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## “Recycling and Reuse of Seatbelt Webbing: Opportunities, Challenges, and Innovations”

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### ABSTRACT

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The increasing emphasis on sustainability and waste reduction in the textile and automotive industries has prompted innovative approaches to managing post-consumer and industrial waste. One such material gaining attention is seatbelt webbing, a synthetic fiber known for its exceptional strength, durability, and resistance to abrasion and chemicals. This review explores the recycling and reuse potential of seatbelt webbing, outlining various strategies employed to repurpose this high-performance textile. Applications of recycled seatbelt webbing range from fashion and accessories to furniture design, construction materials, and automotive interiors. The study discusses mechanical, chemical, and upcycling methods used in processing seatbelt waste, highlighting the environmental and economic benefits of each. Additionally, it identifies the challenges associated with handling seatbelt webbing, such as contamination, separation from composite materials, and the need for standardized processing protocols. Case studies and successful implementations by designers and manufacturers illustrate the practicality and creative scope of seatbelt reuse. Furthermore, the paper emphasizes the role of design innovation and circular economy principles in promoting seatbelt recycling. With growing environmental awareness and regulatory pressures, repurposing seatbelt webbing presents a viable opportunity to reduce landfill waste, conserve resources, and support green product development. The paper concludes with recommendations for future research and policy directions to enhance the scalability and efficiency of recycling systems for seatbelt materials.

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## 1. INTRODUCTION

The automotive industry is one of the largest contributors to industrial waste globally, especially as vehicles reach the end of their life cycle and are dismantled for disposal or recycling. End-of-life vehicles (ELVs) produce a complex stream of waste composed of various materials such as metals, plastics, rubber, glass, textiles, and composite parts(1). While some materials like metals are extensively recycled due to

their high value and established recovery systems, many other components are either partially recycled or discarded altogether, leading to significant environmental concerns. Among these lesser-addressed materials is the interior textile waste, which includes seat covers, airbags, carpets, and seatbelt webbing. Improper disposal of these materials, particularly through landfilling or incineration, contributes to pollution, resource depletion, and increased carbon

emissions. In light of global sustainability goals and the push towards circular economy models, recycling and reusing all possible components from ELVs—including those traditionally overlooked—has become a critical necessity(2).

Seatbelt webbing, a key safety feature in all vehicles, is an especially promising material for recycling due to its unique characteristics. It is predominantly manufactured from high-tenacity polyester (PET) or, less frequently, nylon fibers. These synthetic materials are chosen because of their outstanding mechanical properties, including high tensile strength, resistance to stretching, and long-term durability. The webbing is engineered in a tightly woven, robust configuration to provide maximum restraint and energy absorption during vehicular collisions. Moreover, seatbelt material is designed to withstand extreme temperatures, exposure to ultraviolet (UV) radiation, moisture, and continuous mechanical stress over long periods of use. These properties ensure not only passenger safety during vehicle operation but also long-term performance and structural integrity—qualities that remain intact even after the vehicle is no longer operational(3). From a material science perspective, these attributes make seatbelt webbing an excellent candidate for repurposing in a variety of post-consumer applications.

The rationale behind focusing specifically on seatbelt webbing among the wide range of automotive waste materials lies in its abundant availability, excellent performance characteristics, and current end-of-life treatment practices. During vehicle dismantling, seatbelts are typically not recovered separately but are often shredded along with other non-metallic interior parts or disposed of in landfills. This represents a significant loss of a high-quality textile material that has the potential for reuse in applications such as industrial textiles, fashion accessories, construction reinforcements, or even composite materials for automotive or aerospace use. In addition, the distinctive combination of strength,

flexibility, and durability found in seatbelt webbing is not commonly available in conventional textile waste streams, giving it a unique advantage for secondary usage. Focusing on this material not only supports waste reduction but also aligns with sustainability goals by offering alternatives to virgin raw materials and reducing the environmental footprint of manufacturing(4). The scope of this review is to explore the potential of recycled seatbelt webbing as a sustainable and valuable resource. It will cover a comprehensive analysis of its physical and mechanical properties, current collection and disposal methods, challenges associated with its recovery, and innovative applications identified in recent studies and industrial practices(5). By investigating the full lifecycle of seatbelt webbing from production to disposal and beyond, this review aims to bridge the knowledge gap and provide actionable insights into how this material can be better utilized. The objective of the review is to highlight the untapped value of discarded seatbelt webbing, propose strategies for its effective recovery and reuse, and present case studies or conceptual designs that demonstrate its viability in diverse sectors. Ultimately, the goal is to contribute to the development of sustainable waste management practices in the automotive industry while encouraging innovation in material reuse and circular product design(6).

## 2. MATERIAL CHARACTERISTICS OF SEATBELT WEBBING

In recent decades, the rapid growth of the global automotive industry has resulted in an ever-increasing volume of end-of-life vehicles (ELVs), creating significant environmental challenges related to automotive waste. While metals and major components are commonly recycled, many interior materials—particularly textiles—are either landfilled or incinerated due to limited reuse strategies. Among these materials, **seatbelt webbing** stands out as a high-performance technical textile that is extensively used yet rarely recycled(7). Designed for safety-critical applications,

seatbelt webbing is primarily composed of **high-tenacity polyester (PET)** or, in some cases, **nylon**, both of which exhibit remarkable mechanical and chemical properties. These webbing materials are engineered to endure extreme stress, abrasion, and environmental exposure over the lifespan of a vehicle, yet they are often discarded with minimal recovery efforts. Given their widespread availability, superior strength, and resistance to degradation, seatbelt webbings present a compelling opportunity for material recovery, reuse, and recycling. Focusing on this niche yet valuable textile can help address the larger issue of automotive textile waste while opening new pathways for sustainable material engineering. This review aims to explore the material science of seatbelt webbing in detail, analyze its mechanical and chemical attributes, compare it with other synthetic fibers, and evaluate its end-of-life characteristics and potential recyclability in a circular economy framework(8).

## 1. Mechanical Properties (Tensile Strength, Abrasion Resistance)

### Tensile Strength in Detail:

Seatbelt webbing is made from **high-tenacity polyester yarns**, typically **PET (polyethylene terephthalate)**, engineered to handle immense tensile forces. A standard 46 mm wide seatbelt strap can withstand loads exceeding **13–15 kN (kilonewtons)** before rupture, equating to over **1,300–1,500 kg of force**. This tensile strength is verified through **ISO 10542-1** or **FMVSS 209** testing procedures, where force is applied until the webbing fails. The **multi-filament yarn structure**, often with **over 150 fibers per yarn**, and **dense woven patterns** (like twill or herringbone) provide superior load distribution and resistance to thread slippage(9).

### ELONGATION & ELASTIC RECOVERY:

The webbing must elongate under dynamic loading (e.g., in a crash) to **absorb impact energy** but not so much that it permits excessive occupant movement. The ideal elongation for safety belts is between **6%**

**and 10% at break**, which balances energy dissipation and restraint. Post-elongation, polyester demonstrates excellent **elastic recovery**, returning to its original form with minimal permanent deformation under normal loads(10).

### ABRASION RESISTANCE AND SURFACE INTEGRITY:

Due to regular use (e.g., extending and retracting, rubbing against clothing), abrasion resistance is vital. Polyester webbing is evaluated using **abrasion cycles (e.g., ISO 12947)** and can endure over **50,000 cycles** without significant fiber loss(11). Factors contributing to this resistance include:

- Tightly interlaced yarns
- Use of high-modulus fibers
- Surface finishes and anti-fray coatings

This ensures that even after years of mechanical wear, the belt remains functional and safe.

### FLEXURAL FATIGUE RESISTANCE:

Seatbelts are repeatedly bent, folded, and rolled. Polyester fibers have **excellent flexural fatigue life**, meaning they do not crack or weaken easily even after **millions of flex cycles**. The use of low-crimp yarns and thermally bonded edges minimizes micro-damage(12).

### IMPACT RESISTANCE & SAFETY PERFORMANCE:

In crash simulations, seatbelts must prevent forward momentum of the passenger while working with airbags and vehicle crumple zones. Webbing materials are selected and tested to absorb **high-speed impact forces in milliseconds**, ensuring a coordinated restraint system. The webbing's response is **non-linear**, becoming stiffer with increasing strain to prevent excessive elongation in catastrophic impacts(13).

## 2. Chemical Properties and Environmental Resistance (UV, Heat, Moisture)

### UV Resistance and Photostability:

UV exposure leads to **photodegradation** in many polymers via oxidation, chain scission, and surface embrittlement. Polyester's aromatic backbone gives it intrinsic UV resistance. Additionally, **UV stabilizers like benzotriazoles and hindered amine light**

**stabilizers (HALS)** are incorporated during fiber production to prolong lifespan. Accelerated aging tests (e.g., **ASTM G154** or **QUV exposure tests**) show that polyester webbing retains over **85–90% of its tensile strength** after **800 hours** of simulated UV exposure—far better than nylon or polypropylene(14).

#### Thermal Stability and Heat Resistance:

- **Melting Point: ~255–260°C**
- **Glass transition temperature (Tg): ~70–80°C**

Polyester remains stable across a wide temperature range from **-40°C to +85°C** (common in vehicular cabins). It does not deform or lose strength in daily thermal cycles. It is also self-extinguishing when treated with **phosphorus-based flame retardants**, complying with **FMVSS 302** flammability standards(15).

#### MOISTURE RESISTANCE AND DIMENSIONAL STABILITY:

Polyester is **hydrophobic**, with a moisture regain of only **0.4–0.8%**, ensuring negligible swelling, weight change, or loss of strength. In contrast, **nylon absorbs 4–5% moisture**, leading to dimensional shifts and microbial vulnerability. Polyester's closed-chain structure makes it highly resistant to **hydrolytic degradation**, even in tropical or humid environments. No microbial growth occurs on untreated polyester due to its low water retention(16).

#### RESISTANCE TO CHEMICALS AND CONTAMINANTS:

Polyester resists:

- **Weak acids and alkalis**

- **Automotive oils and greases**
- **Solvents and alcohols**
- **Sweat, skin oils, and detergents**

This chemical robustness allows the webbing to function without degradation in real-world automotive environments, which may contain vapors, spills, or cleaning agents(17).

#### 3. Comparisons with Other Synthetic Fibers

##### Polyester vs. Nylon (Nylon 6/6):

- **Nylon has higher initial tensile strength and more elongation**, making it stretchier—good for flexibility but risky for safety restraints as it can lead to more occupant movement.
- Nylon degrades rapidly under UV exposure and in acidic conditions.
- **Polyester offers better dimensional stability and consistent strength retention** over time, especially in outdoor, high-UV environments(18).
- Moisture absorption in nylon can cause **up to 50% loss in dry tensile strength** and promote **microbial growth**, whereas polyester retains its dry-state properties.

##### POLYESTER VS. POLYPROPYLENE:

- **Polypropylene is cheaper**, less dense, and more chemically inert—but it has poor tensile strength (~30% less than polyester), low melting point (~160°C), and extremely poor UV resistance.
- Polypropylene is unsuitable for structural or safety applications.
- Polyester outperforms in **abrasion resistance, strength, heat tolerance, and recyclability**(19).(table 1)

**Comparison Summary Table1:**

Property	Polyester (PET)	Nylon 6/6	Polypropylene
Tensile Strength (g/denier)	7.5 – 9.5	9 – 12	4 – 6
UV Resistance	Excellent	Poor	Very Poor
Moisture Absorption	0.4–0.8%	4–5%	~0.01%
Melting Point	~255°C	~250°C	~160°C
Heat Resistance	Excellent	Good	Poor
Abrasion Resistance	Excellent	Excellent	Moderate
Recyclability	High	Moderate	Low
Cost	Moderate	High	Low



#### 4. End-of-Life Characteristics and Recyclability

##### Current End-of-Life Practices:

Seatbelt webbing, despite its durability, is typically **not recycled on a large scale**. Reasons include(20):

- Labor-intensive manual removal from vehicle interiors.
- Contamination with dirt, oils, or residues.
- Presence of **coatings, flame retardants, and dyes**, which complicate reprocessing.

As a result, seatbelt materials are often landfilled or incinerated with interior trim waste, contributing to **non-biodegradable automotive textile waste**.

##### Mechanical Recycling Potential:

Seatbelt webbing can be:

- **Shredded into fibers** for use as filler in composite boards or insulation.
- **Melted and extruded into plastic pellets**, though thermal reprocessing can reduce fiber strength due to polymer chain degradation.

However, mechanical recycling faces issues of **fiber quality loss** and dye contamination. Products made from mechanically recycled seatbelt PET are generally **non-load-bearing**.

#### CHEMICAL RECYCLING – CLOSED-LOOP VIABILITY:

**Chemical recycling** technologies (e.g., **glycolysis, methanolysis**) can break PET into **its monomers (terephthalic acid and ethylene glycol)**, which are purified and **re-polymerized into virgin-quality PET**(21). This process:

- Handles dyes and additives more effectively.
- Produces high-purity feedstock for **new fibers or bottles**.
- Supports a **closed-loop circular economy**.

However, chemical recycling is still **costly and infrastructure-dependent**.

#### UPCYCLING AND REUSE APPLICATIONS:

Seatbelt webbing, even without recycling, can be repurposed in **value-added applications** due to its residual strength:

- **Fashion:** belts, backpacks, dog leashes, wallets.
- **Industrial:** tie-down straps, safety harnesses, furniture support.
- **Architecture:** tensile fabric structures, reinforcing elements.
- **Art & Design:** installations, recycled sculptures, functional textiles.

These **creative reuses** reduce landfill waste, promote sustainability, and raise awareness about material repurposing.

#### 3. Sources and Collection of Used Seatbelt Webbing

The global automotive industry generates an enormous volume of waste annually, stemming from both vehicle production and end-of-life processes. Among the many overlooked components in this waste stream is **automotive textile waste**, particularly seatbelt webbing. Seatbelt webbing, primarily made of high-tenacity polyester or occasionally nylon, is a critical safety feature in every vehicle, designed to endure immense mechanical stress, resist environmental degradation, and retain structural integrity over long service periods. However, despite these durable characteristics, seatbelt webbing is rarely considered for material recovery or recycling once a vehicle reaches the end of its lifecycle. Unlike metals or plastics, which have well-established recycling markets and processes, technical textiles like seatbelt webbing fall into a grey area, often being lumped into mixed waste streams or incinerated without any form of value recovery(14). This lack of focus on seatbelt recycling stems from a combination of practical challenges—such as contamination, labor-intensive dismantling, and lack of economic incentives—and a general underrepresentation of textile components in automotive recycling policies. Given the increasing pressure on manufacturers to adopt circular economy models and the rising environmental burden of synthetic fibers, it is essential to explore how seatbelt webbing can be more effectively recovered, recycled, and repurposed. The following sections delve into

the primary sources of this waste, existing collection and dismantling practices, and the multifaceted challenges that hinder its integration into sustainable waste management frameworks(8).

### Primary Sources (Scrap from Vehicle Manufacturing, End-of-Life Vehicles)

Seatbelt webbing waste is generated predominantly from two major sources: automotive manufacturing facilities and end-of-life vehicles (ELVs). In manufacturing settings, seatbelt webbing is produced in bulk from high-performance fibers—mainly high-tenacity polyester—and is cut and assembled into retractable systems during the production of new vehicles. This process, however, is not without waste(5). Scrap material is routinely generated due to off-cuts during cutting operations, excess material from trimming, defective batches that fail quality control, and material left over from roll ends. This waste is typically clean, uncontaminated, and homogeneous in its composition, which makes it a valuable and relatively easy material to collect and process. Unfortunately, such textile waste is often disregarded in favor of more easily

recyclable materials like metals and rigid plastics, and is either incinerated on-site or disposed of through general industrial waste streams(4).

On the other hand, the more substantial source of seatbelt webbing waste is ELVs, which contribute significantly to the total volume of post-consumer automotive textile waste. Each passenger vehicle contains around 5 to 7 meters of seatbelt webbing, and with tens of millions of vehicles reaching end-of-life globally each year, this adds up to thousands of tons of high-performance polyester that is routinely discarded. However, recovering seatbelt webbing from ELVs is complicated by its integration into the vehicle structure. Unlike manufacturing scrap, which is easily collected in a centralized facility, seatbelt material in ELVs must be manually removed from within the cabin of the vehicle—often requiring disassembly of interior panels, seats, and anchoring systems (Table 2). Without a structured recovery process or regulatory push, this high-value material is almost always lost in the broader stream of automotive waste(2).

**Table 2: Comparison of Seatbelt Webbing Waste Sources**

Aspect	Manufacturing Scrap	End-of-Life Vehicles (ELVs)
Source Type	Pre-consumer (industrial)	Post-consumer (vehicle dismantling)
Condition	Clean, uncontaminated, uniform	Soiled, aged, possibly degraded
Ease of Access	High – generated in centralized production lines	Low – embedded in vehicle interiors
Quantity (per vehicle basis)	Small per batch, predictable	5–7 meters per vehicle
Recovery Feasibility	High – consistent and manageable	Low – labor-intensive, unstructured recovery
Current Utilization	Low, often discarded	Extremely low, generally landfilled or incinerated

### CURRENT COLLECTION AND DISMANTLING PRACTICES

Seatbelt webbing recovery from ELVs is not standardized and is generally dependent on the policies and capacity of dismantling facilities. At present, most of the seatbelt collection practices are informal, inefficient,

and largely driven by individual operators rather than structured guidelines or industry-wide protocols(5). In many vehicle dismantling operations—commonly referred to as Authorized Treatment Facilities batteries (ATFs)—the priority is to extract components that have high resale value or

pose environmental risks, such as, electronic modules, tires, and catalytic converters. Seatbelts, despite their mechanical value and reuse potential, are rarely prioritized. Removing a seatbelt typically involves unfastening bolts, dismantling the retractor casing, and carefully extracting the woven webbing—steps that can be time-consuming and physically laborious. In high-throughput facilities, this added time per vehicle translates to increased labor costs with little financial return, making seatbelt recovery unattractive to most operators(10).

In facilities lacking manual dismantling capability or operating under time constraints, entire vehicles are sent to mechanical shredders. Here, the vehicle is crushed and shredded into small pieces, resulting in a mixture of metal fragments, plastics, foams, fabrics, and seatbelt fibers. Seatbelt webbing, being flexible and fibrous, is reduced to undifferentiated textile fluff within the broader automotive shredder residue (ASR). At this stage, the material is virtually unrecoverable as a distinct textile product and is usually either landfilled or incinerated as part of waste-to-energy programs(13). Only a few pioneering programs, often supported by academic partnerships or sustainability-focused companies, have developed pilot schemes for the targeted removal and upcycling of seatbelt webbing. However, these efforts are limited in scale and have yet to be integrated into mainstream automotive recycling systems.

#### **CHALLENGES IN COLLECTION (CONTAMINANTS, MIXED MATERIAL WASTE)**

One of the most significant barriers to the effective collection and recycling of seatbelt webbing from ELVs is the issue of contamination. Over a vehicle's service life, seatbelt webbing is exposed to a variety of substances and environmental conditions that degrade its purity and performance. Common contaminants include dust, grease, motor oil, perspiration, food and drink spills, and other organic residues. Additionally, seatbelt fibers may suffer from UV degradation, microbial

activity, or discoloration due to long-term exposure to sunlight and temperature fluctuations. These factors compromise the material's surface integrity and mechanical properties, making it unsuitable for direct reuse or for certain recycling techniques—particularly chemical recycling, which requires clean input to ensure the efficiency of depolymerization processes(16).

Another major issue arises from the composition of the seatbelt assembly itself. Although the webbing is usually made from polyester, the seatbelt system also includes various other materials such as steel buckles, aluminum anchors, plastic retractor casings, and nylon threads used in stitching. This multimaterial configuration complicates disassembly and sorting, as each component must be separated manually before the webbing can be processed. Furthermore, labels and coatings on the webbing often consist of different polymers or inks that further affect recyclability. During mechanical shredding, these components are not separated, and the resulting mixture becomes a heterogeneous blend of fibers and non-fibrous particles that is extremely difficult to isolate and reuse(17).

The logistical and economic challenges of collecting seatbelt webbing are equally daunting. In most countries, automotive recycling is focused heavily on materials with higher economic value, such as metals and electronics. Textile recovery, especially for components like seatbelts, is seen as a low-priority, high-effort task with limited profitability. The manual labor required to extract webbing from ELVs increases operational costs, and in the absence of government subsidies or extended producer responsibility (EPR) regulations, dismantlers are unlikely to invest in such practices. Moreover, there is a lack of standardized infrastructure and market linkage for the post-recovery processing of automotive textiles. Without dedicated sorting lines, cleaning units, or recycling centers focused on technical textiles, recovered seatbelt webbing remains a difficult material to handle efficiently. This gap in infrastructure,

combined with the absence of economic incentives and environmental mandates, ensures that the vast majority of seatbelt webbing continues to be wasted rather than recycled(22).

#### 4. Recycling and Reuse Strategies

Recycling and reuse strategies are critical components in addressing the environmental impact of synthetic textile waste, particularly materials such as polyester seat belts, nylon ropes, and other high-durability woven fabrics. These materials, due to their

excellent mechanical properties and resistance to degradation, are often underutilized post-consumption. Developing effective approaches for their recovery and reintegration into new product lifecycles helps mitigate landfill accumulation, reduces reliance on virgin raw materials, and supports a circular economy. The three primary strategies explored are mechanical recycling, chemical recycling, and direct reuse in innovative applications (Figure 1 )(22).

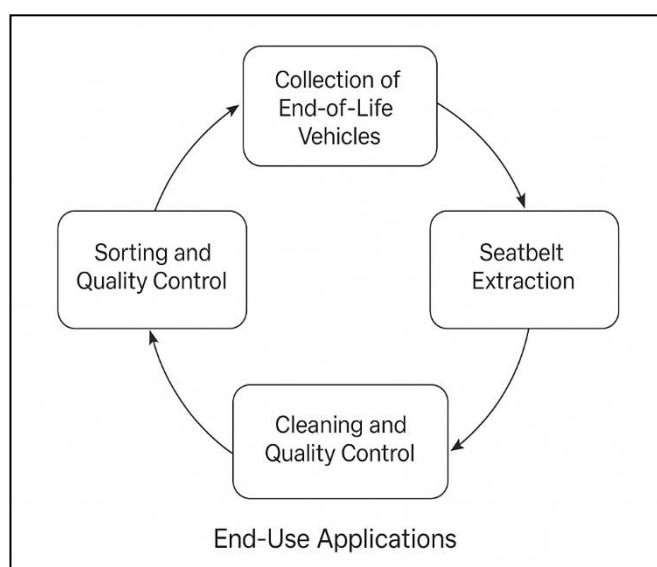


Figure 1: Recycling and Reuse Strategies

##### 4.1 MECHANICAL RECYCLING: TRANSFORMING USED FIBERS THROUGH PHYSICAL PROCESSES

Mechanical recycling is one of the most widely adopted and economically feasible methods for recovering value from synthetic textiles. This approach involves physically processing used materials—without altering their chemical composition—to produce secondary products. It is advantageous due to its simplicity, low cost, and minimal environmental burden, as it does not require solvents or chemical reactions(18).

One practical method in this category involves **cutting and re-weaving the used textile fibers into new materials**. In this process, discarded polyester seat belts or similar materials are first collected and thoroughly cleaned to remove dirt, oils, and

contaminants. They are then mechanically cut into uniform strips or threads, which are subsequently re-woven using manual or semi-automated looms. The re-woven fabric retains much of the original strength and integrity of the base material and can be used in producing items such as bags, rugs, or reinforcing layers in composite products. This technique is particularly effective when the original materials are still structurally sound but no longer suitable for their original application(19).

Another mechanical recycling approach involves utilizing these fibers in **non-critical structural applications**, where the demands on mechanical properties are significantly lower. For instance, mechanically shredded fibers can be used as filler materials in acoustic insulation, automobile interior



panels, or thermal padding. These applications do not require high tensile strength or load-bearing capacity, making them ideal for recycled materials. This method provides an excellent outlet for materials that are otherwise difficult to recycle chemically or are slightly degraded. Furthermore, since the process bypasses complex chemical treatments, it helps conserve energy and avoids secondary pollution (Table 3)(14).

#### 4.2 Chemical Recycling: Breaking Down Polymers to Recover Base Monomers

Chemical recycling represents a more advanced and technically sophisticated strategy for managing synthetic textile waste. Unlike mechanical recycling, chemical recycling involves **breaking down the polymer chains** of materials like polyester through chemical reactions, allowing the recovery of original monomers that can be re-used to synthesize new, virgin-quality polymers. This process closes the loop more completely than mechanical recycling, especially for high-performance or pure polymeric materials(13).

One of the most promising directions in this area is the **depolymerization of polyester fibers**, such as polyethylene terephthalate (PET), commonly used in seat belts and technical textiles. In this method, polyester is subjected to hydrolysis, glycolysis, or methanolysis reactions, breaking the long-chain polymers into their monomeric constituents—primarily terephthalic acid (TPA) and ethylene glycol (EG). These monomers are then purified and used as raw materials in new polymerization processes, effectively creating “like-new” polyester without the environmental burden of virgin fossil-derived inputs. This approach is particularly useful when dealing with materials that have been contaminated or degraded, making them unsuitable for mechanical reuse(9).

However, the chemical recycling of polyester and similar materials is still faced with several **technical and economic limitations**. The process requires **high energy inputs, precise control of reaction conditions**, and

extensive **pre-sorting and cleaning of the input materials** to prevent interference from dyes, finishes, or other polymers. The scalability of chemical recycling technologies is still under development, with most processes currently at the pilot or demonstration scale. Experimental research is focusing on **catalytic enhancements, green solvents, and enzyme-assisted depolymerization** to lower the energy requirements and improve efficiency. While not yet widespread, chemical recycling holds significant promise for the future, particularly in achieving high-purity recovery from post-consumer textile waste(19).

#### 4.3 Direct Reuse Applications: Innovative and Immediate Repurposing of Materials

Direct reuse represents the most environmentally and economically efficient strategy among the three, as it involves **repurposing the material in its current form without undergoing any physical or chemical transformation**. This method is especially suitable for high-strength and visually appealing materials like seat belts, safety harnesses, and woven nylon ropes, which retain their functional properties even after their original usage life(21).

One of the most popular applications of direct reuse is in the **fashion and accessories industry**, where upcycled materials are used to create stylish and durable items such as **bags, belts, wallets, and wearable accessories**. For example, seat belts—due to their glossy finish, tensile strength, and wide color range—have been creatively transformed into handbags, camera straps, and utility pouches. Eco-conscious designers often market these products under the upcycling and sustainability banner, catering to environmentally aware consumers. Not only does this strategy prevent waste from ending up in landfills, but it also adds aesthetic and economic value to what would otherwise be discarded material(23).

In the **furniture and upholstery sector**, strong synthetic textiles are being reused in crafting **chair backs, seat bases, and decorative bindings**. These materials provide both functional support and a modern

industrial aesthetic, appealing to interior designers and manufacturers looking to combine sustainability with style. Woven seat belts, for example, can replace webbing in mid-century modern furniture designs, offering a high-strength, long-lasting alternative to traditional materials(24). Additionally, there is increasing interest in **industrial applications of reused synthetic materials**, especially in areas where their original properties—such as strength,

flexibility, and abrasion resistance—are still beneficial. Old seat belts and similar items can be reused as **cargo straps, tie-downs, securing belts for transportation**, or even as protective edging in packaging and handling systems. These applications do not require further treatment or reprocessing, making them ideal for immediate reuse, often with minimal modification such as cutting or stitching(25).

**Table 3: Recycle and Reuse Applications and Strategies**

Strategy	Key Process	Example Applications	Advantages	Limitations
<b>Mechanical Recycling</b>	Cutting, shredding, re-weaving	Rewoven mats, bags, insulation, automotive linings	Cost-effective, retains strength, low environmental impact	Limited to non-critical applications; quality may degrade
<b>Chemical Recycling</b>	Depolymerization via hydrolysis, glycolysis, methanolysis	Recovery of monomers (TPA, EG) for virgin polymer production	High purity output, closed-loop potential	Energy-intensive; requires pure feedstock; limited scalability
<b>Direct Reuse Applications</b>	Repurposing without processing	Bags, belts, wallets, furniture straps, cargo tie-downs	Lowest cost and energy use; creative applications	Aesthetic and dimensional limitations; not always scalable

## 5. CASE STUDIES AND INNOVATIONS

In recent years, the upcycling of industrial-grade synthetic textiles—particularly seatbelt webbing—has transitioned from a niche practice to a globally recognized sustainability innovation. A growing number of designers, brands, and community-led projects are reimagining post-consumer and post-industrial waste as high-value inputs for fashion, furniture, and utility items. These efforts not only reduce environmental impact but also bring socio-economic benefits through job creation, empowerment of marginalized communities, and consumer education(8). This section highlights key examples of innovative use of recycled seatbelt webbing, the roles played by artisan-led initiatives, and how these products

perform in the market in terms of both function and consumer appeal.

Brands and Designers Using Recycled Seatbelt Webbing: The Example of Elvis & Kresse

One of the most prominent examples of commercial innovation using recycled seatbelt webbing comes from the British brand **Elvis & Kresse**, founded in 2005. This brand pioneered the luxury upcycling movement by transforming decommissioned fire hoses and automotive seatbelts into **high-end bags, wallets, and accessories**. The company sources used seatbelt materials from salvage operations and waste disposal sites, selecting only the highest-quality items for reconditioning(13).

The process includes **deep cleaning, flattening, and precision cutting** of the webbing, followed by handcrafting into durable and aesthetically pleasing products. Elvis & Kresse's designs emphasize minimalism and sustainability, often retaining the original texture and patina of the material as a unique design element. Their products have been featured in major fashion outlets and sustainability expos, earning recognition for their innovation in both design and environmental responsibility(14).

A key aspect of Elvis & Kresse's model is **full transparency and circularity**—a portion of their profits goes toward charitable donations and funding recycling research. Their success showcases how industrial waste, when approached with creativity and ethical intention, can be transformed into luxury products that rival those made from virgin materials. This example has inspired other startups and fashion houses to explore seatbelt webbing as a robust, stylish alternative to leather and synthetic composites(2).

Community and Artisan-Led Projects: Empowering Through Upcycling

Beyond corporate initiatives, a vibrant ecosystem of **community-based and artisan-led projects** has emerged, especially in developing regions. These projects often focus on empowering underprivileged groups—such as women, refugees, and local craftspeople—by equipping them with skills and resources to create marketable products from recycled materials.

For instance, NGOs and cooperatives in parts of Africa, South America, and Southeast Asia have integrated **seatbelt upcycling into their vocational training programs**. Discarded seatbelts are distributed to artisans, who are trained in **basic tailoring, weaving, and leatherwork techniques**. The finished products—ranging from laptop sleeves and messenger bags to belts and home décor items—are then sold in local and international markets. These initiatives not only divert waste from landfills but also **generate income, build community**

**resilience, and promote circular economic models**(23).

One such example is the **Green Sakthi project in India**, which collaborates with local tailors and women's self-help groups to convert seatbelt waste into eco-friendly utility bags. The project operates on the principles of zero-waste production and fair trade, ensuring that the artisans receive equitable compensation and recognition for their work. These programs serve as a **blueprint for sustainable development**, where environmental action intersects with economic empowerment(26).

Product Performance and Consumer Reception: Market Viability of Upcycled Seatbelt Products

An essential dimension of any upcycling innovation is the performance of the final product and its acceptance in the market. Seatbelt webbing offers a unique set of advantages that make it particularly suitable for reuse: **high tensile strength, resistance to abrasion and moisture, UV stability, and aesthetic appeal**. These properties contribute to long-lasting products that often **outperform conventional fabrics and even leather** in specific use-cases(27).

Consumer reception of upcycled seatbelt products has been overwhelmingly positive, especially among environmentally conscious buyers. Surveys and product reviews indicate high satisfaction levels regarding **durability, uniqueness, and the ethical story behind the product**. In fact, many customers report being drawn to these items not just for their functionality, but because they represent a tangible commitment to sustainability and responsible consumption.

Moreover, upcycled seatbelt goods have begun to **gain traction in niche luxury and eco-fashion markets**, where exclusivity and sustainability are valued. Brands emphasize the **narrative aspect**—each product tells a story of transformation, often labeled with information about the material's origin (e.g., former seatbelt from a decommissioned vehicle). This marketing approach appeals to millennials and Gen Z consumers who

prioritize ethics and environmental impact in their purchasing decisions(28).

On the technical side, rigorous testing has shown that seatbelt-derived textiles maintain **exceptional strength and flexibility** even after years of wear, making them ideal for **load-bearing products such as straps, belts, and furniture components**. Additionally, the material's glossy, ribbed surface provides a distinctive aesthetic that sets it apart from other upcycled or recycled materials(29).

## 6.ENVIRONMENTAL AND ECONOMIC IMPACT

The recycling and repurposing of seatbelt webbing and similar synthetic materials carry **significant environmental and economic benefits**, particularly in the context of sustainable industrial design and waste management. These benefits become clearer when examined through a detailed **life cycle assessment (LCA)**, a comparative cost-benefit analysis against virgin material use, and the lens of systemic change toward a **circular economy** within the automotive and textile sectors(28).

Life Cycle Analysis: Carbon Footprint Reduction and Energy Savings

Life cycle analysis (LCA) is a methodological approach used to evaluate the **total environmental impact** of a product or material across all stages—from raw material extraction, manufacturing, use, and end-of-life disposal or recycling. In the case of seatbelt webbing, which is typically made from **high-strength synthetic fibers like polyester (PET), nylon, or polypropylene**, the production of virgin materials involves **energy-intensive petrochemical processes**. These include extraction, polymerization, spinning, weaving, and finishing—all of which emit considerable **greenhouse gases (GHGs)** and consume large volumes of water and fossil fuels(22).

Recycling and upcycling seatbelt materials, however, significantly reduces these environmental burdens. By **reusing existing fibers** instead of manufacturing new ones, the energy demand associated with polymer synthesis and weaving is effectively

bypassed. Multiple LCA studies indicate that mechanical recycling of PET and nylon can result in **up to 60–80% energy savings** compared to virgin production. Furthermore, reusing seatbelt webbing directly (without reprocessing) has an even lower carbon footprint, since it involves **minimal transportation, no thermal processing, and no chemical inputs**. This drastically reduces emissions of CO<sub>2</sub> and other GHGs(23).

Additionally, diverting seatbelt waste from landfills helps reduce environmental pollution, especially because these synthetic fibers are **non-biodegradable** and can persist in the environment for hundreds of years. Preventing incineration also avoids the release of **toxic byproducts such as dioxins and furans**, which are commonly associated with burning synthetic textiles(30).

Cost-Effectiveness Compared to Virgin Materials

From an economic standpoint, the **reuse and recycling of seatbelt webbing** offers a promising cost-effective alternative to virgin synthetic materials, particularly as raw material prices and regulatory pressures increase. The production of virgin fibers involves fluctuating costs tied to global oil markets, energy prices, and supply chain logistics. In contrast, **recycled seatbelt material is often available at low or no cost**, especially when sourced from automotive scrapyards, manufacturing waste, or decommissioned vehicles(28).

The cost benefits extend beyond raw material acquisition. Processing seatbelt webbing for reuse involves **simple cleaning, cutting, and sewing**, which require **less machinery, lower energy use, and fewer skilled labor inputs** than traditional textile manufacturing. As a result, businesses that adopt these practices can achieve **substantial savings in production costs**, which may be passed on to consumers or reinvested into product innovation and sustainability initiatives(25).

Additionally, many brands leveraging recycled materials benefit from **eco-labeling, green certifications, and government incentives**, which can offset initial processing costs or provide access to



sustainable financing. Consumer willingness to pay a premium for ethically produced and environmentally friendly goods further enhances profitability. Studies have shown that sustainable fashion products can command **10–20% higher prices**, especially in high-income markets where environmental consciousness is strong(23).

Potential for Circular Economy Integration in the Automotive Sector

The integration of seatbelt recycling into a **circular economy model** offers transformative potential for the automotive industry. Traditionally, automotive manufacturing has operated on a **linear "take-make-dispose" model**, resulting in large-scale waste, including thousands of tons of synthetic webbing discarded each year from end-of-life vehicles. However, with the emergence of circular economy principles, there is a shift toward designing systems that **maximize resource utility, minimize waste, and retain value within the supply chain**(26).

Seatbelt webbing, given its high durability and single-material composition, is ideally suited for circular design strategies. For example, **automotive manufacturers could design seatbelt systems for disassembly**, enabling easier recovery and sorting of materials. These recovered belts can then be **remanufactured into non-critical interior components**, insulation pads, or sold to third-party upcycling ventures, effectively closing the material loop.

Moreover, collaboration between car manufacturers and sustainable design companies—such as those producing fashion items or furniture from recycled automotive materials—can create **industrial symbiosis**, where waste from one sector becomes input for another. This not only conserves resources but also enhances **brand reputation, compliance with extended producer responsibility (EPR) laws, and alignment with global sustainability goals**, such as those outlined in the EU Green Deal and UN Sustainable Development Goals (SDGs)(27).

Incorporating these practices also helps companies **achieve carbon neutrality targets**, as material circularity directly reduces Scope 3 emissions—those associated with downstream waste treatment and product end-of-life. Thus, seatbelt recycling and reuse are not just isolated waste management solutions but integral components of a **strategic shift toward sustainable and regenerative industry models**.

## 7. CHALLENGES AND LIMITATIONS

While the reuse and recycling of seatbelt webbing hold considerable promise for sustainability and economic value, the path toward widespread adoption is fraught with **technical, regulatory, and market-related challenges**. These limitations must be carefully addressed to ensure that products made from recycled seatbelt materials meet the necessary safety, performance, and consumer acceptance standards. This section explores the major obstacles in three key domains: **safety and quality assurance, certification and regulatory issues, and market-related barriers**(20).

Safety and Quality Control in Reused Materials

One of the most pressing challenges in repurposing seatbelt webbing lies in **ensuring the safety, reliability, and integrity of the reused material**. Seatbelts are designed to absorb shock and endure extreme tensile stress during vehicle collisions. Once involved in an accident or subjected to prolonged environmental exposure, their **mechanical properties can degrade**—even if the damage isn't visibly apparent. Issues such as **UV degradation, chemical exposure, microbial colonization, fraying, or internal fiber weakening** can compromise the structural performance of the webbing. Reusing such compromised materials—especially in load-bearing applications—can pose serious risks(29).

As a result, any upcycling or reuse project involving seatbelt materials must incorporate **rigorous screening, inspection, and quality assurance protocols**. However, this presents practical challenges, as conventional textile



inspection techniques often do not detect **sub-surface fiber degradation** or prior mechanical stress. Advanced testing methods, such as **tensile strength measurement, spectroscopy, or thermal analysis**, are expensive and not always feasible for small-scale or community-based projects. Thus, many initiatives are forced to **limit their use of seatbelt webbing to non-critical, low-risk applications**, such as fashion accessories or decorative elements, rather than functional safety gear or industrial straps.

The lack of uniform access to testing equipment and protocols leads to **variability in product quality**, which can further hinder consumer trust and regulatory approval. For recycled seatbelt products to enter broader markets confidently, **standardized evaluation methods and safety benchmarks** are essential(28).

#### Standardization and Certification Issues

Another major limitation is the **absence of universal standards and certifications** for recycled synthetic webbing. In contrast to virgin materials—which are manufactured under strict ISO, ASTM, or EN standards—recycled materials lack a consistent regulatory framework. This regulatory vacuum leads to ambiguity in classification, labeling, and compliance, especially in international trade. For instance, products made from upcycled seatbelt webbing may face **border clearance issues, certification delays, or product recalls** if they do not meet the destination country's safety and consumer protection regulations(17).

Moreover, the **current certification landscape is fragmented**, with multiple eco-labels and sustainability seals offering different criteria for recycled content, ethical sourcing, and environmental impact. For small and medium enterprises (SMEs), navigating this complex landscape can be cost-prohibitive and time-consuming. Achieving certifications such as **Global Recycled Standard (GRS), OEKO-TEX Standard 100, or Cradle to Cradle Certified™** requires thorough documentation, third-party audits, and

traceability—all of which can be challenging when sourcing post-consumer seatbelts from diverse waste streams(26).

In the absence of recognized certifications, many manufacturers struggle to **communicate product safety and sustainability credibly**, which limits market access—particularly to government tenders, institutional buyers, or eco-conscious retailers. The establishment of **standardized certification systems specific to automotive textile recycling** would help streamline the process and encourage broader industry participation.

#### Market Barriers and Consumer Perceptions

The third significant hurdle is the set of **market-related barriers**, particularly related to **consumer awareness, perception, and acceptance** of products made from recycled seatbelt webbing. Despite a growing interest in sustainable products, many consumers remain hesitant to purchase items made from reclaimed automotive materials, often due to **misconceptions about hygiene, safety, aesthetics, or durability**. Some associate seatbelts with trauma (e.g., car crashes), leading to a **psychological aversion** to using them in personal items like bags or belts(30). Furthermore, upcycled products often face **prejudice as “inferior” or “handmade substitutes”** rather than as premium, design-forward goods. This perception is exacerbated when such products are positioned in the same price bracket as high-end leather or canvas items. Bridging this perception gap requires not only superior product quality but also **educational marketing strategies** that emphasize the environmental benefits, craftsmanship, and uniqueness of each item(16).

Market scalability is also an issue. While niche consumer segments (such as eco-conscious millennials) may embrace upcycled seatbelt goods, **mainstream adoption remains limited**. In addition, **retail channels and e-commerce platforms** often do not provide the right positioning or visibility for such products, making it hard for smaller producers to reach the right audience. Without sustained marketing

investment and brand development, upcycled seatbelt products can remain confined to artisan markets or local fairs(14).

In response, several forward-thinking brands and cooperatives are using **storytelling, transparency, and traceability tools** (e.g., QR codes linking to material provenance) to boost consumer confidence. However, widespread adoption will require stronger **institutional support, incentives, and awareness campaigns** to overcome these ingrained market challenges.

## 8. FUTURE PROSPECTS AND RESEARCH DIRECTIONS

The future of recycling and reusing seatbelt webbing is increasingly aligned with the advancement of **smart materials and functional material science**, where conventional textiles are enhanced through **coatings, chemical modifications, or hybrid integration with other sustainable materials**. Researchers are exploring methods to convert used seatbelt webbing into **composite materials** by embedding them within biodegradable or recycled matrices, thereby increasing their utility in structural applications such as building panels, automotive interiors, or modular furniture. In addition, functional coatings—such as flame retardants, antimicrobial finishes, or hydrophobic treatments—can be applied to repurposed seatbelt materials to expand their usability in sectors like medical textiles, transportation upholstery, or disaster relief products. These enhancements could help overcome some of the current performance limitations of recycled materials and open up **new industrial markets** that require specialized material properties(21).

Equally important is the **integration of reused seatbelt webbing into eco-design principles**, which advocate for sustainability throughout a product's life cycle—from resource-efficient manufacturing to modular design for easy disassembly and recycling at end-of-life. By embedding recycled materials like seatbelt webbing into the **early stages of product design**, manufacturers can reduce environmental impact while also improving circularity and product longevity. This

includes designing for durability, multipurpose functionality, and aesthetic appeal, so that sustainable products are not only environmentally friendly but also desirable to consumers. The application of **life cycle thinking and cradle-to-cradle design** frameworks can ensure that products incorporating repurposed webbing meet the rising demand for responsible consumption and production. Furthermore, product labeling and digital tracking systems can be used to enhance transparency and consumer trust, allowing buyers to make informed, ethical choices(26).

Scaling up these innovations will require **strong collaboration between policymakers, industry stakeholders, academic researchers, and waste management sectors**. Government policy can play a crucial role by introducing **extended producer responsibility (EPR) schemes**, offering subsidies or tax incentives for companies using recycled automotive waste, and setting minimum recycled content mandates in public procurement. Meanwhile, industry-led consortia can pool resources for **shared recycling infrastructure**, material recovery facilities, and research into advanced recycling technologies such as enzymatic or solvent-based fiber recovery. Academia can contribute through **interdisciplinary research**, combining polymer chemistry, industrial design, and systems thinking to refine processing techniques, optimize material properties, and reduce costs. International cooperation and alignment with global standards—such as the EU Circular Economy Action Plan or ISO sustainability standards—can further accelerate adoption and promote market harmonization.

Overall, the future of seatbelt recycling and reuse lies at the intersection of **material innovation, circular product design, and systems-level policy integration**. As consumer awareness grows and environmental regulations tighten, these directions represent not only environmental imperatives but also **economic opportunities**

for industries seeking to stay competitive in a resource-constrained world(28).

## 9. CONCLUSION

The exploration of seatbelt webbing reuse reveals a compelling intersection of sustainability, innovation, and material science. This practice not only provides an environmentally responsible solution to post-consumer automotive waste but also offers a versatile raw material with high tensile strength, durability, and aesthetic appeal. Through applications ranging from fashion accessories to furniture and industrial products, reused seatbelt webbing demonstrates considerable potential to contribute to circular economy goals. Mechanical and chemical recycling techniques, direct reuse, and hybrid material integrations have opened new avenues for both large-scale manufacturers and grassroots artisans to engage in eco-conscious production.

However, realizing the full potential of this practice depends significantly on the advancement of innovative processing technologies and functional material enhancements. Smart coatings, composite engineering, and integration into eco-design frameworks can help overcome current performance limitations and broaden the scope of application. Equally critical is the development of clear standards and certifications, as well as supportive policy frameworks that incentivize the adoption of recycled materials. Policies such as extended producer responsibility, subsidies for sustainable manufacturing, and minimum recycled content requirements can catalyze industry-wide shifts.

In final reflection, the reuse of seatbelt webbing is not only viable but increasingly necessary in a world grappling with resource scarcity and climate change. With the right combination of technological innovation, supportive regulation, and market education, seatbelt webbing can transition from waste to valuable resource—offering both environmental and economic returns. As industries and consumers move toward more sustainable choices, this form of material

reuse stands as a practical and impactful strategy in the journey toward a circular and resilient future.

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