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ADVANCING CIRCULAR ECONOMY IN NIGERIA'S BUILT ENVIRONMENT: THE ROLES OF INDUSTRIAL DESIGN WITHIN MULTIDISCIPLINARY TEAMS

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ABSTRACT: *This study explores the transformative potential of Industrial Design innovations, skills, theories, principles and methodologies, in advancing the circular economy within the built environment, with emphasis on Nigeria. A narrative literature review methodology was adopted. Emphasising their roles in driving efficiency, sustainability, and adaptability, Industrial Design principles, innovations, skills, theories, and/or methodologies are examined in relation to their contributions to enhancing flexibility, reducing developmental or construction timelines, and promoting resource efficiency as well as environmental aesthetics and stewardship. The study's outcomes show that Industrial Design plays key roles in the promotion of circular economy through material efficiency and optimisation, disassembly and reuse, resource recovery and recycling, user centric design and community engagement, persuasive designs in the built environment as well as in the conversion of wastes to usable materials, aesthetic components and equipment. As urbanisation advances and environmental degradation worsens in Nigeria, this study underscores the relevance and impact of Industrial Design (as a field of design practice) in fostering innovative solutions for the wellbeing of both the present and future generations. The research advocates for the integration of multidisciplinary design teams and a holistic approach to design, empowering professionals to create sustainable and thriving communities. It, among others, recommends that greater recognition be accorded the roles of Industrial Designers and other environment-related professions in advancing circular economy and sustainability in the built environment.*

KEYWORDS: Built environment, Circular economy, Industrial design, Multidisciplinary design teams, Sustainable design, Sustainability.

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INTRODUCTION

In recent decades, the urgency of addressing environmental degradation and resource depletion has propelled the concept of sustainability to the forefront of global discourse, particularly in the context of the built environment (Idris et al., 2022; Mfon & Bassey, 2023). In response to this global challenge, i.e. the need for environmental sustainability and maintenance of environmental integrity (which demands ecological stewardship), according to the International Institute of Sustainable Development (2011), sustainable design has emerged. Nigeria, as a rapidly urbanising country, faces profound challenges in reconciling its development aspirations with the imperative of ecological stewardship. Within this context, the integration of Industrial Design innovations, skills, theories and principles holds significant promise as a catalyst for advancing both sustainability and circular economy principles within Nigeria's built environment.

The concept of a circular economy, characterised by the reduction, reuse, and recycling of materials and resources, has gained traction as a holistic framework for promoting sustainable development (Schröder et al., 2020). As insinuated in studies such as Iacovidou et al. (2021), Mansuy et al. (2022) and Schröder et al. (2020), embracing the circular economy paradigm presents an opportunity to decouple economic growth from resource consumption, thereby fostering resilience and long term viability in urban development. However, achieving the full potential of circularity necessitates innovative approaches to design, production, construction and consumption, with Industrial Design as well as other environment-related fields playing pivotal roles in driving this transition (Mansuy et al., 2022; Ncube et al., 2023; Sohal & De Vass, 2022).

Despite the growing global recognition of the importance of Industrial Design in shaping sustainable futures (Odji, 2019b; 2019c), studies that are specifically focused on its application within the Nigerian built environment remain limited. Of course, studies such as Onososen (2019) and Odji (2019) have looked into design for sustainability in the environment in Nigeria, but there still exists a significant gap as to exactly how Industrial Design innovations, skills, methods and theories are applicable in the built environment, especially in the Nigerian context. As at the time of this study, within the Nigerian built environment, the role of Industrial Designers was still significantly ignored or downplayed. Therefore, this study sought to contribute to addressing this gap, by reiterating targeted practicable ways in which Industrial Design innovations, skills, theories and principles may be applied for the advancement of circular economy in Nigeria's built environment. References were made to specific design cases.

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METHOD

The study adopted a narrative literature review methodology, with sources selected based on relevance to exploring the impact of Industrial Design innovations in the promotion of circular economy in Nigeria's built environment. While acknowledging the limited literature specific to the context, this approach allowed for a flexible exploration of theories, methodologies, and principles related to sustainability and efficiency in urban development. Sources were selected based on the inclusion/exclusion criteria outlined in Table 1.

Table 1: Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Literature addressing design innovations, methods, or theories, sustainability and circular economy principles or practices.	Literature not related to design, sustainability or circular economy principles or practices in the built environment.
Literature focusing on the application of Industrial Design in the context of the built environment and sustainability	Literature not specific to the application of Industrial Design in the built environment.
Publications less than 20 years old.	Publications older than 20 years, or irrelevant publications.
Relevant case studies that may be replicated.	Irrelevant or irreplaceable case studies.

Due to an existing dearth in relevant literature specific to the context of the study, grey sources such as blog posts, news articles, and opinion pieces were also utilised to gather diverse perspectives from practitioners, policymakers, and stakeholders on Industrial Design innovations/theories, multidisciplinary design and environment management teams and circular economy in Nigeria's built environment. These sources offer real-world experiences, case studies, and practical applications, enhancing the relevance and applicability of the study's outcomes. The synthesis of data gathered from the sourced literature was aimed at identifying trends and insights regarding Industrial Design's contributions (within multidisciplinary design teams) to efficiency, material reusability, sustainability, and adaptability in the built environment.

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THE CONCEPTS OF SUSTAINABLE DESIGN, INDUSTRIAL DESIGN INNOVATIONS AND THE ROLE OF THE INDUSTRIAL DESIGNER IN A MULTIDISCIPLINARY DESIGN TEAM

This study, of course, recognises the multidisciplinary nature of Sustainable Design (Stock & Burton, 2011). Hence, from a multidisciplinary perspective, the concept of sustainable design encompasses the integration of environmental, social, and economic considerations into the design process to create products, systems, and environments that meet present needs without compromising the ability of future generations to meet their own needs (International Institute of Sustainable Development, 2011). Sustainable design emphasises holistic thinking and collaborative approaches that transcend disciplinary boundaries (Maher et al., 2018; Pathak & Swarnakar, 2023; Weaich et al., 2024). This requires engagement with diverse professionals and/or stakeholders within the built environment, including engineers, architects, urban planners, sociologists, economists, and policymakers, to address complex challenges such as climate change, resource depletion, as well as social equity. By embracing sustainability principles, multidisciplinary design teams in Nigeria will be able to develop innovative solutions that prioritise environmental responsibility, social inclusivity, and economic viability (Baldassarre et al., 2024; Bello et al., 2024; Hariram et al., 2023).

Industrial Design, if and where accorded its rightful regards as a key component of multidisciplinary design teams, will play critical roles in achieving sustainable design objectives. Industrial Designers bring a unique skill set that combines aesthetic sensitivity, technical expertise, and user centred design principles to the table (Plumb, 2023; Sutcliffe, 2009; Veryzer & Borja de Mozota, 2005). They are responsible for translating abstract concepts into tangible products, structural components and systems that not only perform optimally but also minimise environmental impact, enhance user experience, as well as promote social well-being. Working collaboratively with professionals from diverse disciplines, Industrial Designers contribute to the development of environmentally friendly materials, energy efficient technologies, and sustainable manufacturing processes. Examples include (reusable/recyclable) bricks, thermal insulators and insulating materials for buildings, electrical components, fibreglass reinforced polyester plastic, interiors/exterior aesthetic components as well as the embedment of aesthetics (designing functional aesthetics) into the environment, and so on (Adeniyi et al., 2019; Odewale et al., 2015; Odewole et al., 2022; Odji, 2019c, 2019b; Ogbonna et al., 2022). Also, by adopting a systems thinking approach, Industrial Designers identify opportunities for innovation across the entire product lifecycle, from conception and production to use and disposal, thereby driving sustainability outcomes within multidisciplinary design teams (Alahira et al., 2024; Kuys et al., 2022).

According to Alahira et al. (2024), in a multidisciplinary design team, the Industrial Designer serves as a bridge between different disciplines, facilitating communication, collaboration, and creative problem solving, with the various fields bringing to bear their different skills for the achievement of common design objectives. For instance, the Industrial Designer brings a human-centred perspective to the team, advocating for the needs and preferences of end users while balancing technical constraints and environmental considerations. By fostering interdisciplinary dialogue, Industrial Designers encourage knowledge exchange and cross pollination of ideas, leading to more holistic and effective design solutions. Most significantly, Industrial Designers help in promoting design thinking as a mindset that values empathy, experimentation, and iteration, empowering multidisciplinary teams to address complex sustainability challenges with innovation and agility (Ario et al., 2020; Goldman & Zielezinski,

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2016; Hector, 2022; Kateb & Allahdadi, 2018). Through such collaborative efforts as aforementioned, Industrial Designers contribute to the creation of a built environment that is not only aesthetically pleasing and functional but also resilient, inclusive, and environmentally sustainable.

PRACTICAL APPLICATIONS OF INDUSTRIAL DESIGN INNOVATIONS AND SKILLS IN THE BUILT ENVIRONMENT FOR THE ADVANCEMENT OF CIRCULAR ECONOMY: SPECIFIC CASE REFERENCES THAT NIGERIAN PROFESSIONALS MAY EMULATE

Industrial Design innovations, skills and methods significantly influence the built environment, as well as how humans interact with and experience the environment, while addressing sustainability, functionality, and aesthetics challenges (Alahira et al., 2024; Heylighen et al., 2017; Odji, 2019c; Poon, 2021). These innovations span various aspects of the built environment, including aesthetics, architecture, planning of urban areas, infrastructure, as well as interior/exterior designs and components and so on. Some key design innovations in the built environment that Nigerian professionals may adopt for sustainability are reviewed herein, with selected case studies for emphasis highlighted. In all cases highlighted, design thinking is paramount, which makes the Industrial Designer an essential part of the design team in the built environment – both interior and exterior.

Material Efficiency and Optimisation

If well exploited, design innovations can significantly optimise material usage and minimise waste generation in built environment projects (Soares et al., 2017). Designers, in collaboration with other professionals, use innovative materials, planning, and construction techniques to minimise the overall material footprint of infrastructures and buildings while maintaining structural integrity and performance. This may be achieved through the adoption of principles such as the modular design, prefabrication, and lightweight construction techniques (Dave, 2019; Santos et al., 2024). By integrating sustainable materials and advanced manufacturing processes, they create durable, resource-efficient structures that contribute to the circular economy agenda. For example, designing building components with lightweight, high strength materials like engineered wood facilitates the reduction of the overall material footprint (Ding et al., 2023).

Similarly, the adoption of modular construction methods allows for more precise material allocation, minimising waste generation (Banihashemi et al., 2018). Modular design principles in the built environment help provide flexibility, efficiency, and sustainability. Examples include the Futuro house, designed by Finnish designer Matti Suuronen in the 1960s, which features a UFO-shaped, prefabricated structure–Figure 1 (Frearson, 2023; Sanaksenaho, 2021; Voigt, 2022), and the Container City project in London, UK (Figure 2), which repurposed shipping containers to create affordable, sustainable housing and office spaces (Container City, 2024). These projects demonstrate the scalability of modular design solutions and demonstrate how Industrial Designers, in collaboration with other professionals, can leverage existing materials and infrastructure to address urban challenges while prioritising efficiency and environmental sustainability in the built environment. By incorporating sustainable materials and advanced manufacturing processes, designers can create durable, resource-efficient structures that contribute to the circular economy agenda.

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Figure 1: The Futuro" house, designed by Finnish architect Matti Suuronen (Frearson, 2023).

Figure 2: The 'Container City' project (left) and the interior part of a studio within it (right) (Container City, 2024).

Design for Disassembly and Reuse within the Built Environment

Industrial Designers can facilitate circularity in the built environment by incorporating principles of design for disassembly and reuse into product/component and architectural design processes. By prioritising component based assembly methods, standardised interfaces, and reversible connections, designers enable easier dismantling and recovery of materials at the end of a building's life cycle, which may then be repurposed (Browne & Larsen, 2023; Gorgolewski, 2017; Kim & Moon, 2019). Browne & Larsen (2023) for instance strongly emphasised the need to design reversibility into structures/building components, putting into consideration the inherent properties of materials adopted. This approach promotes the reuse and repurposing of design or building components, reducing the demand for virgin as well as minimising the environmental impact associated with i.e. demolition and disposal (Ghisellini et al., 2018). An excellent example is the 'Urban Mining and Recycling' project in Amsterdam (Figure 3) which focuses on salvaging materials from demolished buildings, ensuring they can be repurposed in new construction projects (Koutamanis et al., 2018; Yang et al., 2022). This innovation fosters circular economy and minimises the use of primary materials and components in the built environment (Yang et al., 2022), yielding what Heisel et al. (2019) coined as 'resource respectful construction/design.'

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Figure 3: A resource respectful construction/design – constructed with the use of recycled materials/components (Heisel et al., 2018).

Resource Recovery and Recycling

Industrial Design innovations may also facilitate the implementation of efficient resource recovery and recycling systems within the built environment (Alahira et al., 2024; Filipeboni, 2023). This may be achieved through the integration of systems for efficient material recovery and recycling. For example, bricks, sculptural pieces, thermal insulators, wall claddings and so on may be reprocessed, reused/recycled (Adeniyi et al., 2019; Alahira et al., 2024; Odewale et al., 2015; Odewole et al., 2022; Ogbonna et al., 2022). Through the integration of onsite waste segregation facilities, material recovery centres, and innovative recycling technologies, designers can maximise the recovery of valuable resources from i.e. construction and demolition waste streams. For instance, Bansal & Singh (2014) affirmed that once the cement/mortar is removed, demolished bricks can be used again for renovations or for building new structures, products or components. The ceramist, glass technologist alongside other 3D and graphic designers have roles to play here e.g. in the ideation and fabrication of such new structures, products or components, in collaboration with other members of the design team. Hence, by closing the loop on materials such as bricks, concrete, steel, and glass, Industrial Design contributes to the circular economy by reducing reliance on finite resources and mitigating environmental pollution associated with landfilling and incineration. An example is the use of onsite material sorting facilities in construction projects. For instance, the "Deconstruction and Materials Reuse Center" in Portland, Oregon, sorts and processes construction waste for recycling and reuse (Hangen, 2019).

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User Centric Design in the Built Environment and Community Engagement

Industrial Designers engage communities and stakeholders in the design process to ensure that projects meet the diverse needs and preferences of the end users (Lipp et al., 2023; Xiao & Jiang, 2023). By adopting a user centric design approach, designers can assist the design team in creating components, aesthetics, and structures and/or infrastructure that are adaptable, inclusive, and responsive to changing societal needs. Empowering communities to participate in design decisions fosters a sense of ownership and stewardship, leading to increased longevity and utilisation of built assets, thus contributing to the circular economy agenda (Ciampa et al., 2024; Marchesi & Tweed, 2021). An example is the "Community led Housing" movement, where residents actively participate in the design and construction of housing projects, resulting in spaces that are more adaptable and sustainable for the community (Jarvis, 2014). In this respect, Industrial designers are germane in the creation of user-centric built environments that prioritise inclusivity, accessibility and human well-being. They contribute to the design of accessible public housing, transportation, and interactive urban spaces. They aided in the creation of features like low-floor boarding, tactile signage, and audible announcements for the enhancement of inclusivity and usability. Industrial designers as well participate in the design of smart city infrastructure systems, such as streetlights, waste management, and public Wi-Fi networks, with user-centric features like attractive user-interfaces, real-time data collection sensors and intuitive interfaces. In healthcare facilities, they collaborate with healthcare professionals to create patient-centric environments with ergonomic furniture, calming colour schemes, and intuitive wayfinding systems. Essentially, designers consider user needs and preferences throughout the design process, resulting in functional, sustainable, and enjoyable spaces for everyone.

The Concept of Persuasive Designs in the Built Environment

An Industrial Designer, with focus on sustainability, product design, communication design (and the application in e.g. health i.e. in the management of communicable diseases, manufacturing, etc.) and the environment, introduced the concept of persuasive designs in the Nigerian research sphere, describing such designs as influencing human behaviours in targeted ways depending on the intentions of the designer (Odji, 2019a; 2020a; 2020b). In further studies, focused on the application of design principles for the achievement of sustainability in the environment, Ebenezer Odji, in his proposed "*Environmental Aesthetics and Sustainability Theory*" affirmed that:

"*The more aesthetic the environment is, the less destructive interference it is likely to suffer. Hence, the greater will be its chances at sustainability and vice versa*" (Odji, 2019c, p. 23).

This means that, not only does the environment tell the user how to use, and treat it or interact with it but also that, designers can influence the way humans use or interact with the environment by designing into the environment how they want the environment to inspire the user to interact with it, use it and treat it. This brings to bear the concept of persuasive designs in the built environment as propagated by Ebenezer Odji. An obvious example, as proposed by this researcher, is a perimeter fence or barricade intended to dissuade intruders from crossing or walking through a lawn or a restricted area. Another way is to deliberately make an environment beautiful so as to alleviate negative interaction with it from users (Ciampa et al., 2024; Odji, 2019c; 2019b). This makes the Industrial Designer an integral part of the design

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team in the built environment, and the significance of the roles of these professionals should not be downplayed.

Conversion of Wastes to Usable Materials, Aesthetic Components and Equipment

Industrial Designers and professionals in other allied fields of practice also contribute to sustainability and circular economy through the repurposing or reuse of wastes from other sectors into the built environment. For instance, they play vital roles in promoting sustainability in the built environment by upcycling industrial, construction, and other wastes e.g. agricultural wastes into building materials, collaborating with manufacturers and fabricators to repurpose materials like slag from steel production and/or fly ash from coal-fired power plants into eco-friendly bricks, concrete blocks, or aggregates (Lim et al., 2020). Designers have also facilitated the repurposing of Agro-wastes such as coconut shells for e.g. flooring in the built environment (Nazir et al., 2024; Sankar et al., 2023). They also design furniture and fixtures (for both interior and exterior designs) using recycled materials from various industries, promoting circular economy principles and sustainability (D'Itria et al., 2024; Grotowska & Beer, 2023). Designers also collaborate with artists and architects to create art installations from industrial waste materials, raising environmental awareness and enhancing aesthetic appeal (Ahmed & Aly, 2023). This is in alignment with the concept of "waste to wealth" emphasised by Patil (2023). In addition, they often develop innovative packaging solutions using recycled or biodegradable materials to minimise waste as well as reduce carbon emissions (Ncube et al., 2023; Versino et al., 2023).

CONCLUSION AND RECOMMENDATIONS

This study explored Industrial Design innovations, skills, theories, design methodologies and principles applicable in the advancement of the circular economy in Nigeria's built environment, highlighting their role in driving efficiency, sustainability, and adaptability. From enhancing flexibility and reducing developmental timelines to promoting resource efficiency and environmental stewardship, Industrial Design and Designers are germane for achieving a more resilient and inclusive built environment. Hence, the following recommendations are proposed for the promotion of circular economy in the built environment through Industrial Design (within multidisciplinary design teams) in Nigeria and in other places applicable:

1) Policy Integration

a) Incorporation of Industrial Design into urban development policies to promote sustainability and circular economy principles, due to the significance of the skills, methodologies, theories and principles of this field of design practice to sustainability and circular economy.

b) Creation of incentives for Industrial Design innovations and collaboration among multidisciplinary design teams.

2) Capacity Building

a) Enhancement of the capacity of Industrial Designers and other professionals in sustainable design principles.

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b) Implementation of capacity building training programs, workshops, and knowledge-sharing platforms.

3) Regulatory Frameworks

a) Establishment of frameworks for the promotion of sustainable design practices.

b) Establishment of regulatory or monitoring bodies, where such does not already exist.

4) Public Awareness and Engagement

a) Engagement of communities in design processes to foster ownership and support for sustainable development initiatives.

5) Research and Innovation

a) Continued research and innovation in Industrial Design in relations to the environment to identify and develop sustainable urban development solutions.

As urbanisation advances in Nigeria, and environmental degradation increases, the insights garnered from this study serve as a testament to the enduring relevance and impact of Industrial Design in fostering innovative solutions that will prioritise the wellbeing of both present and future generations.

REFERENCES

Adeniyi, A. G., Ighalo, J. O., & Onifade, D. V. (2019). Banana and plantain fibre-reinforced polymer composites. *Journal of Polymer Engineering*, *39*(7), 597–611. https://doi.org/10.1515/polyeng-2019-0085

Ahmed, H. T., & Aly, A. M. (2023). Recycled Waste Materials in Landscape Design for Sustainable Development (Al-Ahsa as a Model). *Sustainability*, *15*(15), Article 15. https://doi.org/10.3390/su151511705

Alahira, J., Olu-lawal, K., Ejibe, I., & Ninduwezuor-Ehiobu, N. (2024). Sustainable Materials and Methods in Industrial Design: Bridging The Gap With Fine Arts and Graphic Design For Environmental Innovation. *Engineering Science & Technology Journal*, *5*(3), 774–782. https://doi.org/10.51594/estj.v5i3.901

Ario, B. C., Odji, E., & Odewole, O. P. (2020). An overview of the state of industrial design education in Nigeria: The limitations and prospects. *Australian Journal of Science and Technology*, *4*(3), 339–347.

Baldassarre, B., Calabretta, G., Karpen, I. O., Bocken, N., & Hultink, E. J. (2024). Responsible Design Thinking for Sustainable Development: Critical Literature Review, New Conceptual Framework, and Research Agenda. *Journal of Business Ethics*, *1*(1). https://doi.org/10.1007/s10551-023-05600-z

Banihashemi, S., Tabadkani, A., & Hosseini, M. R. (2018). Integration of parametric design into modular coordination: A construction waste reduction workflow. *Automation in Construction*, *88*(1), 1–12. https://doi.org/10.1016/j.autcon.2017.12.026

Bansal, S., & Singh, S. (2014, February 10). Construction & Demolition (C&D) Waste Recycling in New Delhi. *International Fib Congress*. The Fourth International Fib Congress 2014, Mumbai. https://doi.org/10.13140/RG.2.1.1022.9922

Article DOI: 10.52589/AJENSR-GI4VVC6B
DOI URL: https://doi.org/10.52589/AJENSR-GI4VVC6B

Bello, A. O., Okanlawon, T. T., Wuni, I. Y., Arogundade, S., & Oyewobi, L. O. (2024). Exploring the nexus between the barriers and drivers for sustainable smart cities in developing countries: The case of Nigeria. *Sustainable Development*, *n/a*(n/a). https://doi.org/10.1002/sd.2861

Browne, X., & Larsen, O. P. (2023). Reversible timber only connections – an investigation into the potential of threaded dowels and swelling for reconfigurable truss components. *Proceedings of IASS Annual Symposia*, *2023*(2), 1–13.

Ciampa, F., Fabbricatti, K., Freda, G., & Pinto, M. R. (2024). A Playground and Arts for a Community in Transition: A Circular Model for Built Heritage Regeneration in the Sanità District (Naples, Italy). *Sustainability*, *16*(7), Article 7. https://doi.org/10.3390/su16072640

Container-City. (2024). Container City. In Wikipedia. https://en.wikipedia.org/w/index.php?title=Container_City&oldid=1213072286

Dave, M. (2019). *High performance prefab housing: Towards an evaluation framework for design, sustainability and affordability* [Thesis, UNSW Sydney]. https://doi.org/10.26190/unsworks/3913

Ding, Y., Pang, Z., Lan, K., Yao, Y., Panzarasa, G., Xu, L., Lo Ricco, M., Rammer, D. R., Zhu, J. Y., Hu, M., Pan, X., Li, T., Burgert, I., & Hu, L. (2023). Emerging Engineered Wood for Building Applications. *Chemical Reviews*, *123*(5), 1843–1888. https://doi.org/10.1021/acs.chemrev.2c00450

D'Itria, E., Pei, X., & Bertola, P. (2024). Designing Sustainability Today: An Analytical Framework for a Design for Sustainability Model in European Fashion and Furniture Industries. *Sustainability*, *16*(8), Article 8. https://doi.org/10.3390/su16083240

Filipeboni. (2023, April 3). Understanding Zero Waste Design: A Guide For Building Professionals. *UGREEN*. https://ugreen.io/understanding-zero-waste-design-a-guide-for-building-professionals/

Frearson, A. (2023, February 21). *The surprising history of the flying saucer-shaped Futuro house*. ELLE Decoration. https://www.elledecoration.co.uk/lifestyle-culture/a42983770/futuro-house/

Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, *178*(1), 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207

Goldman, S., & Zielezinski, M. B. (2016). Teaching with Design Thinking: Developing New Vision and Approaches to Twenty-First Century Learning. In L. A. Annetta & J. Minogue (Eds.), *Connecting Science and Engineering Education Practices in Meaningful Ways: Building Bridges* (pp. 237–262). Springer International Publishing. https://doi.org/10.1007/978-3-319-16399-4_10

Gorgolewski, M. (2017). *Resource Salvation: The Architecture of Reuse*. John Wiley & Sons. https://books.google.com.ng/books?hl=en&lr=&id=GFw6DwAAQBAJ&oi=fnd&pg=PP13&dq=component-based+assembly+methods,+standardised+interfaces,+and+reversible+connections,+designers+enable+easier+dismantling+and+recovery+of+materials+at+the+end+of+a+building%27s+lifecycle&ots=PXraWQBIwz&sig=vXAkMn-2BZMgDxegvRG07HmiXAM&redir_esc=y#v=onepage&q&f=false

Grotowska, M., & Beer, P. (2023). Smart design upcycling of post-production display panels into new creative materials to support the sustainable development of a circular economy

Article DOI: 10.52589/AJENSR-GI4VVC6B
DOI URL: https://doi.org/10.52589/AJENSR-GI4VVC6B

in the furniture industry. *Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology*, *122*(1), 36–46. https://doi.org/10.5604/01.3001.0053.8667

Hangen, E. (2019). *United Villages: A Case Study on Building Material Reuse in Portland Oregon*. I Squared Community Development Consulting, Inc. With the United Villages and the Portland ReBuilding Center, NeighborWorks® America. https://core.ac.uk/reader/71341270

Hariram, N. P., Mekha, K. B., Suganthan, V., & Sudhakar, K. (2023). Sustainism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability. *Sustainability*, *15*(13), Article 13. https://doi.org/10.3390/su151310682

Hector, P. G. C. (2022). Using Design Thinking to Accelerate Progress Toward the 2030 Sustainable Development Goals in the Middle East and North Africa Region. In S. Sindakis & S. Aggarwal (Eds.), *Entrepreneurial Rise in the Middle East and North Africa: The Influence of Quadruple Helix on Technological Innovation* (pp. 125–148). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80071-517-220221007

Heisel, F., Hebel, D. E., & Sobek, W. (2019). Resource-respectful construction – the case of the Urban Mining and Recycling unit (UMAR). *IOP Conference Series: Earth and Environmental Science*, *225*(1), 012049. https://doi.org/10.1088/1755-1315/225/1/012049

Heylighen, A., Van der Linden, V., & Van Steenwinkel, I. (2017). Ten questions concerning inclusive design of the built environment. *Building and Environment*, *114*(1), 507–517. https://doi.org/10.1016/j.buildenv.2016.12.008

Iacovidou, E., Hahladakis, J. N., & Purnell, P. (2021). A systems thinking approach to understanding the challenges of achieving the circular economy. *Environmental Science and Pollution Research*, *28*(19), 24785–24806. https://doi.org/10.1007/s11356-020-11725-9

Idris, O. A., Opute, P., Orimoloye, I. R., & Maboeta, M. S. (2022). Climate Change in Africa and Vegetation Response: A Bibliometric and Spatially Based Information Assessment. *Sustainability*, *14*(9), Article 9. https://doi.org/10.3390/su14094974

International Institute of Sustainable Development. (2011, July 6). *Guest Article: The Contribution of Design to Sustainable Development | SDG Knowledge Hub | IISD*. International Institute of Sustainable Development. https://sdg.iisd.org/commentary/guest-articles/the-contribution-of-design-to-sustainable-development/

Jarvis, H. (2014). Community-led Housing and 'Slow' Opposition to Corporate Development: Citizen Participation as Common Ground? *Geography Compass*, *9*(4), 1–24. https://doi.org/10.1111/gec3.12206

Kateb, F., & Allahdadi, M. (2018, October 18). Design thinking: Its power in designing better. *International Conference On Marketing and Design: Intersection and Challenges*. International Conference On Marketing and Design, Faro- Portugal. https://www.researchgate.net/publication/347935813_Design_thinking_its_power_in_designing_better

Kim, S., & Moon, S. K. (2019). Eco-modular product architecture identification and assessment for product recovery. *Journal of Intelligent Manufacturing*, *30*(1), 383–403. https://doi.org/10.1007/s10845-016-1253-7

Koutamanis, A., van Reijn, B., & van Bueren, E. (2018). Urban mining and buildings: A review of possibilities and limitations. *Resources, Conservation and Recycling*, *138*(1), 32–39. https://doi.org/10.1016/j.resconrec.2018.06.024

Article DOI: 10.52589/AJENSR-GI4VVC6B
DOI URL: https://doi.org/10.52589/AJENSR-GI4VVC6B

Kuys, B., Koch, C., & Renda, G. (2022). The Priority Given to Sustainability by Industrial Designers within an Industry 4.0 Paradigm. *Sustainability*, *14*(1), Article 1. https://doi.org/10.3390/su14010076

Lim, A., Cao, Y., Dias-da-Costa, D., Ebrahimi, A., & Abbas, A. (2020). Recycled Materials in Roads and Pavements: A Technical Review. *Local Government NSW*, 1–105. https://www.researchgate.net/profile/Yifang-Cao/publication/369693450_Recycled_Materials_in_Roads_and_Pavements_A_Technical_Review/links/6428435092cfd54f84470f77/Recycled-Materials-in-Roads-and-Pavements-A-Technical-Review.pdf

Lipp, B., Baudrin, M., Cuevas-Garcia, C., Pepponi, F., Rozwadowska, M., & Tsui, S. (2023). Co-creating end-user roles. Understanding the new variety of user involvement in public sector innovation. *Science and Public Policy*, *50*(1), 146–159. https://doi.org/10.1093/scipol/scac050

Maher, R., Maher, M., Mann, S., & McAlpine, C. A. (2018). Integrating design thinking with sustainability science: A Research through Design approach. *Sustainability Science*, *13*(6), 1565–1587. https://doi.org/10.1007/s11625-018-0618-6

Mansuy, J., Pel, B., Messagie, M., Lebeau, P., Achten, W., Khan, A. Z., & Macharis, C. (2022). *Transitioning to a circular economy: Changing business models and business ecosystems*. ASP Academic & Scientific Publ. https://library.oapen.org/bitstream/handle/20.500.12657/59775/1/10.46944.9789461173942.pdf#page=17

Marchesi, M., & Tweed, C. (2021). Social innovation for a circular economy in social housing. *Sustainable Cities and Society*, *71*(1), 102925. https://doi.org/10.1016/j.scs.2021.102925

Mfon, I., & Bassey, L. (2023). Sustainable Materials and Construction Practices in Industrial Buildings. *International Journal of Developmental Studies and Environmental Monitoring*, *2*(1), 41–52. https://doi.org/10.6084/m9.figshare.24514870

Nazir, A., Maina, S. M., & Osanjo, L. (2024). Coconut Shell Flooring for Affordable Housing in Kenya. *Africa Design Review Journal*, *1*(5), Article 5.

Ncube, A., Mtetwa, S., Bukhari, M., Fiorentino, G., & Passaro, R. (2023). Circular Economy and Green Chemistry: The Need for Radical Innovative Approaches in the Design for New Products. *Energies*, *16*(4), Article 4. https://doi.org/10.3390/en16041752

Odewale, I., Michael, O., & Terna, T. (2015). Production and Characterization of Aluminosilicate Refractory Brick Using Unwana Beach Silica Sand, Ekebedi and Unwana Clays. *British Journal of Applied Science & Technology*, *5*(5), 461–471. https://doi.org/10.9734/BJAST/2015/12532

Odewole, O. P., Kashim, I. B., & Akinbogun, T. L. (2022). Investigation into the viability of the properties of porous glass-ceramics produced from granite dust and maize cob for use in thermal insulation of external walls of residential buildings. *Journal of Mechanical Engineering and Sciences*, *16*(2), 8943–8952.

Odji, E. (2019a). Abuse by Design: The Implications and Prospects of Adopting Child-Character Centred Persuasive Designs and Systems. *International Journal of Health and Pharmaceutical Research*, *5*(2), 31–48.

Odji, E. (2019b). Aesthetics Application in Solid Waste Management as a Means of Optimising Environmental Sustainability in Urbanizing Third-World Environments. *International Journal of Engineering and Manufacturing*, *9*(4), 15–32. https://doi.org/10.5815/ijem.2019.04.02

Article DOI: 10.52589/AJENSR-GI4VVC6B
DOI URL: https://doi.org/10.52589/AJENSR-GI4VVC6B

Odji, E. (2019c). Graphic Design Principles and Theories Application in Rendering Aesthetic and Functional Installations for Improved Environmental Sustainability and Development. *International Journal of Engineering and Manufacturing*, *9*(1), 21.

Odji, E. (2020a). Influencing Children: Limitations of the Computer-Human-Interactive Persuasive Systems in Developing Societies. *International Journal of Modern Education and Computer Science*, *12*(5), 1.

Odji, E. (2020b). Limiting the Community Transmission of Communicable Disease Outbreaks through Local-Evidence-Based Awareness Creation. *International Journal of Advanced Academic Research*, *6*(6), 12–31. https://doi.org/10.46654/ij.24889849.e6618

Ogbonna, V. E., Popoola, A. P. I., Popoola, O. M., & Adeosun, S. O. (2022). A review on corrosion, mechanical, and electrical properties of glass fibre-reinforced epoxy composites for high-voltage insulator core rod applications: Challenges and recommendations. *Polymer Bulletin*, *79*(9), 6857–6884. https://doi.org/10.1007/s00289-021-03846-z

Onososen, A. (2019). Unilorin Environmental Sciences Conference 2019 ICES | Request PDF. *Collaboration for Sustainable Development in the Built Environment*. International Conference of Environmental Sciences, ICES 2019, Ilorin, Kwara State, Nigeria. https://www.researchgate.net/publication/335928048_unilorin_environmental_sciences_conference_2019_ices

Pathak, S., & Swarnakar, S. (2023). *Beyond Subject Boundaries: Creating Holistic Learning Experiences* (pp. 16–20).

Patil, D. (2023). 'Waste to Wealth, Art of Reuse'- Learnings from Innovations in Urban Public Space Designs. *Journal of Advanced Research in Construction and Urban Architecture*, *8*(1), 13–22. https://doi.org/10.24321/2456.9925.202302

Plumb, J. (2023, June 14). Key Principles of Effective Industrial Design: Creating User-Centric Products. *Cambridge Design Technology*. https://www.cambridge-dt.com/principles-of-industrial-design-creating-user-centric-products/

Poon, S. (2021). Deconstructing Sustainability Perceptions: Investigating Technological Innovation-Environmental Interaction in Green Buildings and the Influence of Architectural Design. *International Journal of Built Environment and Sustainability*, *8*(1), 91–101. https://doi.org/10.11113/ijbes.v8.n1.621

Sanaksenaho, P. (2021). 1950s and 1960s Modern Home: Magazines as research material. *Architectural Research in Finland*, *4*(1), 10–19. https://doi.org/10.37457/arf.110605

Sankar, A., Srinivasarao, S. V., Sivasankaran, S., Basha, A. F. K., & Ismail, Z. (2023). Survey on applications of coconut timber, shell and coir in construction industry. *AIP Conference Proceedings*, *2643*(1), 030031. https://doi.org/10.1063/5.0110298

Santos, P., Cervantes, G. C., Zaragoza-Benzal, A., Byrne, A., Karaca, F., Ferrández, D., Salles, A., & Bragança, L. (2024). Circular Material Usage Strategies and Principles in Buildings: A Review. *Buildings*, *14*(1), Article 1. https://doi.org/10.3390/buildings14010281

Schröder, P., Lemille, A., & Desmond, P. (2020). Making the circular economy work for human development. *Resources, Conservation and Recycling*, *156*(1), 104686. https://doi.org/10.1016/j.resconrec.2020.104686

Soares, N., Bastos, J., Pereira, L. D., Soares, A., Amaral, A. R., Asadi, E., Rodrigues, E., Lamas, F. B., Monteiro, H., Lopes, M. A. R., & Gaspar, A. R. (2017). A review on current advances in the energy and environmental performance of buildings towards a more sustainable built environment. *Renewable and Sustainable Energy Reviews*, *77*(1), 845–860. https://doi.org/10.1016/j.rser.2017.04.027

Article DOI: 10.52589/AJENSR-GI4VVC6B
DOI URL: https://doi.org/10.52589/AJENSR-GI4VVC6B

Sohal, A., & De Vass, T. (2022). Australian SMEs experience transitioning to a circular economy. *Journal of Business Research*, *142*(1), 594–604. https://doi.org/10.1016/j.jbusres.2021.12.070

Stock, P., & Burton, R. J. F. (2011). Defining Terms for Integrated (Multi-Inter-Trans-Disciplinary) Sustainability Research. *Sustainability*, *3*(8), Article 8. https://doi.org/10.3390/su3081090

Sutcliffe, A. (2009). Designing for User Engagement: Aesthetic and Attractive User Interfaces. In *Synthesis Lectures on Human-Centred Informatics* (1st ed., Vol. 2). https://doi.org/10.2200/S00210ED1V01Y200910HCI005

Versino, F., Ortega, F., Monroy, Y., Rivero, S., López, O. V., & García, M. A. (2023). Sustainable and Bio-Based Food Packaging: A Review on Past and Current Design Innovations. *Foods*, *12*(5), Article 5. https://doi.org/10.3390/foods12051057

Veryzer, R. W., & Borja de Mozota, B. (2005). The Impact of User-Oriented Design on New Product Development: An Examination of Fundamental Relationships*. *Journal of Product Innovation Management*, *22*(2), 128–143. https://doi.org/10.1111/j.0737-6782.2005.00110.x

Voigt, P. (2022). The Futuro: History, Design and Construction in Finland and the USA. *Docomomo Journal*, *1*(1), 40–49. https://doi.org/10.52200/docomomo.66.05

Weaich, M., Simbanegavi, P., Ndlovu, P., Root, D., Bedi, T. K., Parafiniuk, A., Latos, B., & Adewunmi, Y. (2024). *Achieving Sustainable Transdisciplinary Research in Construction Project Management: A Bibliometric Approach*. https://doi.org/10.31224/3550

Xiao, Y., & Jiang, C. (2023). Industrial designers' thinking in the stage of concept generation for social design: Themes, strategies and modes. *International Journal of Technology and Design Education*, *33*(1), 281–311. https://doi.org/10.1007/s10798-022-09732-7

Yang, X., Hu, M., Zhang, C., & Steubing, B. (2022). Urban mining potential to reduce primary material use and carbon emissions in the Dutch residential building sector. *Resources, Conservation and Recycling*, *180*(1), 106215. https://doi.org/10.1016/j.resconrec.2022.106215

Article DOI: 10.52589/AJENSR-GI4VVC6B
DOI URL: https://doi.org/10.52589/AJENSR-GI4VVC6B