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UPCYCLING OF SOLID WASTE IN THE KUMASI METROPOLIS FOR FURNITURE PRODUCTION: AN ENVIRONMENTALLY SUSTAINABLE SOLUTION FOR WASTE DISPOSAL

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Purpose. This study aimed to demonstrate, using studio research approaches, how solid waste in Kumasi Metropolis, Ghana, can be innovatively recycled into aesthetically pleasing and functional furniture pieces as a waste management strategy to achieve environmental sustainability.
Results. Environmental sustainability and the economic profitability of solid waste generated during furniture production go hand in hand. By using recycled or reclaimed materials, implementing sustainable production practices and responding to the demand for environmentally friendly products, furniture manufacturers can contribute to a more sustainable future while receiving financial benefits. The study showed that upcycling is an excellent waste management strategy that creative persons and other innovators could use to help in the management of solid waste that have become an environmental nuisance. Also, the study revealed that creative persons could potentially train others in their locality to be more creative-centered so as to innovatively transform solid waste materials into more aesthetically relevant and functional items for environmental sustainability.
Scientific novelty. The discarded solid wastes were repurposed to create new, functional and aesthetically pleasing furniture. The process of upcycling not only reduces solid waste but also minimizes the need for raw materials and energy consumption in furniture production. This is a new and an innovative concept in the field of furniture in Ghana.
Practical value. Upcycling of solid waste for furniture production in the Kumasi Metropolis offers

usable relevance by reducing waste, conserving physical resources, and creating economic opportunities which is mutually beneficial for both the environment and the community. Applying sustainable practices in furniture production can improve the brand image and attract public or consumer attention to environmentally conscious people.

Key words: environmental sustainability, furniture production, Ghana, solid waste, upcycling, waste disposal.

Introduction. Furniture production is a constantly developing and renewing industry. New materials and techniques are constantly being developed that make it possible to create furniture that is more durable, more comfortable and more aesthetic than ever before (Yao and Carlson, 2003). According to Bianco et al. (2021), furniture making is an important and exciting industry that allows us to create items that are both functional and beautiful. The furniture industry has a significant environmental impact, from material sourcing to the manufacturing process and the end of the product's life cycle (Muhammed et al., 2022). Cordella Setillo et al. (2016) opine that one way to promote environmental sustainability in furniture production is the use of sustainable materials. This includes the use of wood from sustainably managed forests and the use of recycled materials such as plastics and metals. Upcycling focuses on sustainable practice that involves transforming waste materials into new and useful products such as furniture. Yuan et al. (2022) affirm that upcycling is the process of converting waste into useful products. In the context of furniture production, solid waste such as; wood, metal and plastic could be upcycled into a variety of beautiful and functional furniture products best fit for domestic, office and public use (Michelsen et al., 2006). One of the great things about upcycling is that it helps reduce the amount of waste that ends up in landfills (Shanmugam et al., 2022). Zhuo and Levendis (2014) support the view that by giving new life to solid waste, the rate of greenhouse gas emissions is reduced thereby sustaining the natural resources for human posterity. In addition, upcycling can be a great way to create unique and eco-friendly furniture that is not only functional but also beautiful (Zhang, 2023). Darr and Pretzsch (2021) observe that obtaining waste for upcycling into furniture can be difficult just as special equipment may be required to convert waste into usable products. However, with the right tools and handcrafting techniques, upcycling can be a sustainable and rewarding way to create furniture that is both environmentally friendly and functional.

Since the incorporation of solid waste as an innovative materiality in furniture production has environmental sustainability implications, there is a need for in-depth research to be conducted into the possibility of repurposing all forms of solid waste into eco-friendly furniture for human use (Adom et al., 2023). Just as Wiprächtiger's et al. (2022) study focused on repurposing solid trash into useful clothing and furniture products as a means of preventing waste pollution and promoting environmental sustainability in Switzerland, the current study, from a Ghanaian context, dives into upcycling of solid waste into fashionable furniture in Kumasi Metropolis.

The study was necessitated by the outcome of a preliminary observation by the researchers that revealed a situation of mismanaged disposal of solid waste leading to

choked gutters, flooding and bad smell in gutters of some parts of the Kumasi Metropolis. In an attempt to help manage solid waste disposal in the Kumasi Metropolis, the current study sought to upcycle solid waste such as; sachet water, fabric waste, and cardboard boxes discarded at shops at Adum, Roman Hill, and Central Market in Kumasi Metropolis into furniture for economic gains and environmental sustainability.

Review of literature. *Theoretical Model for the Study*. The study adopted Huang's et al. (2022) solid waste recycling and reuse theoretical model. The solid waste recycling and reuse theoretical framework revolves around the principles of sustainability, creativity and ingenuity (Huang et al., 2022). It focuses on recycling waste into new and valuable products, reducing the amount of waste that ends up in dumpsites, and promoting the circular economy. In recycling, discarded waste is upcycled and given new life through reuse. This process requires innovative thinking and problem-solving skills to find creative ways to transform waste into useful and aesthetically pleasing objects.

By combining different creative art forms and art media, solid waste recycling allows people to express their creativity while having a positive impact on the environment. It encourages the use of materials that would otherwise be considered waste and minimise the use of natural resources. Xu and Gu (2015) support the view that the approach to recycling does not only reduce the environmental footprint but also promotes a change in mindset towards appreciating the potential of everyday products.

Hwang's et al. (2022) theoretical model talks about how the economic benefits from the recycling of plastics for application linking the diagram to various steps in recycling. The first step in the diagram is the eco-friendly materials; traditional plastics, biodegradable made from plant-based material plastics, plastic bottles, buckets and other non-hazardous plastic materials. The first element to consider was to consider eco-friendly materials that are sustainable for furniture production. These choices were made to minimise harm to the user and promote conservation. The next step on the diagram is solving waste management problems. This step involves using plastics in waste management by promoting recycling and minimizing single-use plastic consumption. The next step about solving waste management problems was to help manage the solid wastes at Kumasi Metropolitan Area where solid wastes were intentionally discarded. The next step on the diagram is the protection of natural resources. Hwang et al. (2022) highlight that recycling helps protect our natural resources by conserving materials like water, energy and raw materials. It minimises the need for extracting and producing new resources which helps conserve and protect our environment. The step about the diagram was the removal of solid waste in order to protect and conserve our natural resources. The next step in the diagram talks about reduction in environmental pollution. Upcycling plays a crucial role in reducing environmental pollution by diverting waste from dumpsites and incineration. By recycling materials like plastics, there can be a reduction of need for new production, which in turn reduces pollution from extraction, production and transportation

processes. This step is adopted in the protection, reduction or prevention of pollution in Kumasi Metropolis. The last step shows how the economy, being the consumer of plastics. These steps are linked to how our economy will benefit from recycling plastics for application. The model depicts how jobs can be created in the recycling industry, stimulates local economies and reduces costs associated with waste management for the prevention of waste pollution in environmental conservation and also the production of upcycled solid waste in Kumasi Metropolis for furniture production and it being economically friendly. The model of upcycling is illustrated in Figure 1.

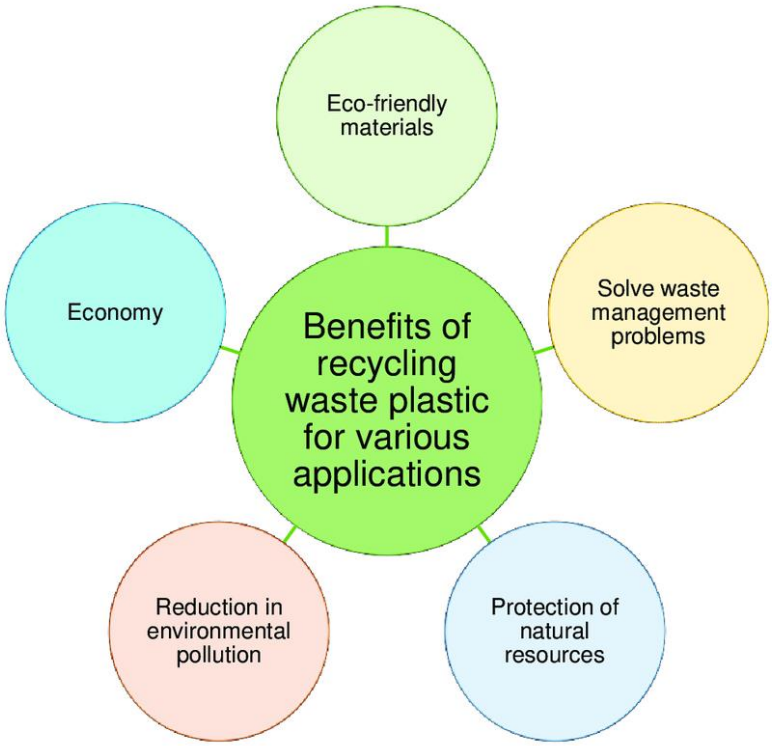

Figure1. **Advantages of plastic waste recycling and reuse**

Source: Huang et al. (2022).

Types of Solid Waste in Furniture Production: Wood, Plastic and Metal. Different types of wood waste are generated in furniture production (Daian and Ozarska, 2012). According to Akhator et al. (2017), some of the most common types of wood waste are sawdust, shavings, and wood chips. These materials are created during the cutting and shaping of wooden parts used in furniture production. Sawdust is a finely divided material that is created during the cutting and shaping of wooden parts (Cultrone et al., 2020). Tamanna et al. (2022) show how sawdust is processed into wood pellets and boards which are used in the recycling industry for furniture production. Batool et al. (2021) opines that sawdust can be found in a variety of furniture, including chairs, tables and other components that comprises solid waste generated by environmental pollution.

Steel is a common metal used in furniture manufacturing and is found in many components, including chair frames, table legs, and other parts. According to Agbeshie et al. (2020), several types of metal scrap (waste) can be generated in the manufacturing

process such as steel. Steel scrap can be produced when metal parts are cut and shaped, and it can contain both large and small pieces of metal (Aydin, 2018). Braulio-Gonzalo and Bovea et al. (2020) assert that steels are upcycled in the production of adjustable seats and backs in furniture. Aluminium is another metal often used in furniture production. It is a light and durable material that is often used in the manufacture of chair frames, table legs, and other components. During the production process, aluminum scrap can be generated, which can contain both large and small pieces of metal which can be used as pedestals and armrests in furniture production (Edwards, 2001). Liu et al. (2023) opine that copper is a rarer metal used in furniture production, but can still be found in certain components of furniture. It is often used in the manufacture of electrical components and wires and is found in some types of furniture. Wang et al. (2009) opines that copper is used in antique pedestal in furniture production.

Some of the commonest types of plastic waste are polyethene (PE), polypropylene (PP), and polystyrene (PS). These plastics are often used in the manufacture of furniture components such as chairs and backs, table tops and other parts (Wieser, 2021). Zaidi et al. (2017) give insight on polyethylene (PE) highlighting that it is a plastic commonly used in the furniture industry. It is a light and durable material that is often used in the manufacture of chairs, tables and other furniture components. Polypropylene (PP) is another type of plastic which is a versatile material that is commonly used to make chairs, tables and other furniture components. PP is known for its strength and durability, making it a popular choice among furniture manufacturers (Mohammadi et al., 2020). Meng et al. (2021) indicates polystyrene (PS) as a light and universal plastic used in the furniture industry for furniture materials. It is often used in the manufacture of furniture components such as chairs and backs, as well as table tops and other parts. To sum it up, finding ways to reuse or recycle solid waste, reduces the amount of solid waste for furniture production. Substitution with other materials and properly managing waste can help create a more sustainable and environmentally friendly furniture industry.

Environmental Sustainability, Economic Viability of Solid Waste in Furniture Production. There are many ways to turn waste into a valuable resource. For example, wood waste can be used for energy production, such as biomass energy production. Wu et al. (2023) assert that metal and plastic waste could also be recycled and used to create functional and aesthetical pleasing products for aesthetics. By finding ways to recycle or reuse waste materials, furniture manufacturers can reduce their costs and improve their profits by upcycling solid waste (Xiong et al., 2020). Plieninger et al. (2015) show that from an economic point of view, the inclusion of solid waste in furniture production can offer several advantages. First, using recycled or reclaimed materials can potentially reduce production costs compared to using new resources. This cost advantage can be particularly important when solid waste material is reliably available.

In addition, the adoption of sustainable practices in furniture production can

improve the image of the product and attract environmentally conscious consumers. As the demand for environmentally friendly products increases, furniture manufacturers who prioritise environmental sustainability have a competitive advantage in the market. This can increase sales and customer loyalty, ultimately contributing to the financial viability of the business (Ding et al., 2021).

In summary, it can be stated that environmental sustainability and the economic profitability of solid waste generated during furniture production go hand in hand. By using recycled or reclaimed materials, implementing sustainable manufacturing practices and responding to the demand for environmentally friendly products, furniture manufacturers can contribute to a more sustainable future while reaping financial benefits. It's a win-win situation that supports both the environment and the bottom line.

Materials and methods. This study was aimed at demonstrating via studio-based research approaches, how on solid waste in Kumasi Metropolis, Ghana could be innovatively upcycled into aesthetically pleasing and functional furniture pieces as a waste management strategy to achieve environmental sustainability.

The qualitative research approach asserted by Eljaoued et al. (2020) for a description of the various processes in a study was employed in the research. Under qualitative research, studio-based research was employed for the conduct of the study. The researchers identified a large chunk of solid waste disposed of by shops at Kumasi Metropolis (Adum, Central Market and Roman Hill), in the Ashanti region of Ghana. It was observed that, on a regular basis, shop operatives and hawkers dispose of waste products such as; CDs, unwanted fabrics, sachet waters and other solid wastes in the streets of Kumasi Metropolis (Adum, Central Market and Roman Hill). Some of these solid wastes are found in gutters thereby choking them and possibly contributing to the usual destructive flooding situations experienced in parts of the Kumasi metropolis every rainy season. There was a need for the collection of disposed cardboard boxes, discarded fabrics and Compact Discs (CD) waste around Adum, Central Market, and Roman Hill in the Kumasi Metropolis for upcycling into fashionable furniture for use, hence, the focus of the study. In terms of the target population, the collection of solid waste centred on shops with disposed cardboard boxes, discarded fabric waste from tailors and tailoring shops, disposed CDs by music retailers, and water sachets by hawkers around shops of these specified areas. The data collection instruments used for the research were observations at various furniture shops on how their production of furniture was done and photographs which assisted in furniture production. In all, 84 shops with disposable waste around them were counted in the Kumasi metropolitan area out of which 28 shops, representing 30 % of the shops counted, were conveniently sampled and visited for the collection of various solid wastes for the furniture production discourse. Conveniently sampling 30 % (28 shops) of the total population (84 shops) for the study is in tandem with Rahman's (2020) prescription. Considering the nature of the study, the identities of the sampled shops and/or their owners were ethically shielded to protect their anonymity. The study was conducted between July

2019 and January 2021. The research made use of thematic analysis of organising data asserted by Strijker et al. (2020). The data analysis shows the organisation, transcription, generating themes, coding and short quotations. Table 1 presents the distribution of the accessible and sampled population for the study.

Table 1

Distribution of the Accessible and Sampled Population of the Study

Population of the study	Accessible population	Sample size 30%
Shops located at Adum	39	13
Shops located at Central Market	30	10
Shops located at Roman Hill	15	5
Total	84	28

Source: Fieldwork, 2021.

Results and discussion. *Upcycling Solid Wastes in Kumasi Metropolis for Furniture Production.* Using solid waste to make furniture can be a great way to reduce waste and create beautiful, unique pieces. When it comes to the use of fabrics in furniture production, there are many options. For example, old clothes and other textile waste can be recycled to cover chairs and couches. In the same way, a piece of fabric can be used to create decorative accents for furniture, such as cushions and curtains. Waste cardboard boxes can also be used to make furniture. For example, a row of cardboard boxes can be stacked and attached to form a bookshelf or other kinds of storage furniture. Therefore, upcycling solid waste presents a great opportunity to create functional furniture that is also environmentally friendly and affordable. In the metropolis of Kumasi in the Ashanti region of Ghana, the researchers collected various types of solid waste, and transformed them into functional living room furniture using basic tools and other auxiliary materials. The entire process is presented and discussed under three steps such as; pre-cycling, up-cycling and post-cycling stage.

Pre-Upcycling Phase. The pre-upcycling phase consisted of the assemblage and sorting of solid waste around selected shops in Kumasi Metropolis in the Ashanti Region of Ghana. Solid waste collection and sorting focused on shops with discarded cardboard boxes (Figure 2), fabric wastes (Figure 5) from tailors and seamstresses and discarded CDs from retailors and sachet waste around shops in the study area (Figure 2 and 3). The tools, materials and equipment used to upcycle the assorted solid waste into furniture included; a hammer, stapler, needles, strings, screwdriver, screws and paintbrush, paint, nails, foams, glue and pins. The hammer was used for hammering nails and parts together. The stapler was used to staple fabrics on foams and cardboard boxes. The needles were used in line with the strings for sewing. The screwdrivers were also used for fixing screws in furniture for joining parts of backs and seats together in the furniture. The glue is used as an adhesive for tacking two more waste together. The paintbrush was used to paint parts of the furniture for decoration purposes. Figures 4 and 5 show some of the solid wastes collected at Adum, Roman Hill and Central Market and assorted and ready for upcycling into furniture.

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Figure 2. Collection of cardboard boxes
Source: Studio Work, 2021.

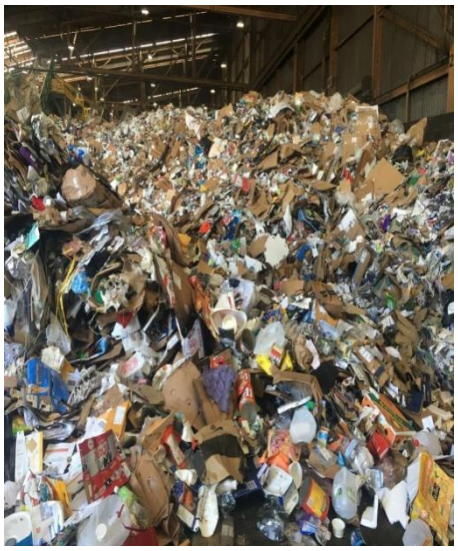

Figure 3. Collection of sachet and discs
Source: Studio Work, 2021.

Figure 4. Sorting and straightening of boxes
Source: Studio Work, 2021.

Figure 5. Sorting of fabric
Source: Studio Work, 2021.

Upcycling Production Phase. Solid Waste for Furniture Production. One of the most important factors that determine the suitability of a particular waste for use in furniture production is its physical characteristics. For example, wood waste from cardboard boxes is made of a uniform grain pattern and is ideal for use in furniture production. Also, durable and long-lasting furniture can be made from stainless metal scraps like discs used for the couch and other additives. Another important factor to consider when choosing solid waste for furniture production is its environmental impact. By upcycling solid waste materials already in circulation, producers can reduce the amount of solid waste from the environment. This can help reduce environmental

pollution and help create a more sustainable and environmentally friendly industry.

Production of Furniture Cushions. Various water sachets and fabric waste were assorted and stapled together using the stapler which was used for the cushions of the furniture. The water sachets were clipped and sewn together and designs were attached to the water sachets for beautification purposes (Figures 6–8). Foams were attached to waste plywood and later fabric waste was woven around it with some fabrics and foams placed inside the cushions, as shown in (Figures 9–13).

Figure 6. Clipping of water sachets with the stapler
Source: Studio Work, 2021.

Figure 7. Sewing of water sachets
Source: Studio Work, 2021.

Figure 8. Addition of flower designs to water sachet for cushion
Source: Studio Work, 2021.

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Figure 9. Production of cushions with fabrics
Source: Studio Work, 2021.

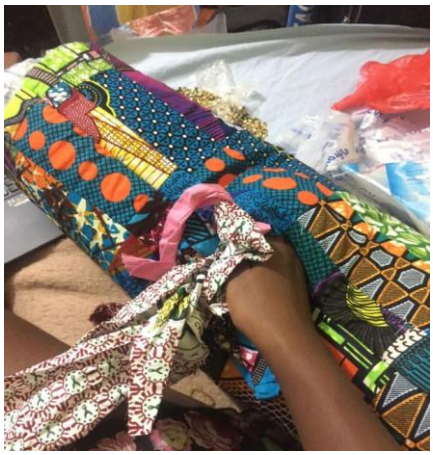

Figure 10. Addition of fabrics to cushion
Source: Studio Work, 2021.

Figure 11. Clipping fabric around foam and plywood with stapler
Source: Studio Work, 2021.

Figure 12. Finished two cushions
Source: Studio Work, 2021.

Figure 13. Finished cushion
Source: Studio Work, 2021.

Production of the Furniture Couches. The production of the couches started with the stacking of cardboard boxes then cutting them into various dimensions and later joining them in a rectangular form with fabric cushion placed on top of it (Figures 14–16). Four pedestals were given to the furniture, one on each side of the couch, as shown in (Figures 17, 18). The couch was later covered with waste pieces of fabric and designs were done on the furniture with the inclusion of discs (Figures 19, 20).

Figure 14. Stacking of boxes for couch with glue
Source: Studio Work, 2021.

Figure 15. Base of couch with fabric on top
Source: Studio Work, 2021.

Figure 16. Application of plain fabric for inner covering of couch
Source: Studio Work 2021.

Figure 17. Positioning of stand for couch

Source: Studio Work, 2021.

Figure 18. Fixing of stand for couch

Source: Studio Work, 2021.

Figure 19. Addition of disc designs to the couch

Source: Studio Work, 2021.

Figure 20. Making of designs on the couch

Source: Studio Work, 2021.

Figure 21. Finished furniture from solid waste

Source: Studio Work, 2021.

Post-Upcycling Phase. Type of Furniture Produced. The couch was the type of furniture produced, also known as a sofa, a popular and useful piece of furniture in many households and offices. When it comes to environmental sustainability and economic viability related to the literature review, there are a few steps to consider. From an environmental perspective, the materials used in couch production play a significant role. Opting for couches made from sustainable materials such as wood waste, recycled metal frames, and natural fibres like organic cotton or hemp can contribute to reducing the environmental impact as asserted by Aydin (2015). In terms of economic viability, investing in a high-quality couch won't be a wise decision but a well-made couch from upcycled solid waste tends to be more durable and long-lasting. Upcycled waste for furniture can bring several economic benefits. Firstly, it reduces the need for new furniture production, resulting in cost savings on raw materials and manufacturing processes. Secondly, upcycled furniture can be sold at a higher price compared to regular furniture, as it is often considered unique and environmentally friendly. This can lead to increased profits for businesses or individuals involved in upcycling. Additionally, upcycling waste furniture can create new job opportunities in the recycling and upcycling industry. Overall, the economic benefits of upcycled waste furniture include cost savings, higher selling prices, and job creation. By using materials that might otherwise end up in dumping areas in waste pollution, we can create furniture that is not only eco-friendly but also affordable and functional. This means that you won't need to replace it as frequently, saving you money in the long run. In a nutshell, when it comes to the couch in furniture production, considering environmental sustainability by choosing eco-friendly materials and prioritizing its longevity can go together with economic viability.

Responses from Shop Owners. Responses from selected shop owners in Kumasi

Metropolitan Area varied widely depending on the individual participant. Public responses by some participants were based on:

- Interest: The shop owners were interested in the process involved in the furniture production and were keen in perceiving the process.

Participant 1: The furniture is interesting; trying to use discarded solid waste to produce furniture is amazing (C. Darko, personal communication, February 15, 2021).

- Astonishment: Some shop owners were amazed by the innovation of using solid waste in the production of furniture.

Participant 2: Amazing, how the solid waste is recycled into furniture is mind-blowing (F. Afrifa, personal communication, February 15, 2021)

- Durability: Some shop owners, however, were doubtful about the value and durability of the solid waste furniture.

Participant 3: With the idea of solid waste innovation into furniture, I worry about the durability of the product (M. Mawunyo, personal communication, February 15, 2021).

Limitations of the Upcycled Furniture. The study encountered some few limitations, the quality of the materials for the furniture production varied, which resulted in durability of some parts of the upcycled furniture. Also, the availability of specific technologies such as design softwares for creating virtual prototypes of furniture, equipment like advanced machines for sewing (automatic needle threader and thread cutter) and infrastructure for storing solid waste for upcycling were needed in furniture production. There was the need for improvisation of upcycling of solid waste for furniture production. This could pose challenges to implementing large scale upcycling projects in Kumasi where having skilled labour and training in upcycling techniques are crucial.

Conclusions. Using solid waste to create furniture is a great way to reduce waste and create unique eco-friendly items. In this study, solid waste materials such as: disposed cardboard boxes, CDs, pieces of fabric, discarded water sachets and other solid wastes in the streets of Kumasi Metropolis (Adum, Central Market and Roman Hill) of Ghana were variously assorted for upcycling into a couch in furniture production. Incorporating sustainable manufacturing practices can contribute to the environmental sustainability of furniture production. By reducing the environmental footprint throughout the production cycle, including material sourcing, manufacturing, transportation, and disposal, we can reduce environmental pollution and conserve natural resources. From an economic perspective, incorporating solid waste materials into furniture production can offer several benefits. Using upcycled or reclaimed materials can potentially lower production costs compared to using other natural resources. This cost advantage can be particularly important when there is a reliable supply of solid waste materials available.

Moreover, embracing sustainable practices in furniture production can enhance the brand image and appeal to environmentally conscious to the public or consumers. With an increasing demand for eco-friendly products, furniture manufacturers that take

into consideration environmental sustainability have a competitive advantage in the market. This can lead to increased sales and customer loyalty, ultimately contributing to the economic viability of the furniture production business. Addressing the environmental implications of solid waste in furniture production requires a holistic approach that considers the entire lifecycle of the furniture. By adopting sustainable practices, reducing waste generation, and promoting responsible disposal as adopted from Hwang's (2022) model, the furniture industry can contribute to a more environmentally friendly and sustainable future. The research recommends further studies on material analysis, design and innovations on upcycled furniture from solid waste materials in the various jurisdictions in the Kumasi Metropolis of Ghana. Since there are different types of waste materials available in the Kumasi Metropolis and design techniques and ideas for upcycled furniture.

Implications for Practice:

- Furniture manufacturers should prioritise and promote the use of sustainable materials and production processes that minimise waste. This may include using recycled or recycled materials, implementing efficient manufacturing materials and designing products with a focus on longevity and reusability.

- Stakeholders and manufacturers can implement government support for effective waste management systems in furniture manufacturing companies. This may include establishing recycling programs, properly sorting and disposing of waste, and exploring ways to reduce waste through initiatives such as composting or recycling waste materials.

- Collaboration with local waste management organisations or recycling facilities can help establish efficient collection and recycling systems of solid waste for furniture production. This is crucial to ensure sustainable waste management throughout the supply chain where recycling that can be done with machines for production becomes easier and convenient. By working together to reduce waste production and promote recycling, the furniture industry can have a positive impact on the environment.

References

1. Adom, D., Donkor, E. K., & Asante, D. B. (2023). Why innovations in art and culture matters in the quest for solutions to the global environmental and biodiversity crisis: introducing the journal of innovations in art and culture for nature conservation and environmental sustainability. *Journal of Innovations in Art and Culture for Nature Conservation and Environmental Sustainability*, 1(1), 1–7. https://jourrnals.adompublications.com/index.php/jinces/article/view/3.

2. Agbeshie, A. A., Adjei, R., Anokye, J., & Banunle, A. (2020). Municipal waste dumpsite: impact on soil properties and heavy metal concentrations, Sunyani, Ghana. *Scientific African*, 8, e00390. https://doi.org/10.1016/j.sciaf.2020.e00390.

3. Akhator, P., Obanor, A., & Ugege, A. (2017). Nigerian wood waste: a potential resource for economic development. *Journal of Applied Sciences and Environmental Management*, 21(2), 246–251. https://doi.org/10.4314/jasem.v21i2.4.

4. Aydin, E. G. (2018). Designing for sustainability: a comparative analysis of

steel and wood-based furniture. Available at: https://urn.fi/URN:NBN:fi-fe2018053024988.

5. Aydin, M. (2015). Additive manufacturing: is it a new era for furniture production? *Journal of Mechanics Engineering and Automation*, 7(1), 338–347. https//doi.org/10.17265/2159-5275/2015.06.002.

6. Batool, F., Islam, K., Cakiroglu, C., & Shahriar, A. (2021). Effectiveness of wood waste sawdust to produce medium-to low-strength concrete materials. *Journal of Building Engineering*, 44, 103237. https://doi.org/10.1016/j.jobe.2021.103237.

7. Bianco, I., Thiébat, F., Carbonaro, C., Pagliolico, S., Blengini, G. A., & Comino, E. (2021). Life cycle assessment (LCA)-based tools for the eco-design of wooden furniture. *Journal of Cleaner Production*, 324, 129249. https://doi.org/10.1016/j.jclepro.2021.129249.

8. Braulio-Gonzalo, M., & Bovea, M. D. (2020). Criteria analysis of green public procurement in the Spanish furniture sector. *Journal of Cleaner Production*, 258, 120704. https://doi.org/10.1016/j.jclepro.2020.120704.

9. Cultrone, G., Aurrekoetxea, I., Casado, C., & Arizzi, A. (2020). Sawdust recycling in the production of lightweight bricks: how the amount of additive and the firing temperature influence the physical properties of the bricks. *Construction and Building Materials*, 235, 117436. https://doi.org/10.1016/j.conbuildmat.2019.117436.

10. Daian, G., & Ozarska, B. (2009). Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector. *Journal of Cleaner Production*, 17(17), 1594–1602. https://doi.org/10.1016/j.jclepro.2009.07.008.

11. Darr, D., & Pretzsch, J. (2021). Analysis of Acacia hybrid timber value chains: a case study of woodchip and furniture production in central Vietnam. *Forest Policy and Economics*, 125,102401. https://doi.org/10.1016/j.forpol.2021.102401.

12. Ding, J., Wang, M., Zeng, X., Qu, W., & Vassiliadis, V. S. (2021). Mass personalization strategy under industrial internet of things: a case study on furniture production. *Advanced Engineering Informatics*, 50, 101439. https://doi.org/10.1016/j.aei.2021.101439.

13. Edwards, C. (2001). Aluminium furniture, 1886–1986: the changing applications and reception of modern material. *Journal of Design History*, 14(3), 207–225. http://www.jstor.org/stable/3527147.

14. Eljaoued, W., Yahia, N. B., & Saoud, N. B. B. (2020). A qualitative-quantitative resilience assessment approach for socio-technical systems. *Procedia Computer Science*, 176, 2625–2634. https://doi.org/10.1016/j.procs.2020.09.305.

15. Huang, S., Wang, H., Ahmad, W., Ahmad, A., Vatin, N., Mohamed, A. M., Deifalla, A. M., & Mehmood, I. (2022). Plastic waste management strategies and their environmental aspects: a scientometric analysis and comprehensive review. *International Journal of Environmental Research and Public Health*, 19(8), 4556. https://doi.org/10.3390/ijerph1908456.

16. Liu, Y., Zeng, C., Wang, M., Shao, X., Yao, Y., Wang, G., … & Ye, D.

(2023). Characteristics and environmental and health impacts of volatile organic compounds in furniture manufacturing with different coating types in the Pearl River Delta. *Journal of Cleaner Production*, 397, 136599. https://doi.org/10.1016/j.jclepro.2023.136599.

17. Meng, X., Fan, W., Mahari, W. A. W., Ge, S., Xia, C., Wu, F., … & Lam, S. S. (2021). Production of three-dimensional fiber needle-punching composites from denim waste for utilization as furniture materials. *Journal of Cleaner Production*, 281, 125321. https://doi.org/10.1016/j.jclepro.2020.125321.

18. Michelsen, O., Fet, A. M., & Dahlsrud, A. (2006). Eco-efficiency in extended supply chains: a case study of furniture production. *Journal of Environmental Management*, 79(3), 290–297. https://doi.org/10.1016/j.jenvman.2005.07.007.

19. Mohammadi, S., Al-e-Hashem, S. M., & Rekik, Y. (2020). An integrated production scheduling and delivery route planning with multi-purpose machines: a case study from a furniture manufacturing company. *International Journal of Production Economics*, 219, 347–359. https://doi.org/10.1016/j.ijpe.2019.05.017.

20. Muhammad-Suandi, M. E., Amlus, M. H., Hemdi, A. R., Abd Rahim, S. Z., Ghazali, M. F., & Rahim, N. L. (2022). A review on sustainability characteristics development for wooden furniture design. *Journal of Sustainability*, 14(14),8748. https://doi.org/10.3390/su14148748.

21. Plieninger, T., Hartel, T., Martín-López, B., Beaufoy, G., Bergmeier, E., Kirby, K., ... & Van Uytvanck, J. (2015). Wood-pastures of Europe: geographic coverage, social–ecological values, conservation management, and policy implications. *Biological Conservation*, 190, 70–79. https://doi.org/10.1016/j.biocon.2015.05.014.

22. Rahman, M. S. (2020). The advantages and disadvantages of using qualitative and quantitative approaches and methods in language “testing and assessment” research: a literature review. *Journal of Education and Learning*, 6(1), 102–112. https://doi.org/10.5539/jel.v6n1p102.

23. Shanmugam, M., Chuaicham, C., Augustin, A., Sasaki, K., Sagayaraj, P. J., & Sekar, K. (2022). Upcycling hazardous metals and PET waste-derived metal-organic frameworks: a review on recent progress and prospects. *New Journal of Chemistry*, 46(33), 15776–15794. https://doi.org/10.1039/D2NJ02481K.

24. Strijker, D., Bosworth, G., & Bouter, G. (2020). Research methods in rural studies: qualitative, quantitative and mixed methods. *Journal of Rural Studies*, 78, 262–270. https://doi.org/10.1016/j.jrurstud.2020.06.007.

25. Tamanna, K., Raman, S. N., Jamil, M., & Hamid, R. (2020). Utilization of wood waste ash in construction technology. *Journal of Construction and Building Materials*, 237, 117654. https://doi.org/10.1016/j.conbuildmat.2019.117654.

26. Wang, J., Zhang, L., & Liu, X. (2009). Material application and innovation in furniture design. *2009 IEEE 10th International Conference on Computer-Aided Industrial Design & Conceptual Design* (pp. 463–466). IEEE. https://doi.org/10.1109/CAIDCD.2009.5375316.

27. Wieser, M. K. (2021). Circular design guide for the use of plastic in furniture (Master's thesis), NTNU. Available at: https://hdl.handle.net/11250/2829428.

28. Wiprächtiger, M., Rapp, M., Hellweg, S., Shinde, R., & Haupt, M. (2022). Turning trash into treasure: an approach to the environmental assessment of waste prevention and its application to clothing and furniture in Switzerland. *Journal of Industrial Ecology*, 26(4), 1389–1405. https://doi.org/10.1111/jiec.13275.

29. Wu, Z., Zong, F., Zhang, F., Wang, J., Zhu, Z., Guo, X., & Cao, P. (2023). Investigation of the customized furniture industry's production management systems. *Journal of Engineering Research*, 11(3), 164–175. https://doi.org/10.1016/j.jer.2023.100072.

30. Xiong, X., Ma, Q., Wu, Z., & Zhang, M. (2020). Current situation and key manufacturing considerations of green furniture in China: a review. *Journal of Cleaner Production*, 267, 121957. https://doi.org/10.1016/j.jclepro.2020.121957.

31. Yao, A. C., & Carlson, J. G. (2003). Agility and mixed-model furniture production. *International Journal of Production Economics*, 81–82, 95–102. https://doi.org/10.1016/S0925-5273(02)00359-6.

32. Yuan, X., Wang, J., Deng, S., Suvarna, M., Wang, X., Zhang, W., … & Ok, Y. S. (2022). Recent advancements in sustainable upcycling of solid waste into porous carbons for carbon dioxide capture. *Journal of Renewable and Sustainable Energy Reviews*, 162, 112413. https://doi.org/10.1016/j.rser.2022.112413.

33. Zaidi, N. A., Rosli, M. F., Effendi, M. S. M., & Abdullah, M. H. (2017). Analysis of polyethene terephthalate PET plastic bottle jointing system using finite element method (FEM). *AIP Conference Proceedings*, 1885(1). AIP Publishing. https://doi.org/10.1063/1.5002199.

34. Zhang, L., Duan, Y., Gao, R., Chen, Z., Yue, Y., An, W., & Du, H. (2023). Upcycling of refinery solid waste by chemical activation: fabrication of molybdenum sulfide/hierarchical porous carbon composites for highly stable supercapacitor. *Fuel*, 342, 127770. https://doi.org/10.1016/j.fuel.2023.127770.

35. Zhuo, C., & Levendis, Y. A. (2014). Upcycling waste plastics into carbon nanomaterials: a review. *Journal of Applied Polymer Science*, 131(4). https://doi.org/10.1002/app.3991.