant subcategory with 30 cases representing 76% of the cases overall. These results differ slightly with the preliminary analysis in the initiatives subcategory. We believe that this is due to the individual project in an educational setting, as this subcategory was mainly supported by governments in the preliminary analysis.

In terms of the Scale category, the subcategories presented (city-home-person) covered the full spectrum of possibilities. We placed projects in its subsequent subcategory based on the criteria established before. In this context fashion interventions also dominate the person/human scale subcategory, and furniture related interventions also dominate the home scale subcategory. The city scale subcategory was dominated in this case by urban-led waste collection regenerative initiatives (e.g., park waste collection or supermarkets bags collection), rather than decarbonisation initiatives.

As a result, in this study the city subcategory was the least intervene subcategory accounting to 7 cases representing 17% overall. Person/human related interventions were the second most popular subcategory accounting to 14 cases representing 35% overall. Finally, home related interventions remained the dominant subcategory with 19 cases representing 48% of the cases overall. These results differ slightly with the preliminary analysis in the number of interventions within the city and human categories. We believe that this is due to the 4 design archetypes; fashion, furniture, utensils, and shoes. These archetypes operate predominantly on human and home scales.

In terms of the Rawness category, the subcategories presented (biomass-carbon-plastic) did not fully cover the spectrum of possibilities. This category needed one extra subcategory, fabrics, to address all cases. As



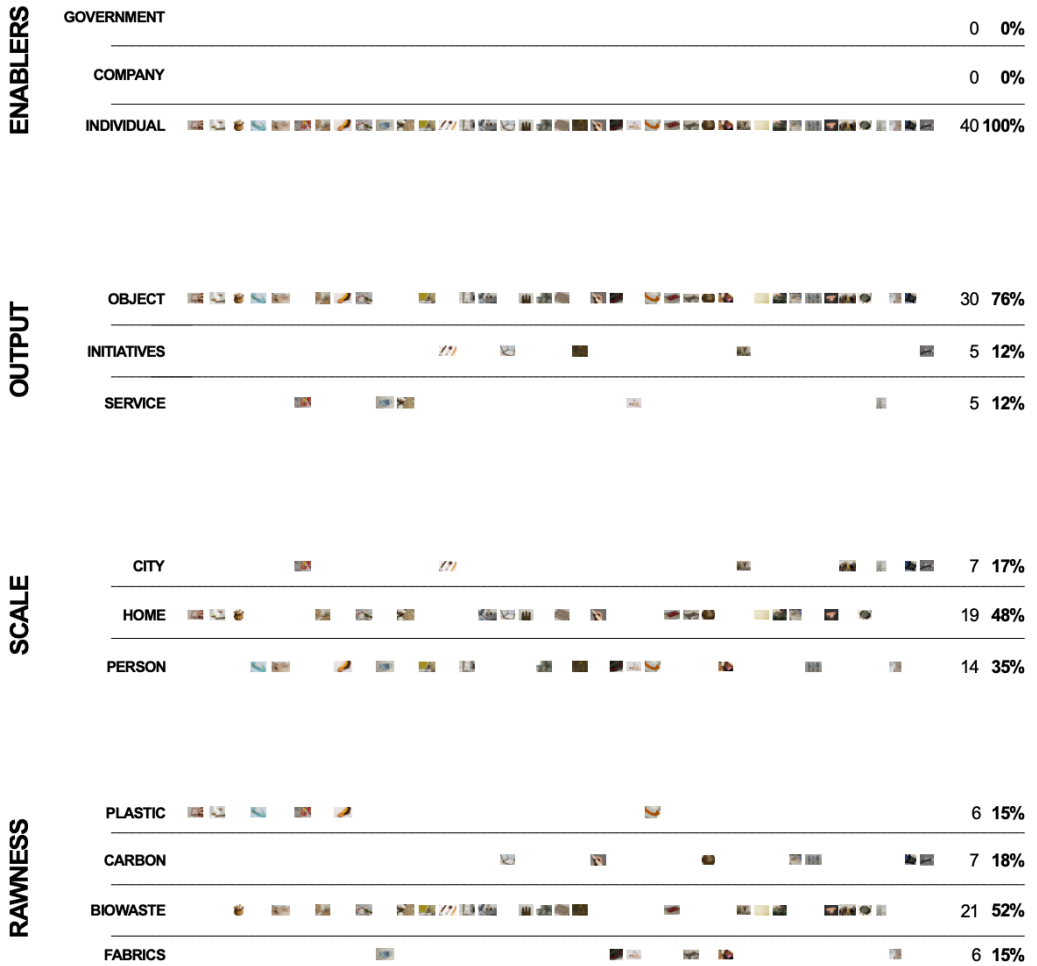
we predicted in the initial analysis, the more cases emerge, the more likely this category would expand into additional subcategories for addressing all possible outputs. The unexpected category of fabric emerged due to projects operating specifically with fabric waste either on preventing it or re-using it in other contexts (e.g., leather off-cuts). As with carbon and plastic, this subcategory also tends to operate in its own domain

As a result, the plastic and the fabric subcategory were the least intervene subcategory accounting to 6 cases representing 15% overall each. Carbon related interventions were the second most popular subcategory accounting to 7 cases representing 18% overall. Finally, biowaste related interventions were the dominant subcategory with 21 cases representing 52% of the cases overall. These results differ slightly with the preliminary analysis in the number of interventions within the biowaste as it emerges as a very dominant subcategory. We believe that this is due to the individual project in an educational setting. This subcategory is very approachable for students, unlike decarbonisation.

4.1.2.1. Dimensions



↑ Fig. 9. Evolute traces from Supergreen module.



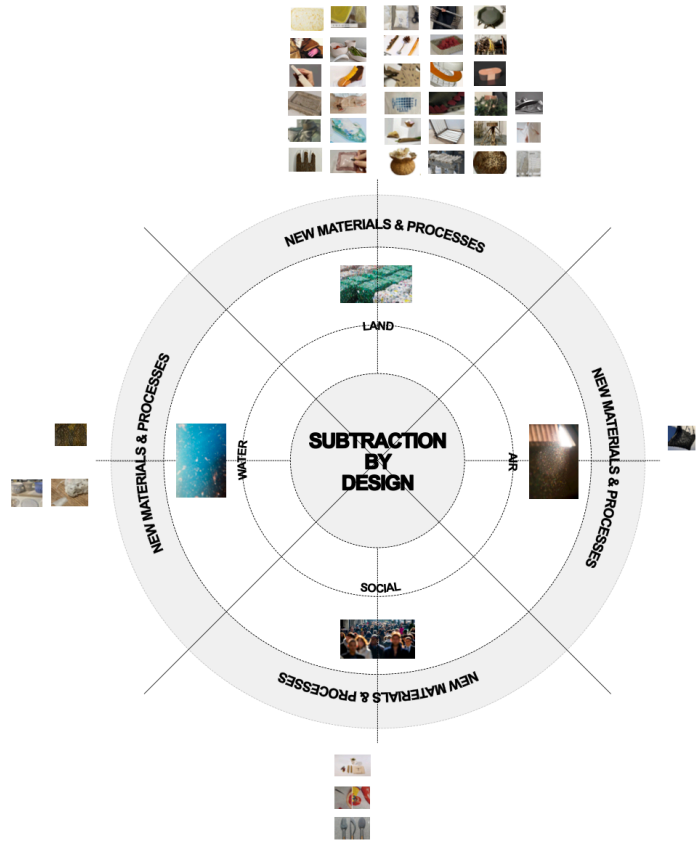
↑ Fig. 9. Evolute traces from Supergreen module.



4.1.2.2. Quadrant 1 – Subtractive location

This quadrant addresses from where the waste removal is placed in terms of the four fundamental earth elements (air, water, land, and social).

→ Fig. 10. Quadrants: case distribution by subtraction areas from Supergreen module.



As results show, the subtractive quadrant was able to integrate all the cases within the dimensions provided. As with the first analysis land waste removal remains the main category for design interventions.

These preliminary estimations are helping us to predict and locate what waste streams are lacking interventions and which design strategies are being and should be implemented by designers to address subtraction-by-design.

4.1.2.3. Quadrant 2 – Interventions

This quadrant addresses where the design interventions sit along two dominant interventional axes (social-technological, and pragmatic-speculative).



← Fig. 11. Quadrants: case distribution by interventional approaches from Supergreen module.

As results show, the interventions quadrant was able to integrate all the cases within the dimensions provided. As with the preliminary study, the technological-pragmatic area remains as the main category for design interventions. It is followed by the social-pragmatic quadrant.

These preliminary estimations are helping us to predict and locate which design strategies are being and should be implemented by designers to address subtraction-by-design.



5. Conclusions

This paper represents a continuation of research by the authors (2022) via the articulation, implementation, and evaluation of a taxonomical study in the context of subtraction-through-design as a regenerative alternative to industrial design.

Building from a survey specifically designed to address the rising concerns of the impact of design in ecology, this paper presents a multi-dimensional taxonomy of subtraction-by-design approaches. Based on our research findings, the authors introduce a range of dimensions emerging from the cases collected; achievements (negative zero-net zero-partial removal), process (biological-mechanical- digital), enablers (independent-companies-governments), output (objects-services-initiatives), scale (person-house-city), and rawness (biomass-carbon-plastic-fabric). In addition, we present two quadrants; one showcasing location — where the waste removal is implemented in terms of the four fundamental earth elements (air, water, land, and social), and another quadrant placing interventions along two dominant interventional axes (social-technological, and pragmatic-speculative). With this framework and tools, we can underpin current trends, uncover gaps of knowledge for impact and innovation, and guide design interventions.

By developing and implementing an educational module in the context of regenerative design with a subtraction-through-design perspective, we could test, evaluate and refine the reliability of the framework. The initial model was capable of estimating traces, subtraction streams, and design practises. However, as knowledge in design is probabilistic due to be contextually dependent to social, economics, environmental and technological factors (e.g., creation of new methods, techniques and technologies), it is expected some variability to emerge. This may lead to the introduction of new categories or subcategories to be able to address all possible cases.

The results and the critical analysis presented in this paper outline a range of opportunities and especially challenges for designers as we/they are transitioning towards a regenerative/subtractive paradigm; the need to create new mindsets, strategies, traceability tools or protocols, and impact assessments. The taxonomy also evidenced the lack of projects related to ocean and social participation in terms of waste removal, and in the social and speculative domains in terms of design interventions. The authors believe that there is an opportunity to develop collective practises within communities and grounded speculative practises at the intersection of regenerative design operating beyond the fictional.

Present and future work is and will be dedicated to further implement subtraction-by-design in educational modules at the RCA, as well as testing, further evaluating and expanding the multi-level taxonomy presented by extending its database and qualities (e.g., aesthetics). Within the latest, a paper will be presented at IADRS2023 in Milan underpinning new aesthetic qualities emerging by intersecting design with a regenerative/subtractive paradigm.



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