LAYERED SUSTAINABILITY. DESIGN INFERENCE FOR CIRCULAR ECONOMY IN ADDITIVE MANUFACTURING.

Noemi Emidi*[a]

a Politecnico di Torino, Italy
* noemi.emidi@polito.it

DOI: 10.63442/RKSR7385

LAYERED SUSTAINABILITY. DESIGN INFERENCE FOR CIRCULAR ECONOMY IN ADDITIVE MANUFACTURING.

Noemi Emidi*[a]

a Politecnico di Torino, Italy
* noemi.emidi@polito.it

P/REFERENCES OF DESIGN
CUMULUS BUDAPEST 2024
15–17 MAY 2024

TAMING ENTROPY: SYSTEMS DESIGN FOR CLIMATE AND CHANGE

Abstract

This contribution explores the intersection of Additive Manufacturing (AM) technology and Circular Economy (CE) models through a Design lens. In contrast to the current limitation of AM processes, the layer-by-layer deposition results in jointless lightweight structures that can be customized, on-demand, and eco-efficient, presenting fundamental ecological implications such as resource efficiency, waste reduction, and lower material and energy consumption. The study delves into both the theoretical foundations and practical applications, emphasizing the potential for circularity in AM.

A case-based reasoning method is used to examine the Design variables of inference across micro, meso, macro, and meta (5M) scales, combining the Issue-Concept-Form (ICF) model for a semantic analysis of case studies. This investigation contributes to design learnings and adaptive guidelines for transformative interventions, providing insights into mitigative design solutions to drive paradigm changes towards CE models in AM. Moreover, the involvement of animate materials, which introduce programmable and adaptive material properties, provides a glimpse into future challenges.

Methodology

By employing a case-based reasoning method across micro, meso, macro, and meta (5M) scales, the research contributes designing insights and adaptive guidelines for transformative interventions, suggesting mitigative design solutions to drive circular changes towards CE models in AM. The 5M scales framework, derived from the Design for Sustainability Evolutionary Framework by Ceschin and Gaziulusoy (2016), forms the basis for case studies classification. The contribution involves the ICF model designed by Oxman (1994) for breaking down, interpreting, and deducing learnings from case studies and refined by Zambelli (2002) for design purposes. Through the model, the author deconstructed the cases' data (gathered by triangulating scientific resources and grey literature) into conceptual keywords regarding questions or goals of the projects (issues), potential design solutions to solve issues (concept) and physical features to materialize concepts (form).

A network of contents is designed through a backward review by tracing and linking ICF keywords from lower-order to higher levels. The flexibility of the models allows further connection among variables and multiple cases. The map displaying the correlation between design variables can be helpful for designers to derive information from the concrete experience of a sample and understand and improve changes in that or other realms. Moreover, it underlines the design potential to deal with multi-scale complexities when designing circularity through transformative interventions.

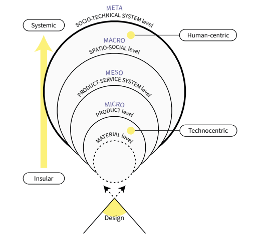
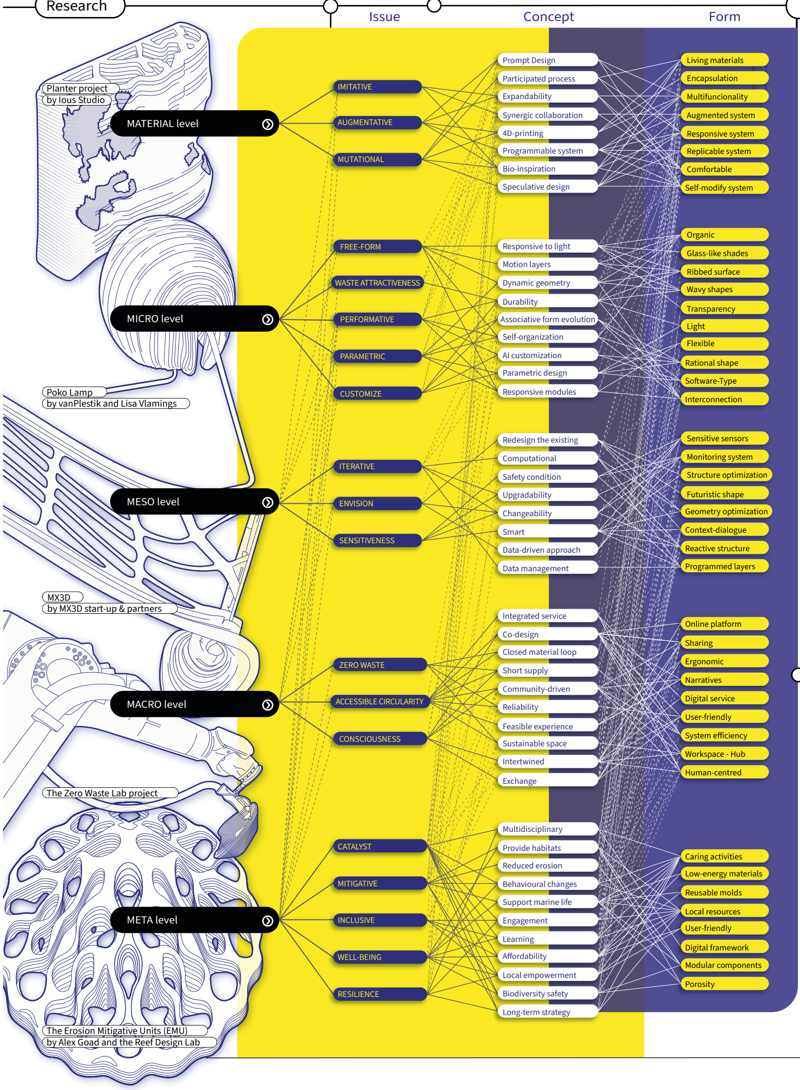


Figure:
The methodological approach of the 5M scales: Material, Micro, Meso, Macro and Meta.

Research



Results

The network diagram showcasing the relationships among the ICF keywords depicts the intertwined relations across 5M levels, highlighting potential design inference's interconnectedness and branching and prompting a more integrated and systemic approach to design thinking for AM.

The connections allow to recognize and depict the broader implications on social, cultural, ecological, and technological levels and emphasize the need for interdisciplinarity capabilities necessary to address challenges and drive innovation across various scales within the larger design ecosystem.

Circularity principles such as reuse, reduce, remanufacture, repair, and recycle are prevalent in the case studies, emphasizing i) the use of recycled materials in higher-value perceived applications; ii) source for local resources in terms of energy, materials, and knowledge; ii) the involvement of local communities into the design process; iv) provide customization options for increasing products sustainability; v) optimize product circularity by conscious design agency; vi) envision and make reliable long-term maintenance strategies.

The research emphasizes Design's transformative role as a catalyst for sustainable changes (Earley, 2017), aligning advanced technologies with societal and ecological needs. The increasing availability of new materials for AM processes due to good recovery practices (Romani et al., 2021) enables the development of innovative AM-based approaches (Oxman, 2013). As merged by cases, a systemic-thinking mindset could stimulate the strengthening of powerful collaboration (Pereno & Barbero, 2020), leveraging community knowledge for valuable sustainable contributions. In addition, by providing reference contexts and making AM processes more affordable, Design can attract stakeholders, fostering greater awareness and social responsibility as well as new co-production, consumption, and resource management models that prompt systemic changes (Hermann et al., 2018). By adapting advanced technologies to societal and ecological needs, Design facilitates transformations in behavior, production, and consumption patterns, aligning with the goals of Circular Economy models.

Despite advancements, challenges persist along social perspectives, regulatory frameworks, and technological impacts. The contribution advocates for a holistic environmental impact assessment that encompasses the entire lifecycle of digital AM processes. This could be included into long-term strategies, involving local efforts alongside low-impact materials (Romani et al., 2021), which can mitigate ecological implications. More political and industrial efforts should be focused on the standardization of AM and new circular materials (Hegab et al., 2023) in order to disseminate sustainable strategies that meet societal needs. Additionally, the exploration of new frontiers of matter (The Royal Society, 2021; Pollini et al., 2022; Emidi, 2023) incorporating animate materials into AM products introduces programmable and adaptive properties, providing a glimpse into future challenges – such as ethical, technological, performances, evolution factors – and suggesting further establishing a nature-artificial symbiosis to efficiently use the right amount of energy and resources while eliminating waste.

References

Ceschin, F., & Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. *Design Studies,* 47, 118–163. https://doi.org/10.1016/j.destud.2016.09.002

Earley, R. (2017). Circular design futures. *The Design Journal,* 20(4), 421–434. https://doi.org/10.1080/14606925.2017.1328164

Emidi, N. (2023). (Re)Active materials. Well-being's concept evolution and advanced material innovations. In *Proceedings of the 8th International Forum of Design as a Process, Disrupting Geographies in the Design World. DIID (Digital Special Issue 1).* https://doi.org/10.30682/diiddsi23t3g458-466

Hegab, H., Khanna, N., Monib, N., & Salem, A. (2023). Design for sustainable additive manufacturing: A review. *Sustainable Materials and Technologies,* 35, e00576.

Hermann, C., Dewulf, W., Hauschild, M., Kaluza, A., Kara, S., & Skerlos, S. (2018). Life cycle engineering of lightweight structures. *CIRP Annals,* 67(2), 651–672. https://doi.org/10.1016/j.cirp.2018.05.008

Oxman, R. E. (1994). Precedents in design: A computational model for the organization of precedent knowledge. *Design Studies,* 15(2), 141–157.

Oxman, N. (2013). Towards a material ecology. In *Proceedings of the 32nd Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA).* San Francisco: ACADIA, 19–20. https://doi.org/10.1016/0142-694x(94)90021-3

Pereno, A., & Barbero, S. (2020). Systemic design for territorial enhancement: An overview on design tools supporting socio-technical system innovation. *Strategic Design Research Journal,* 13(2), 113–136. https://doi.org/10.4013/sdrj.2020.132.02

Pollini, B., Contardo, T., & Paciotti, D. (2022). Designing bioreceptivity. In *Proceedings of the 34th Conference of the Italian Lichenological Society (SLI),* Pavia.

Romani, A., Rognoli, V., & Levi, M. (2021). Design, materials, and extrusion-based additive manufacturing in circular economy contexts: From waste to new products. *Sustainability,* 13(13), 7269.

Stavropoulos, P. (2023). *Additive manufacturing: Design, processes and applications.* SpringerBriefs in Applied Science and Technology. https://doi.org/10.1007/978-3-031-33793-2

The Royal Society. (2021). *Animate materials report.* https://royalsociety.org/-/media/policy/projects/animate-materials/animate-materials-report.pdf

Zambelli, M. (2022). *La conoscenza per il progetto. Il case-based reasoning nell'architettura e nel design.* Firenze: Firenze University Press. https://doi.org/10.36253/978-88-5518-654-4

Cumulus Association

P/REFERENCES OF DESIGN

This contribution was presented at Cumulus Budapest 2024: P/References of Design conference, hosted by the Moholy-Nagy University of Art and Design Budapest, Hungary between May 15-17, 2024.

Conference Website
cumulusbudapest2024.mome.hu

Conference Tracks
Centres and Peripheries
Converging Bodies of Knowledge
Redefining Data Boundaries
Bridging Design and Economics
Speculative Perspectives
The Power of Immersion
The Future of Well-being
Taming Entropy: Systems Design for Climate and Change
Ways of Living Together
Cumulus PhD Network

Full Conference Proceedings
https://cumulusbudapest2024.mome.hu/proceedings

ISBN Volume 1: 978-952-7549-02-5 (PDF)
ISBN Volume 2: 978-952-7549-03-2 (PDF)

DOI Volume 1: https://doi.org/10.63442/IZUP8898
DOI Volume 2: https://doi.org/10.63442/TADX4016

Conference Organisers
Moholy-Nagy University of Art and Design Budapest (MOME)
mome.hu
Cumulus Association
cumulusassociation.org