

Using Innovative Sustainable Materials of Mobile Units in Improving Interior Design and Comfort of Occupants in Fixed Buildings

Dr.Inas Mohamed Abdel Hamid Gohar

Assistant Lecturer- Interior Design & Furniture Department

Faculty of Applied Arts – Egyptian Russian University

enasgohar94@gmail.com

ABSTRACT

The field of interior design faces increasing and multifaceted challenges related to sustainability, environmental preservation, as well as the demands of climate change and the rising environmental awareness. The fundamental problem lies in the necessity to develop and use innovative and sustainable materials in interior design, so that they meet the evolving and diverse needs of clients without causing negative impacts on natural resources or increasing the carbon footprint of buildings and designed spaces. In this context, sustainable mobile units emerge as pioneering solutions, due to their flexibility in use and high economic efficiency, alongside full compliance with environmental standards aimed at protecting nature and reducing harmful emissions. These units provide living and working environments characterized by quick responsiveness and the flexibility required to meet the fast-paced and continuously changing lifestyle and work patterns.

This research aims to elevate the quality of life and sustainable living by reducing the carbon footprint compared to traditional buildings, through adopting and using innovative and sustainable materials in the field of interior design that meet client aspirations and align with contemporary requirements. The importance of this research stems from highlighting the most important eco-friendly materials and substances that interior designers can rely on in their projects to achieve high-quality designs that keep pace with current environmental challenges, ensuring the improvement of the design environment's quality and providing a healthy and comfortable environment for the end-user. Additionally, the research contributes to enhancing the understanding of the importance of green building and the use of sustainable materials in modern design, thereby effectively supporting long-term sustainable development.

The research relies on the descriptive-analytical methodology, which combines a review of the literature related to sustainable interior design, analysis of recent research studies, and evaluation of practical applications of innovative and sustainable materials in multiple interior design projects, aiming to provide a comprehensive and integrated vision that contributes to the sustainable and effective development of modern design practices.

Keywords:

Innovation, mobile units, sustainability, renewable energy

الملخص:

يواجه مجال التصميم الداخلي تحديات متزايدة ومتعددة الأبعاد تتعلق بالاستدامة والحفاظ على البيئة، بالإضافة إلى متطلبات تغيير المناخ والوعي البيئي المتصاعد. تتمثل المشكلة الأساسية في ضرورة تطوير واستخدام خامات مبتكرة ومستدامة في التصميم الداخلي، بحيث تلبي الاحتياجات المتغيرة والمتنوعة للعملاء دون التسبب في تأثيرات سلبية على الموارد الطبيعية أو زيادة البصمة الكربونية للمباني والمساحات المصممة. في هذا السياق، تظهر الوحدات المتنقلة المستدامة كحلول رائدة، نظراً لما تمتاز به من مرونة في الاستخدام وكفاءة اقتصادية عالية، إلى جانب الالتزام التام بالمعايير البيئية الخاصة بحماية البيئة الطبيعية وتقليل الانبعاثات الضارة. هذه الوحدات توفر بيانات معيشية وعملية تتسم بالاستجابة السريعة والمرونة المطلوبة لتلبية نمط الحياة والعمل العصري الذي يتسم بالسرعة والتغير المستمر.

ويهدف هذا البحث إلى الارتقاء بمستوى جودة الحياة والعيش المستدام من خلال تقليل البصمة الكربونية مقارنة مع المباني التقليدية، وذلك عبر تبني واستخدام خامات مبتكرة ومستدامة في مجال التصميم الداخلي، تلبي تطلعات العملاء وتتناغم مع متطلبات العصر. أهمية هذا البحث تنبع من تسليط الضوء على أبرز المواد والخامات الصديقة للبيئة، والتي يمكن أن يعتمد عليها المصمم الداخلي في مشاريعه لتحقيق تصميمات عالية الجودة تكون مواكبة للتحديات البيئية الراهنة، مع ضمان تحسين جودة بيئة التصميم وتوفير بيئة صحية ومريحة للمستخدم النهائي. كما يساهم البحث في تعزيز فهم أهمية البناء الصديق للبيئة واستخدام المواد المستدامة في التصميم الحديث، متيحاً بذلك دعماً فعالاً لتحقيق التنمية المستدامة على المدى الطويل. يعتمد البحث على المنهج الوصفي التحليلي، حيث يجمع بين مراجعة الأدبيات المتعلقة بالتصميم الداخلي المستدام، وتحليل الدراسات البحثية الحديثة، بالإضافة إلى تقييم التطبيقات العملية لخامات مبتكرة ومستدامة في مشاريع تصميم داخلية متعددة، بهدف تقديم رؤية شاملة ومتكاملة تساهم في تطوير الممارسات التصميمية الحديثة بشكل مستدام وفعال.

الكلمات المفتاحية:

الابتكار، الوحدات المتنقلة، الاستدامة، الطاقة المتجددة.

1. INTRODUCTION AND RATIONALE**INTRODUCTION**

Today's interior designers are faced with serious challenges including climate change, sustainability, and a lack of appropriate workplace and residential space. Innovative solutions that integrate environmental responsibility, simplicity, and aesthetics are becoming increasingly necessary. Sustainable mobile units are coming to be an innovative idea that provides adaptable, effective, and environmentally responsible solutions for standard places.

KEY WORDS AND DEFINITIONS

Innovation: Innovation is the process of producing and putting into practice novel concepts, procedures, goods, or services that significantly improve things and add value. It entails transforming imaginative ideas into workable solutions that raise productivity, effectiveness, or meet missing requirements [1].

Mobile units: Mobile units are buildings or facilities that are made to be easily transported from one location to another. Caravans, mobile clinics, and research labs integrated into cars or trailers are examples of these, they allow flexible use in many locations as needed [2].

Sustainability: Sustainability refers to the ability to sustain or uphold procedures over an extended period without wasting natural resources. By striking a balance between social, economic, and environmental variables, it aims to meet present needs while guaranteeing that future generations can meet theirs [3].

Renewable Energy: Renewable energy is energy generated from rapidly replenishing natural resources like biomass, wind, water, and sunlight. These resources contribute to less environmental effect and dependence on fossil fuels [4].

RESEARCH PROBLEM

The lack of use of innovative, environmentally friendly materials employed in mobile units to improve the interior design of permanent buildings, provide a comfortable environment, and preserve the health of the user.

RESEARCH QUESTIONS

- How may environmentally friendly movable units be used into interior design to improve adaptability and sustainability?
- How do sustainable mobile units affect carbon emissions and quality of life in comparison to conventional buildings?
- What design techniques and materials maximize mobile units' sustainability and usability?

RESEARCH OBJECTIVES

Improve the quality of life and reduce the carbon footprint compared to traditional buildings by using innovative materials in interior design that meet the changing requirements of clients.

RESEARCH IMPORTANCE

Highlight the most important environmentally friendly materials that interior designers can use to ensure the enhancement of the design environment, preservation of the environment, and provision of comfort and health to the user.

RESEARCH HYPOTHESIS

Integrating sustainable mobile units into interior design can significantly improve flexibility, economic efficiency, and environmental sustainability, while reducing the carbon footprint compared to conventional buildings.

RESEARCH METHODOLOGY

This study will use a descriptive analytical approach combining:

Literature Review: To explore existing research on sustainable mobile units and interior design innovations.

Analytical study: Analysis of sustainable mobile units and materials to identify best practices and challenges.

2. CONTEXTUAL TERRITORY

Using Renewable and Lightweight Materials

Mobile units, such as campers and caravans, use wood-based and other renewable materials to reduce total weight and, consequently, energy consumption over the course of the vehicle's lifecycle. These materials are more climate-friendly than traditional ones like plastic and aluminium because they also store CO₂ during growth and use. This method allows for the production of trendy and cozy rooms while promoting sustainability without reducing usability [5].

Transferable and Modular Interiors

With its great degree of modification and space optimization, modular interior design is a game-changer for mobile units. Because mobile units have limited space, it is essential that components can be changed out or reconfigured to accommodate changing needs. In keeping with sustainable design principles, this adaptability expands the life of interiors and lowers waste. In addition to being useful for mobile living, modular units enable cost-effective solutions and fast installation [6].

Smart Technology Integration

Mobile units are rapidly using AI and smart home technology to improve user experience, comfort, and energy efficiency. Smart thermostats, connected appliances, and automated lighting all maximize energy efficiency and promote sustainability. By creating multipurpose areas that can be used for a variety of purposes, smart interior design also increases spatial flexibility by lowering the demand for extra built space and materials [7,8].

Sustainability and Eco-Innovation

Eco-innovations including locally produced and recycled materials, energy-efficient equipment, and non-toxic finishes are all part of sustainable mobile units. These actions reduce their negative effects on the environment and encourage healthier living conditions. The emphasis on adaptation and longevity guarantees that interiors continue to be useful and relevant over time, reducing waste and resource usage [9,10].

Eco-friendly mobile units' relationship and impact on human well-being

Studies show that eco-friendly mobile units and human wellbeing have a strong connection, with environmental, physical, and psychological benefits being highlighted:

- **Health and Environmental Impact:**

Eco-friendly mobile units improve air quality and lower exposure to dangerous pollutants, which directly improves public health. They also reduce energy consumption, carbon emissions, and pollution of the air and water. These units have healthier living and working conditions because of their reduced environmental effect [11,12].

- **Connection to Nature and Mental Wellbeing:** By lowering stress and elevating mood, including green design and natural components into permanent buildings and mobile homes improves residents' mental health. Research demonstrates that initiatives that enhance

people's interaction with nature, through digital or mobile platforms, greatly enhance mental health [14].

- **Technology Integration for Sustainability and Health:** Employing smart systems and green technology in mobile and fixed units maximizes environmental performance and energy use while promoting occupant comfort and health. During pandemics, mobile health units are particularly important for everyday care and well-being, but their environmental impact needs to be carefully controlled [15,16].

- **Behavioural Influence:** Studies have demonstrated the effectiveness of mobile units' materials that encourage sustainable behaviours (e.g., cutting emissions, supporting eco-friendly transportation) in minimizing environmental impact and promoting healthy lifestyle choices, which in turn promote well-being [17,18].

- **Social and Accessibility Dimensions:** Micro-mobility solutions and using environmentally friendly mobile unit materials in fixed buildings can improve social inclusion and accessibility, but certain groups may not be able to use them due to issues like cost and technical proficiency. They provide flexible, sustainable living and transportation alternatives, which, once available, enhance subjective well-being [13].

An overview, the combination of eco-friendly methods, modular adaptability, lightweight renewable materials, and intelligent technology integration defines innovation in sustainable interior design. Together, these components produce movable and fixed areas that are efficient, adaptable, comfortable, and ecologically friendly, demonstrating a progressive approach to interior design within the framework of sustainability and mobility.

Additionally, eco-friendly buildings improve human well-being by lowering pollutants, promoting physical activity, improving air quality, and improving mental health by connecting people with nature. Such buildings are significant contributors to sustainable development and enhanced quality of life since they combine behaviourally supportive buildings with sustainable technologies to further enhance these advantages.

3. LITERATURE REVIEW

Interior Design Sustainability

In order to maximize lighting, thermal comfort, ventilation, and water use—all of which contribute to operational efficiency and cost savings—smart interior design solutions integrate sensors, gadgets, and computing platforms. By lowering the need for numerous design elements and increasing the life of interior spaces, smart materials and furniture further improve sustainability. Examples include phase-changing materials that control temperature and smart solar energy systems integrated into interior finishes [19].

Community Initiatives and Sustainable Design Approaches

The integration of environmental limitations into the design process through eco-design frameworks and community initiatives is another way that sustainability in design is covered. These strategies provide an emphasis on the useful use of sustainable design principles in the creation of goods and services, which can be applied to permanent and mobile internal units.

These frameworks enhance the development of sustainable practices by integrating ecological responsibility with innovation [22].

Innovations in Sustainable Materials and Construction

One of the main innovations in mobile interior design, according to recent trends, is the use of environmentally friendly materials. In order to improve durability and insulation while lowering weight and environmental impact, lightweight, renewable materials like recycled aluminium, expanded polypropylene (EPP), and wood-based composites are being utilized more and more [23, 24]. For instance, the new Twins campervans from Adria Mobil use lightweight, 100% recyclable EPP cabinets, which lower weight and release of carbon dioxide [Figure 1, 27]. Furthermore, by lowering dependency on outside power and maintenance resources, solar-integrated walls and self-cleaning surfaces improve hygiene and energy efficiency [20,25]. Innovative materials that improve flexibility and energy efficiency, such phase-changing pellets and smart glasses, are essential to sustainable movable interior modules. For instance, structural glass provides durability and transparency for dynamic interior applications, while smart building technologies allow interiors to modify their functions and atmospheres to support sustainability objectives [19, 24].



Figure 1: Adria's Twin vans are known for their creative design, dependability, and simplicity of use, making them one of the most popular campervans. In the past, the Twin series was a pioneer in a number of useful design ideas, including the panoramic roof window and other developments [https://www.adria-mobil.com].

Nature-Based Design and Green Architecture:

Some studies have highlighted the importance of integrating nature-based design and green architecture in interior spaces, especially in mobile administrative units. These studies focus on:

- Using modern technologies and materials to enhance diversity and innovation in interior spaces.
- Overcoming the challenges facing the application of sustainability in interior design.
- Enhancing individuals' well-being and increasing their productivity through healthy and sustainable work environments.
- Applying sustainable design strategies such as improving air quality, visual and acoustic comfort, and rationalizing energy consumption [28, 29].

Climate Adaptability, Comfort, and Luxury

Contemporary caravan designs are developing to rival conventional living areas to provide a cozy and luxurious experience. In addition to spa-like bathrooms with rainfall showers, high-end features like leather couches, quartz worktops, and bamboo flooring are becoming more and more popular [20, 22]. The challenges of mobile living in harsh climates like the UAE are addressed by climate control improvements, such as improved insulation and solar-powered systems, which guarantee comfort in a variety of indifferent environments [20, 26].

Industry Acknowledgment and Upcoming Prospects

The industry's dedication to sustainability and innovation is demonstrated by honours such as the European Innovation Award 2025, which Adria's Twins campervans received for their clever interior design and sustainable materials [27]. With an emphasis on the full value chain from materials to craftsmanship, trade shows like as Interzum 2025 highlight how lightweight engineering and sustainable materials have the potential to revolutionize mobile units design [23].

In summary, several major themes appear from the literature on interior design innovation using sustainable mobile units:

- By maximizing resource consumption and enhancing occupant comfort, smart technologies (IoT, sensors, and AI) included into mobile interiors improve sustainability [19, 25].
- By increasing product life and decreasing waste, expandable interior areas address environmental impact and personalization [20,21].
- Eco-design frameworks and grassroots initiatives offer useful examples of how to incorporate sustainability into design procedures [22].
- Dynamic, energy-efficient interiors that adjust to changing needs are made possible by advanced materials and smart building techniques [19, 24].

According to the literature, innovative interior design for sustainable buildings incorporates numerous elements, such as cutting-edge eco-friendly materials, multipurpose and space-saving furniture, smart technology, and luxurious finishes tailored to permanent and mobile lifestyles. By improving user experience and lowering environmental effect, these innovations make sustainable buildings affordable and attractive.

In order to improve interior design for fixed buildings in an ecologically conscious way, this body of research suggests a multidisciplinary strategy that combines material innovation, technology, and sustainable design principles.

4. ANALYTICAL STUDY

• PROCEDURE FOR SAMPLING

Most New Sustainable Materials for Caravan Construction

A number of innovative, environmentally friendly materials are revolutionising caravan building, according to recent industry advancements and studies. These materials are intended to reduce their negative effects on the environment, increase resource efficiency, and improve the comfort and health of occupants.

Table [1] Innovative Eco-Friendly Materials

Natural Fiber Composites (NFCs)	Renewable, biodegradable, low toxicity	Panels, insulation, interiors
Engineered Wood (CLT, plywood)	Renewable, carbon storage, lightweight	Frames, walls, furniture
Hempcrete, Straw Panels	Carbon-negative, excellent insulation	Walls, floors, insulation
Bio-based/Recycled Insulation	Moisture control, low toxicity	Wall/roof insulation
Bamboo	Fast-growing, durable, renewable	Furniture, cabinetry, finishes
Eco-friendly Composite Panels	Lightweight, moisture-resistant, recyclable	Walls, floors, roofs
Celuka Composite	Rot-free, flame retardant, recyclable	Walls, cabinetry
Low-VOC/Recycled Finishes	Improved air quality, reduced waste	Paints, fittings, surfaces
Recycled Polymers & 3D Printing	Minimizes waste, enables circular design, customizable	Camper structures, interior panels, insulation, temperature regulation
Recycled Aluminium and Steel	Durable, lightweight, reduces resource use	Frames, chassis, cladding

This table highlights alternatives that combine environmental benefits with performance and health considerations, reflecting the most recent sustainable advances in caravan materials.

Innovative Eco-Friendly Materials:

Natural Fiber Composites (NFCs): NFCs are biodegradable, have little embodied energy, and have strong mechanical qualities because they are made from renewable fibres including hemp, flax, jute, and bamboo. They are gradually replacing the position of fibreglass and traditional polymers in panels, insulation, and interior fixtures [30, 31,32].

Engineered Wood Products (such as plywood and cross-laminated timber (CLT)), are structurally strong, carbon-sequestered, and renewable. They provide a lightweight and environmentally friendly replacement for metals and plastics in furniture, walls, and frames [33, 23].

Hempcrete and Straw Panels: Hempcrete is a bio-composite made of hemp fibres and lime that is valued for its low toxicity, insulating qualities, and carbon-negative footprint. Compressed straw is used to make straw panels and boards (such as EcoCocon and Ekopanel), which offer extremely insulating, biodegradable, and renewable wall systems [32,34].

Bio-based and recycled insulation: Insulation derived from grass fibres (like Gramitherm®), sheep's wool, and recycled fabrics provides superior moisture control, low toxicity, and thermal performance, resulting in more pleasant and healthy caravan interiors [32, 35].

Sustainable Bamboo: Bamboo is perfect for furniture, cabinetry, and interior procedures since its rapid renewability as it grows much faster than hardwoods—up to one meter per day, low environmental impact as it absorbs more carbon dioxide and releases more oxygen than most trees, strength, light weight, resistant to cracking, warping, moisture, and insects make it a superior sustainable choice for innovative furniture compared to traditional wood materials. Its use decreases dependency on plastics and hardwoods that grow more slowly[31,35].

Composite Sandwich Panels (with Eco-Friendly Cores): These panels combine lightweight skins (such fiberglass or GRP) with recycled PET foam or natural fibre cores in place of conventional polystyrene. These panels have a smaller environmental impact and provide enhanced insulation, durability, and moisture resistance [36, 37].

Celuka Composite: A strong, recyclable PVC-based material for cabinets and walls. It is lightweight, flame-resistant, rot-free, and adaptable, but its sustainability ratings rely on how it is made and recycled [37].

Low-VOC and Non-Toxic Finishes: By reducing chemical exposure and waste, low-VOC paints, recycled fixtures, and plastic-free finishes enhance indoor air quality and sustainability [35].

Recycled Polymers & 3D Printing: By using recycled polymers, creative 3D-printed campers greatly reduce waste and enable circular design concepts. Phase-change materials, recycled textile wall panels, and biobased insulation can all be used inside to improve comfort and passive temperature control [38].

Recycled Steel and Aluminium: They are frequently used for caravan frames, chassis, and cladding because they are lightweight, durable, and have less of an adverse effect on the environment than virgin metals. Recycling helps achieve sustainability goals by reducing waste and resource exploitation [39,38].

In conclusion, natural fibre composites, engineered wood products, hempcrete, straw panels, low-VOC/recycled finishes, bamboo, recycled and bio-based insulation, and advanced composite sandwich panels are the most cutting-edge environmentally friendly components used in caravan building. These materials were picked because they are long-lasting, sustainable, and can be used to make mobile homes that are healthier and less harmful.

• SWOT ANALYSIS



According to this SWOT analysis, **innovative environmentally friendly materials like hempcrete and CLT have significant health and sustainability advantages** and are becoming more widely accepted and supported by technology. However, there are still issues with market competition, regional production capacity, and manufacturing emissions. Increasing acceptance and optimizing the environmental and social benefits of these materials in caravan building will require utilizing technology advancements, increasing local production, and enhancing customer education.

• INTERPRETATION OF DATA AND ANALYSIS

➤ Sustainability and Human Harm Ratings of Innovative Caravan Materials During Manufacturing

Table [2] Sustainability and Human Harm Ratings of Innovative Caravan Materials

Recycled Aluminium	95	30	Manufacturing involves energy-intensive smelting and emissions; exposure to dust and fumes can affect workers.
Composite Sandwich Panels	70	60	Use of synthetic cores like XPS foam involves VOCs and formaldehyde emissions, which can cause respiratory irritation and long-term health risks.
Recycled Steel	80	40	Steel production emits pollutants and dust; recycling reduces impact but still involves exposure to heavy metals and particulates.
Sustainably Sourced Wood	85	15	Low-VOC adhesives minimize formaldehyde emissions; responsibly harvested timber supports carbon sequestration.
Bamboo	90	5	Rapidly renewable with minimal chemical processing; ideal for interiors and fittings.
Low-VOC Finishes	85	5	Eco-friendly paints and adhesives reduce indoor air pollution and long-term health risks.
Glass Reinforced Plastic [GRP] (Fiberglass)	60	20	Lightweight and water-resistant but relies on plastic composites; production involves non-renewable resources.
Cross-Laminated Timber (CLT)	85	10	Generally low toxicity; risk mainly from adhesives or resins used, which may emit low levels of formaldehyde.
Hempcrete	90	5	Low toxicity; manufacturing mostly natural with minimal chemical processing.
Mycelium Composites	50	5	Biodegradable and low toxicity; manufacturing is low-impact but still emerging technology with limited data.

This table, which is crucial for sustainable caravan design, strikes a balance between occupational and user health factors and environmental benefits.

Human Harm percentage represents possible health hazards resulting from formaldehyde, dust, volatile organic compounds (VOCs), chemicals, and emissions during the manufacture and usage of materials.

Recycled Steel: Recycling steel decreases the environmental impact of primary steel manufacturing, but it still releases dust and pollutants and exposes workers to particulates and heavy metals [40].

Recycled Aluminium : Recycling aluminium has a far smaller environmental impact than primary production, but it still requires a lot of energy and may expose workers to fumes and dust. Particulate and emission exposure is one among the health concerns associated with smelting and recycling [41, 42, 43, 44].

Composite Sandwich Panels : Composite panels, particularly those with chemicals cores like extruded polystyrene (XPS) foam, frequently contain adhesives and resins that release formaldehyde and volatile organic compounds (VOCs). These emissions have been linked to long-term health dangers including cancer risk, and irritation to the lungs [40].

Sustainably Sourced Wood: Plywood and other engineered wood products with low volatile organic chemicals (VOCs) strike a compromise between minimal harmful effects and structural integrity. However, destruction may result from inappropriate sourcing [45, 46].

Low-VOC Materials and Bamboo: Because of its quick growth and minimal toxicity, bamboo is perfect for environmentally aware interior design. Its combination with low-VOC finishes guarantees better indoor air quality [46].

GRP (Fiberglass) and Foam Insulation: Insulation made of GRP (Fiberglass) and foam is dependable and resistant to decay, although it depends on plastics. Although closed-cell foam insulation uses synthetic materials, it lowers the possibility of mould growth [47].

Cross-Laminated Timber (CLT) : Although CLT is often not harmful, the glues used to make it may release small amounts of formaldehyde. Modern polymers with extremely low carbon emissions, frequently below regulatory levels, include polyurethane (PUR) and soy-based glues [45].

Hempcrete : Hempcrete requires very little chemical processing and is a very sustainable material. Because it is primarily made of natural materials, it has low toxicity and little toxic fumes. In addition to being biodegradable, hempcrete absorbs carbon throughout its life cycle [46].

Mycelium Composites : Mycelium composites are low toxicity and biodegradable. The energy required for culturing and processing, which varies based on the energy source, is the main factor influencing the environmental effect of their production. Although there is little evidence

and the technology is still developing, they are generally regarded as a low-harm and sustainable material [47].

Note: For manufacturers, transparency in material sourcing and adherence to formaldehyde emission standards (e.g., <0.09 ppm) are critical for reducing health risks [45, 47].

➤ **Sustainability, Human Harm Ratings, Cost and Country Usage of the Most Innovative Caravan Materials**

Table [3] Sustainability, Human Harm, Cost, and Country Usage of Innovative Caravan Materials

Cross-Laminated Timber (CLT)	85	10	\$41 - \$68 per m²	Austria, Germany, Canada, Sweden, USA, Australia, Egypt (import/use possible, not major producer)	Popular in Europe, North America, Asia-Pacific; Egypt uses timber in construction but is not a major CLT producer.
Hempcrete	90	5	\$28 - \$55 per m ²	UK, France, USA, Australia, Egypt (limited pilot projects/interest)	Used mainly in Europe, North America, Australia; Egypt has emerging interest in hemp-based materials.
Recycled Aluminium	95	30	\$2,000 - \$3,000 per ton	China, USA, Germany, Japan, Egypt (producer, 0.2% global share)	Major production in China, USA, Germany, Japan; Egypt produces aluminium and recycles to a limited extent.

Composite Sandwich Panels	70	60	\$68 - \$136 per m ²	USA, Germany, China, Egypt (import/use possible, not major producer)	Manufactured mainly in developed markets; Egypt imports and uses composites in construction, not a major producer.
Recycled Steel	80	40	\$600 - \$1,200 per ton	China, USA, India, Germany, Egypt (producer/recycler)	Large-scale production globally; Egypt produces and recycles steel for construction.

The table offers a comparison of the five main components utilized in creative and environmentally friendly caravan construction. It assesses each substance according to four important criteria: Average cost, potential harm to humans during manufacturing, sustainability rating, and the nations where these resources are frequently used or manufactured. It also has remarks emphasizing significant background information.

Cross-Laminated Timber (CLT): CLT is manufactured extensively in Germany, Austria, and other European nations, and its markets in North America and Asia-Pacific are expanding [48, 49]. Egypt is not a large producer of CLT, although it may import it and uses it in building.

Hempcrete: Popular in the USA, Australia, France, and the UK. While some studies and pilot projects have demonstrated Egypt's interest in hemp-based construction, widespread adoption is still in early stages [50, 51, 52].

Recycled Aluminium: China, the United States, Germany, and Japan are the top manufacturers of recycled aluminium. Egypt has the ability to recycle aluminium, primarily for domestic consumption, and produces 0.2% of the world's total output [53, 54].

Composite sandwich panels: They are mostly made in China, Germany, and the United States. Although it is not a big manufacturer, Egypt imports and uses these panels for building [55].

Recycled steel: It is mostly produced in Germany, China, the United States, and India. Egypt has a large steel sector and recycles steel for use in domestic manufacture and building [54].

Note:

- Egypt produces steel and aluminium and engages in recycling in both industries, but it is not a significant player in the world market for CLT or composite panels.
- In Egypt, hempcrete and CLT are becoming more popular for environmentally friendly building, while widespread use is still in development.

5. EXPECTED OUTCOME

The incorporation of eco-friendly materials originally developed for mobile living and working environments—such as hempcrete, natural fibre composites, recycled metals, and cross-laminated timber (CLT)—can significantly enhance the sustainability, usability, and occupant comfort of fixed buildings. These materials offer an optimal balance between environmental impact, human health safety, cost-effectiveness, and durability when applied to interior design in permanent structures.

Furthermore, the research highlights the potential of integrating smart technologies, including the Internet of Things (IoT), adapted from mobile units to optimize resource consumption, improve indoor environmental quality, and increase the adaptability and flexibility of interior spaces in fixed buildings. This integration supports more sustainable, healthy, and user-centred living and working environments that respond effectively to evolving occupant needs.

6. CONCLUSION

Sustainable mobile units, which successfully combine mobility with environmental responsibility, offer valuable insights and innovative approaches for enhancing interior design in fixed buildings. Compared to conventional materials such as composites and metals that involve higher production emissions, the adoption of renewable, low-toxicity materials like cross-laminated timber (CLT) and hempcrete significantly reduces environmental impact and health risks when applied in permanent building interiors. While recycled steel and aluminium contribute in durability and recyclability, their energy-intensive manufacturing and associated human health concerns require careful assessment in fixed building applications.

The integration of smart technologies originally developed for mobile units enhances sustainability by enabling efficient resource management and personalized occupant experiences within fixed building interiors. However, challenges remain concerning regulatory frameworks, market perception, and production flexibility, especially in emerging economies. Overall, the future of sustainable interior design in fixed buildings is likely to be shaped by combining innovative design strategies with eco-friendly materials derived from mobile unit development, promoting healthier, adaptable, and environmentally responsible living and working spaces.

7. RECOMMENDATIONS

- Investigate the adaptation of renewable materials (e.g., CLT, hempcrete) from mobile units for fixed building interiors to enhance sustainability and occupant comfort.
- Analyse the cost-effectiveness and environmental benefits of locally producing such innovative materials in different regions.
- Explore integration of smart technologies (IoT) used in mobile units to optimize indoor environmental quality and comfort in fixed buildings.
- Develop and test low-VOC adhesives and bio-based composites inspired by mobile unit materials to improve indoor air quality.
- Conduct lifecycle assessments comparing innovative sustainable materials from mobile units versus traditional fixed building materials.
- Establish clear sustainability assessment criteria and certification frameworks specific to the interior use of these materials in permanent buildings.
- Evaluate occupant health and comfort improvements when applying mobile unit sustainable materials in fixed interior environments.
- Study barriers and drivers for the acceptance of mobile unit-derived sustainable materials among architects, designers, and occupants of fixed buildings.

8. REFERENCES

1. <https://ideascale.com/blog/what-is-innovation/>
2. <https://www.allbusiness.com/dictionary-mobile-unit-4963031-1.html>
3. <https://www.investopedia.com/terms/s/sustainability.asp>
4. https://en.wikipedia.org/wiki/Renewable_energy
5. <https://www.interzum.com/en/magazine/articles/eco-friendly-lightness-mobile-interior-design.php>
6. <https://www.linkedin.com/pulse/embracing-future-significance-modular-interiors-puqhc>
7. Al Khafaji, Ibtisam Abdulelah Mohammed, and Raz Kamaran. "The Influence of Spatial Flexibility to Improve Sustainability of Interior Design by Using Smart Technology (Case Study – Future Smart Home in Iraq)." *European Journal of Sustainable Development* 8, no. 4 (2019): 438. <https://doi.org/10.14207/ejsd.2019.v8n4p438>.
8. <https://okoskoti.co.uk/sustainable-interior-design/>
9. <https://happyeconews.com/15-eco-innovations-that-will-shape-the-sustainable-homes-of-the-future/>
10. <https://theishaankone.com/design-ideas/exploring-the-future-of-interior-design-innovations-and-trends-to-watch/>
11. Fernández-Aguilar, Carlos, Marta Browsed-Lázaro, and Daniel Carmona-Derqui. "Effectiveness of Mobility and Urban Sustainability Measures in Improving Citizen Health: A Scoping Review." *International Journal of Environmental Research and Public Health* 20, no. 3 (2023): 2649. <https://doi.org/10.3390/ijerph20032649>.
12. <https://airly.org/en/the-benefits-of-eco-friendly-living-for-you-and-the-environment/>
13. Milakis, Dimitris, Laura Gedhardt, Daniel Ehebrecht, and Barbara Lenz. "Chapter 19 Is micro-mobility sustainable? An overview of implications for accessibility, air pollution, safety, physical activity and subjective wellbeing". In *Handbook of Sustainable Transport*,

- (Cheltenham, UK: Edward Elgar Publishing, 2020) accessed Jun 10, 2025. <https://doi.org/10.4337/9781789900477.00030>
14. McEwan, Kirsten, Miles Richardson, David Sheffield, Fiona J. Ferguson, and Paul Brindley. 2019. "A Smartphone App for Improving Mental Health through Connecting with Urban Nature" *International Journal of Environmental Research and Public Health* 16, no. 18: 3373. <https://doi.org/10.3390/ijerph16183373>
 15. TaheriNejad, Nima, Paolo Perego, and Amir M. Rahmani. "Mobile Health Technology: From Daily Care and Pandemics to Their Energy Consumption and Environmental Impact." *Mobile Networks and Applications* 27, no. 2 (April 1, 2022): 652–56. <https://doi.org/10.1007/s11036-022-01959-x>
 16. Prochorskaite, Agne, Chris Couch, Naglis Malys, and Vida Maliene. 2016. "Housing Stakeholder Preferences for the "Soft" Features of Sustainable and Healthy Housing Design in the UK" *International Journal of Environmental Research and Public Health* 13, no. 1: 111. <https://doi.org/10.3390/ijerph13010111>
 17. Goetz, Alexander, Ioana Marinica, Harald Mayr, Luca Mosetti, and Renate Schubert. "Do Mobile Applications Foster Sustainable Mobility? Evidence From a Field Experiment." *Zeitschrift Für Schweizerische Statistik Und Volkswirtschaft/Schweizerische Zeitschrift Für Volkswirtschaft Und Statistik/Swiss Journal of Economics and Statistics* 160, no. 1 (September 23, 2024). <https://pmc.ncbi.nlm.nih.gov/articles/PMC11420393/>
 18. Teran-Escobar, C., Duché, S., Bouscasse, H. et al. InterMob: a 24-month randomised controlled trial comparing the effectiveness of an intervention including behavioural change techniques and free transport versus an intervention including air pollution awareness-raising on car use reduction among regular car users living in Grenoble, France. *BMC Public Health* 22, 1763 (2022). <https://doi.org/10.1186/s12889-022-14099-4>
 19. Rashdan, W. "The Impact of Innovative Smart Design Solutions on Achieving Sustainable Interior Design." *WIT Transactions on Ecology and the Environment* 1 (July 12, 2016): 623–34. <https://www.witpress.com/Secure/elibrary/papers/SC16/SC16052FU1.pdf>
 20. Liu, Zongming, Xuhui Chen, and Xinan Liang. "Growable Design of Passenger Vehicle Interior Space Based on FAHP and FQFD." *PLoS ONE* 19, no. 6 (June 20, 2024): e0303233. <https://doi.org/10.1371/journal.pone.0303233>
 21. Kim, Taesu, Gyunpyo Lee, Jiwoo Hong, and Hyeon-Jeong Suk. "Affective Role of the Future Autonomous Vehicle Interior." *Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, September 12, 2023, 7–12. <https://dl.acm.org/doi/10.1145/3581961.3609886>
 22. Rio, Maud, and Benjamin Tyl. "Exploring Design to Environment Methods Through Grassroots Initiatives." *Procedia CIRP* 100 (January 1, 2021): 25–30. <https://doi.org/10.1016/j.procir.2021.05.004>
 23. <https://www.interzum.com/en/magazine/articles/eco-friendly-lightness-mobile-interior-design.php>
 24. Oikonomopoulou, Faidra. "Unveiling the third dimension of glass." *Architecture and the Built Environment* (2019): n. pag.
 25. <https://www.icartea.com/en/wiki/2025-the-ultimate-guide-to-caravan-interiors>
 26. <https://moderncampground.com/usa/new-features-and-innovations-in-caravan-design-shaping-the-way-we-travel/>

27. <https://www.adria-mobil.com/news/new-twins-win-european-innovation-award-2025>
28. <https://seaf.journals.ekb.eg/article>
29. <https://www.ajsp.net/research>
30. Santhosh, Nagaraja, Praveena, Bindiganavile Anand, Gowda, Ashwin C., Duhduh, Alauldeen A., Rajhi, Ali A., Alamri, Sagr, Berwal, Parveen, Khan, Mohammad Amir and Wodajo, Anteneh Wogasso. "Innovative eco-friendly bio-composites: A comprehensive review of the fabrication, characterization, and applications" Reviews On Advanced Materials Science 63, no. 1 (2024): 20240057. <https://doi.org/10.1515/rams-2024-0057>
31. <https://www.fortiscaravans.co.nz/post/future-of-caravan-materials-innovations-and-trends>
32. <https://www.revalu.io/journal/50-sustainable-construction-materials-to-watch-in-2025>
33. Matloob, Huma. "Towards Sustainable Architecture: Exploring Innovative Materials, Construction Technology, and Design Concepts for Eco-Friendly Buildings." Engineering Headway. Trans Tech Publications Ltd, July 22, 2024. <https://doi.org/10.4028/p-wb5308>.
34. Madiraju, Saisanthosh Vamshi Harsha, and Abhiram Siva Prasad Pamula. "A Brief Guide to the 50 Eco-Friendly Materials Transforming Sustainable Construction." Austin Environmental Sciences 9, no. 1 (April 29, 2024). <https://doi.org/10.26420/austinenvironsci.2024.1105>.
35. <https://www.retreatcaravans.com.au/blog/sustainable-caravan-living-tips/>
36. <https://linersupply.com.au/latest-approaches-to-composite-caravan-construction/>
37. <https://www.paramountcaravans.com.au/caravan-building-materials/>
38. Pournoori, Pooyan, Amirhossein Davarpanah TQ, Arash Rajaei, Morteza Ghodrathnama, Saeed Abrishami, and Amir R. Masoodi. "Experimental Exploration of Fracture Behaviour (Pure Mode III) in Eco-friendly Steel Fiber-reinforced Self-compacting Concrete with Waste Tempered Glass as Coarse Aggregates." Scientific Reports 14, no. 1 (April 19, 2024). <https://doi.org/10.1038/s41598-024-58912-z>.
39. Hassan, Jahid, Clinton Ronjon Barikdar, Evha Rozario, Sazzat Hossain, Md Kamal Ahmed, Abu Saleh Muhammad Saimon, and Gazi Touhidul Alam. "Emerging Trends and Performance Evaluation of Eco-Friendly Construction Materials for Sustainable Urban Development." Journal of Mechanical Civil and Industrial Engineering 2, no. 2 (December 29, 2022): 80–90. <https://doi.org/10.32996/jmcie.2021.2.2.11>.
40. Islam, Ashiqul, Wahid Ferdous, Paulomi (Polly) Burey, Kamrun Nahar, Libo Yan, and Allan Manalo. 2025. "Polymer Composite Sandwich Panels Composed of Hemp and Plastic Skins and Composite Wood, Recycled Plastic, and Styrofoam Cores" Polymers 17, no. 10: 1359. <https://doi.org/10.3390/polym17101359>
41. De Caro, Daniele, Michele Maria Tedesco, Jaume Pujante, Andrea Bongiovanni, Giovanni Sbrega, Marcello Baricco, and Paola Rizzi. 2023. "Effect of Recycling on the Mechanical Properties of 6000 Series Aluminium-Alloy Sheet" Materials 16, no. 20: 6778. <https://doi.org/10.3390/ma16206778>
42. Yusuf, Nur Kamilah, Mohd Amri Lajis, and Azlan Ahmad. 2019. "Multi-response Optimization and Environmental Analysis in Direct Recycling Hot Press Forging of Aluminium AA6061" Materials 12, no. 12: 1918. <https://doi.org/10.3390/ma12121918>
43. Martin, Stephen Claude, and Claude Larivière. "Community Health Risk Assessment of Primary Aluminium Smelter Emissions." Journal of Occupational and Environmental

- Medicine 56, no. Supplement 5S (May 1, 2014): S33–39. <https://doi.org/10.1097/jom.000000000000135>.
44. Wesdock, James C., and Ian M. F. Arnold. "Occupational and Environmental Health in the Aluminium Industry." *Journal of Occupational and Environmental Medicine* 56, no. Supplement 5S (May 1, 2014): S5–11. <https://doi.org/10.1097/jom.000000000000071>.
45. Yauk, Michael, Jason Stenson, Micah Donor, and Kevin Van Den Wymelenberg. 2020. "Evaluating Volatile Organic Compound Emissions from Cross-Laminated Timber Bonded with a Soy-Based Adhesive" *Buildings* 10, no. 11: 191. <https://doi.org/10.3390/buildings10110191>
46. <https://www.ekohunters.com/hempcrete-sustainable-architecture/>
47. Akromah, Stefania, Neha Chandarana, Jemma L. Rowlandson, and Stephen J. Eichhorn. "Potential Environmental Impact of Mycelium Composites on African Communities." *Scientific Reports* 14, no. 1 (May 24, 2024). <https://doi.org/10.1038/s41598-024-62561-7>.
48. [Dogwood Alliance – CLT: Why This Emerging Technology Is So Dangerous?](#)
49. [Research and Markets – Cross Laminated Timber Market Report 2025](#)
50. Norouzi, Yasaman, Feng Guangxi, Kifah Alhazaa, Farnaz Nazari, Manish Dixit, Wei Yan, and Petros Sideris. "Comparing the Life Cycle Assessment of Hempcrete and Conventional Concrete Walls with a Wood-Framed Wall as a Benchmark." Available at SSRN, January 1, 2024. <https://doi.org/10.2139/ssrn.4860586>.
51. [Hemp Block Company – Hempcrete Blocks](#)
52. [LinkedIn – Hempcrete Market Trends](#)
53. [Capital.com – Aluminium Price Forecast 2025](#)
54. [World Population Review – Aluminum Production by Country 2025](#)
55. <https://dataintelo.com/report/global-sandwich-panel-system-market>