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Environmental Considerations and Sustainable Solutions for Outdoor Advertising Banners

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Abstract: Despite advancements in digital technology, outdoor advertising remains a robust communication tool with broad audience appeal. However, heightened environmental awareness necessitates proactive measures within the industry. This study examines the environmental impact of banners and proposes sustainable strategies. Market analysis underscores the widespread use of banners despite alternative advertising methods, prompting an investigation into their environmental implications and mitigation solutions. The research specifically focuses on prolonging banner lifespan and campaign duration through innovative recycling approaches aligned with circular economy principles. A comprehensive literature review informs these models and strategies, identifying opportunities for sustainable banner management. A case study approach is employed to present the transformation of banners into functional raincoats using Gemini X20 Pattern Designer software. The study emphasizes the optimization of resources and adherence to copyright regulations. This practical example demonstrates the feasibility and benefits of recycling in outdoor advertising. Collaborations with tailoring workshops facilitate community engagement and contribute to economic benefits. The implementation of these practices by companies serves to enhance their sustainability credentials and leadership in environmental responsibility within the outdoor advertising sector. In conclusion, this study provides valuable insights into sustainable practices that mitigate environmental impacts while fostering economic and social benefits.

Keywords: outdoor advertising; banner; circular economy; upcycling; Gemini CAD software

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1. Introduction

Outdoor advertising, also known as out-of-home advertising, stands as one of the earliest forms of mass communication known to humankind [1]. Despite the rise of online advertising platforms, which have revolutionized traditional advertising methodologies [2,3], outdoor advertising maintains its relevance and efficacy in the modern era. Its enduring value lies in its capacity to engage with a broad audience simultaneously [4]. Many enterprises continue to integrate outdoor advertising into their marketing strategies alongside digital campaigns, recognizing the distinct advantages each medium offers in reaching diverse demographics and fulfilling varied promotional objectives.

However, amidst a growing societal consciousness regarding environmental sustainability, it becomes imperative for the outdoor advertising industry to adopt a proactive approach toward environmental concerns. This article aims to highlight the critical role of environmental considerations in out-of-home advertising and to outline strategies aimed at promoting sustainability within this sector. The research objective is to offer an overview of the current landscape of outdoor advertising, with a specific focus on the environmental impact of banners used in this industry.

The primary aim is to investigate models and strategies that can extend the lifespan of banners while also prolonging the duration of advertising campaigns. This research objective aligns with market research findings [5], which indicate a significant increase in

the use of banners for outdoor advertising, despite the availability of several alternative advertising methods. Consequently, the first research question arises: What are the advantages and disadvantages of banners, including their environmental impact, and what viable solutions exist to mitigate their negative effects? This area of study has been relatively underrepresented in academic discourse, as most research in the field has primarily focused on the marketing aspects of advertising campaigns [6–8], specifically the effectiveness of outdoor advertising with particular attention to recall and recognition [9]. As a result, there has been limited examination of potential methods and strategies that could be employed to extend the longevity of banners beyond their initial use and integrate them into a closed-loop system [10].

The second area of research focuses on identifying solutions to extend the lifespan of banners through upcycling and integrating new products into extended advertising platforms. This leads to the second research question: What innovative models and strategies can be developed to prolong the lifespan of banners through upcycling, particularly in terms of designing materials that can be reused in subsequent advertising activities?

To answer the above research questions and objectives, we build a framework by conducting a comprehensive review of the existing literature, which includes market reports, academic journals, and research papers that examine the role of banners in the outdoor advertising industry. This review also explores the environmental issues that arise during the production and disposal phases of banners, while identifying solutions oriented towards circular economy principles. The subsequent analysis integrates the findings from this literature review and specifically addresses the two defined research questions. Section 2 provides an elaboration on the answer to the first research question, while Sections 3 and 4 focus on the answer to the second research question. Section 4 presents a detailed case study of transforming a banner into a raincoat, illustrating the practical applications of sustainable practices in the outdoor advertising sector. In this context, we put forth the design of a waterproof material derived from a banner and its utilization as an alternative format for outdoor advertising platforms. This is to be achieved by leveraging the capabilities of Gemini CAD software for precise design and implementation.

2. Advantages, Disadvantages, and Environmental Impact of Banners

2.1. Overview of the Outdoor Advertising Industry

Traditionally, out-of-home (OOH) advertising accounted for a smaller share of advertising budgets [11]; however, there has been a noticeable increase in overall expenditure in recent years. According to statistics, the global outdoor advertising market size was valued at USD 21.96 billion in 2022, and in the next period, it is expected to continue its growth and diversification to reach USD 40.49 Billion by 2032, growing at a CAGR of 6.3% during the forecast period [5].

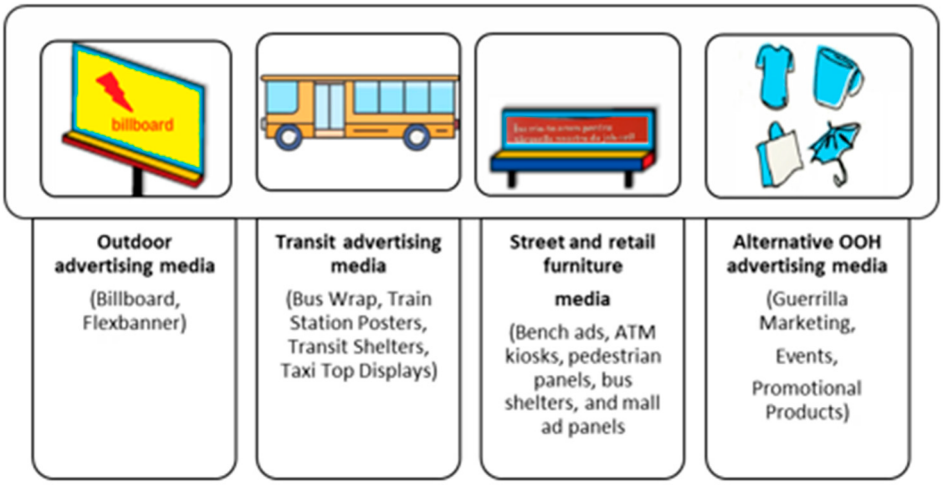
The prevalent tools employed in outdoor advertising encompass a range of formats. Billboards, characterized by their stationary and distinct panels and posters, stand out as one of the most commonly utilized formats [2].

Transit advertising involves strategically positioning advertisements on public transportation vehicles and facilities, spanning a variety of locations such as the exterior of buses, trains, and taxis, as well as the interior of subway cars, bus stations, and areas near train or bus platforms. Another notable form of outdoor advertising media within this realm includes transit panels, which are prevalent in diverse settings such as airports, trains, subways, buses, and taxis.

Street furniture advertisements, such as those displayed on benches in transportation hubs, ATM kiosks, pedestrian panels along walkways, bus shelters, phone kiosks, and mall ad panels, offer targeted and impactful out-of-home advertising at street level. These advertisements are strategically positioned at eye level to ensure easy visibility and to establish a high-impact connection with pedestrians and commuters alike. Benches represent the most prevalent type of street furniture advertising. Bench advertisements are typically found in transportation hubs, offering an affordable and highly targeted marketing channel to reach

both drivers and pedestrians. These advertisements are employed to target and engage with key segments of the audience, as they can be strategically located in city centers, airports, bus stations, and other high-traffic areas.

Promotional products, encompassing items such as hats, t-shirts, bags, and umbrellas, serve as an effective strategy for outdoor brand promotion. These products can be disseminated during events or integrated into marketing initiatives. Through the utilization of promotional items, individuals essentially transform into mobile brand ambassadors, amplifying brand visibility as they incorporate these products into their daily routines. A comparative analysis of the main traditional methods of outdoor advertising is presented in Figure 1.



Outdoor advertising audience			
Vehicular traffic	Commuters	Pedestrian, Shoppers	Specific targets
Outdoor advertising media environment			
Roadside	Traffic	Lesure, Shopping	Various locations
Ability for interaction/engagenment			
Low		High	

Figure 1. Comparison of the major traditional outdoor promotional advertising methods.

The recent period has witnessed significant developments in the advertising sector, with the advent of digital billboards. These digital displays permit the incorporation of dynamic content that can be updated remotely and tailored to specific audiences or times of day. The incorporation of animations, videos and interactive elements enables advertisers to utilize digital billboards to greater creative effect and with greater impact. Furthermore, the field of outdoor advertising has also undergone a technological transformation. The integration of augmented reality (AR) and quick response (QR) codes has facilitated the convergence of the physical and digital realms [12,13]. The integration of digital experiences with physical advertisements enables the creation of immersive and interactive campaigns that capture attention and provide real-time engagement. However, among these various formats, billboards emerge as the most popular and widely utilized means of outdoor advertising [14].

The market segmentation includes categories such as static billboards, digital billboards, transit advertising, street furniture advertising, place-based advertising, and others. Among these, the static billboards segment held the largest revenue share of 37.8% in 2022. Despite the prevalence of digital technologies and online advertising, static billboards retain significant relevance and occupy a prominent position in out-of-home (OOH) advertising strategies. The traditional out-of-home advertising sector represents the largest segment within the OOH market, with a market volume of USD 20.62 billion in 2024 [15]. The projected average ad spending per capita in the out-of-home advertising market is

estimated to be USD 5.07 in 2024 [15]. Ad spending in Europe's Out-of-Home Advertising market is projected to reach US$7.71 billion in 2024, with the largest sector being traditional OOH advertising, totaling US$4.30 billion in 2024. The average ad spending per capita in Europe's out-of-home advertising market is forecasted to be USD 9.14 in 2024 [16]. This is not only because of its cost-effectiveness but also because it remains one of the most effective means of reaching increasingly elusive consumers.

As the world becomes increasingly digital, outdoor advertising provides an anchor for integrated marketing communications strategies that are designed to engage consumers across multiple channels. Billboards, a prominent form of out-of-home (OOH) advertising, offer numerous advantages identified by academic researchers [17,18], including wide reach, high visibility, proximity to point of sale, frequent exposure to commuters, continuous presence, geographic flexibility, cost efficiency, visual impact, and enhanced brand awareness due to their stationary nature and memorable size and message [19].

Banners, differing from billboards in construction materials, exposure duration, and flexibility, primarily offer the same advantages. The specific advantage of banners lies in their ability to be used in narrower or temporary contexts, such as local events or specific promotions, contributing to more precise audience targeting and the adaptability of advertising campaigns to the specific needs and requirements of each context [20]. Flex banners are extensively utilized in various domains such as digital printing for advertising, wall coverings for decorative art, exhibition displays for informative purposes, and illuminated canvas printing arts.

Flex vinyl banners have become a popular choice for outdoor advertising due to their ability to withstand various weather conditions while still maintaining vibrant and high-quality graphics. Their popularity has grown over the years due to advancements in printing technology, which allow for high-quality graphics and designs to be printed on flex vinyl banners. Additionally, their cost-effectiveness compared to other outdoor advertising materials also makes them a popular choice for many advertising campaigns. Therefore, the global flex banner market size is expected to grow from USD 2.87 billion in 2022 to USD 3.06 billion by 2030, at a CAGR of 7.2% during the forecast period [21].

The average lifetime of a flex banner ranges from 6 months to 7 years, depending on the thickness and other technical parameters [22]; however, the average lifetime of an outdoor campaign can vary greatly, from a few days to 3–5 years depending on the type of campaign and the environment in which it is placed [22]. The out-of-home advertising in each European country is influenced by its unique cultural, social, and regulatory landscape. For instance, countries such as the Netherlands or Belgium, with high population densities, exhibit heightened demand for out-of-home advertising due to extensive daily exposure. Conversely, nations with stringent advertising regulations such as France or Germany may experience limitations on the placement and content of out-of-home advertisements [16]. However, generally, banner outdoor campaigns can last anywhere from a few weeks to several months.

2.2. Flex Banners and the Environmental Impact

The global flexible banner market is highly fragmented, with a number of prominent players operating in fierce competition. In addition, several local players, as well as smaller companies, hold a majority of the flexible banners market share. Major players in the global market include Ultraflexx, Qrex Flex, Pioneer Flex, LG, 3M, Cooley Brand, and Hongshida [23].

A flexible banner is commonly known as a "PVC banner", which is a misnomer because it is a three-layer laminated structure in which polyester material is sandwiched between films composed of calcium carbonate ($CaCO_3$), polyvinyl chloride (PVC) resin, plasticizers, and additives. For banners that are laminated, it is common to use a special polyester fabric between the two PVC films. The PVC is melted and then extruded into a thin sheet, which is then cut into the desired shape and size. Chemically, PVC is a polymer that is made up of repeating units of vinyl chloride (CH2=CHCl). During the production of

PVC, the vinyl chloride monomer is polymerized, resulting in a long-chain polymer. Vinyl has a flexural modulus of 2.2–3.4 GPa, a flexural strength of 24–34 MPa, a tensile strain at break of 0.2–1.2%, and a tensile stress at break of 8–17 MPa [10].

Vinyl is used in liquid form and is composed of a series of chemicals, primarily vinyl chloride and a plasticizer. Plasticizers serve as softening agents that provide added flexibility; they can be monomeric or polymeric. The utilization of polymeric plasticizers confers upon the final product a greater degree of resistance over time than monomeric plasticizers (approximately one year). This polyester fabric serves as a backing layer and is often a heavier, denser polyester fabric to provide strength and durability. The polyester material's strength is derived from the polyester matrix fabric, which is a macromolecular chemical composed of numerous ester molecules. This polyester layer between the two PVC sheets helps to increase the strength of the banner and prevent tearing or damage during outdoor use. The quality of the polyester used in the production process is of significant importance. The polyester material gives rigidity and durability, while the PVC films give flexibility and allow low-cost digital printing of flexible banners [24]. The resulting PVC material is strong, flexible, and resistant to a variety of chemicals and environmental conditions.

The unit of measurement specific to the linear weight of the matrix fibers is the denier. Typically, matrix values can vary between 150 and 1000. The types of fabrics commonly used in banner production are 300 × 500, 500 × 500, 500 × 1000, and 1000 × 1000. The weave is the primary determinant of the material's strength, although a higher weave density does not necessarily guarantee strength. PVC has been criticized for its potential negative environmental impact, particularly during production and disposal [25–27].

The entire life cycle of the polyvinyl chloride banner industry results in the generation of a considerable quantity of solid, airborne, and liquid wastes, as well as other environmental toxins that have a detrimental impact on the environment and future generations. The energy consumption of a solvent-based coating, which is usually dried by IR light, is considerably higher than that of a pure UV coating. The use of mercury vapor lamps in UV curing has the potential to result in the emission of ozone. Isopropyl alcohol and the aromatic hydrocarbon toluene are commonly used solvents in printing technology. The chemicals emitted into the atmosphere during the printing process have the potential to form ozone through a photochemical process. In addition to emissions generated during the printing process, the potential for emissions to occur subsequently is also worthy of consideration. The toluene retained in the printed products has the potential to pose a risk to human health [25]. The production of PVC can release toxic chemicals into the air and water, and PVC waste can take hundreds of years to degrade in landfills.

PVC is notoriously resistant to biodegradation due to its persistent, hydrophobic, and abrasion-resistant properties. Despite these limitations, previous studies have demonstrated that PVC biodegradation is subject to microbial cultures that degrade the plastic into low molecular weight organic compounds, which are subsequently mineralized to CO_2.

The recycling of PVC materials can be achieved through a number of different processes, including mechanical, chemical, and energy recovery methods [28]. Chemical recovery entails the degradation of PVC through dehydrochlorination, resulting in the formation of low-molecular weight fractions, crosslinking, and the introduction of oxygenated groups [29]. Energy recovery, typically through incineration, has been a prevalent approach employed for the treatment of plastic waste. Nevertheless, the combustion of plastics during incineration processes releases noxious gases that have been linked to deleterious effects on human health, including carcinogenic outcomes and reproductive impairments. Burning PVC requires a high temperature of around 300 °C, which not only affects the immediate environment but also releases harmful pollutants such as sulfates and nitrates that are heavier than air and reduce the supply of oxygen [30]. Chlorine in PVC leads to the creation of dioxins and other chlorinated organic compounds, which are then released into the environment [31]. Additionally, PVC gradually leaches into the soil, contaminating it [32,33]. The cost of protective measures, such as lining landfills, to prevent leachate

from contaminating groundwater and soil can be high and may not be effective in terms of environmental protection [34].

The disposal of discarded banners has a significant impact on the accumulation of plastic waste in landfills, which in turn poses a number of significant environmental, community, and human health risks. Furthermore, the intricate composition of banners renders their recycling process challenging, resulting in a low recycling efficiency. The recycling of vinyl banners is challenging due to their complex composition and the presence of ink and other coatings on the surface of the material. In general, recycling PVC requires specialized processes that are not widely available, and the lack of infrastructure for PVC recycling can make it challenging to recycle PVC materials such as vinyl banners. In addition, the ink used to print designs on vinyl banners can be difficult to remove, further complicating the recycling process. Some recycling companies may not accept vinyl banners at all, while others may only accept them if they are clean and free from contaminants. Therefore, most of the banner vinyl waste is disposed of in landfills [10], leading to serious environmental issues. As a result, it is crucial to adopt innovative and eco-friendly strategies that promote the reuse of flex banners, given the non-biodegradable nature of PVC.

3. Models and Strategies for Extending Banner Lifespan and Promoting the Circular Economy

While the outdoor advertising industry plays a significant role in modern marketing strategies and this industry has experienced considerable growth over the years, the disposal of vinyl banners used for short-term promotional sessions contributes significantly to environmental waste [35]. This disposal practice presents significant environmental challenges due to the non-biodegradable nature of vinyl banners, which leads to their accumulation in landfills and subsequent resource depletion [36]. The disposal of plastic waste, including banners, in landfills has been associated with the release of microplastics into ecosystems, which poses a substantial threat [37].

Within the academic discourse, it is essential to acknowledge the prevailing concept of circularity, which has garnered considerable attention within the domain of industrial ecology [38]. Specifically, terms such as circular economy and cradle-to-cradle have emerged as focal points in academic research, particularly within the manufacturing sector. Additionally, the scholarly literature indicates that terminology such as cradle-to-cradle, closed-loop, and industrial technology are at times used interchangeably with the circular economy [39]. This comprehensive understanding of circularity and its associated terminology lays the groundwork for exploring the application of circular principles to repurpose vinyl banners into useful products to extend their lifespan.

One of the most popular concepts today is that of circularity, derived from the principles of the circular economy (CE). This advocates the maximization of the use of materials in closed-loop systems. In recent years, the concept of the CE has gained importance as a strategy to address the growing environmental concerns associated with linear consumption patterns. The objective of the circular economy (CE) is to facilitate the transition from the conventional "take, make, throw" model to a more sustainable framework in which materials remain in use for extended periods and waste generation is minimized through strategies such as reuse, recycling, and regeneration [39,40]. The 9R framework, which encompasses refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover, serves as a cornerstone of the CE [41].

The circular economy embodies an industrial paradigm distinguished by deliberate and structured restorative or regenerative processes. This departure from the conventional "end-of-life" approach entails the use of renewable energy sources, avoidance of toxic chemicals that hinder reuse, and prioritization of waste reduction through enhanced design of materials, products, systems, and business models. The overarching objective is to optimize material, energy, labor, and information flows, thereby fostering the restoration of natural and social capital.

The circular economy encompasses diverse activities aimed at reducing, reusing, and recycling materials across the production, distribution, and consumption phases.

3.1. Rethink, Reduce

Concerning the first aspect, namely production, it is of paramount importance to analyze the potential for utilizing the aforementioned principles in the production and utilization of the principal raw materials. The principal components of flex banners are calcium carbonate (36%), PVC resin (33%), polyester fabric (18%), plasticizers (9%), and additives (4%) [42], and we will subsequently review the potential for employing the aforementioned variants that have the least detrimental impact on the environment.

Calcium carbonate is widespread in nature in the form of the mineral's calcite, aragonite, and vaterite, and in organisms, bones, teeth, shells, corals, and crustaceans. There are also studies that transform mussel shell waste into calcium carbonate [43]. The calcium carbonate needed in industry is produced from natural sources such as limestone, chalk, or marble, which are widely available worldwide. In addition, appropriate and sustainable management practices have been implemented to promote the efficient use of resources [44]. Calcium carbonate ($CaCO_3$) calcination contributes to our climate-changing carbon dioxide (CO_2) emissions and the calcination process requires high temperatures (~900 °C) [45]. However, as the life cycle inventory data compiled by CEC-Europe show, the footprint left by the extraction and processing of calcium carbonate (ground calcium carbonate and precipitated calcium carbonate) is small [44]. Thus, we can conclude that calcium carbonate is a bio-mineralized or naturally produced resource that is constantly renewed through various natural processes, ensuring available reserves for many future generations.

The second main constituent, polyvinyl chloride (PVC), has been identified as one of the most hazardous plastics for human health and the environment. Firstly, PVC is derived from petroleum, a finite natural resource, and throughout its life cycle, from production to disposal, PVC releases toxic substances. Therefore, it is obvious that the optimal solution would be to replace PVC with recycled polyvinyl chloride [46] or with more environmentally friendly materials, such as Kavalan, an eco-friendly option due to its composition, which is primarily made up of recycled vinyl materials [47] or only polyester fabric that is a synthetic, recyclable material and does not contain toxic substances.

Polyester, constituting the third major component, represents another unsustainable material due to its extraction from non-renewable resources, namely oil, which is finite in supply. The production of polyester contributes to CO_2 emissions and results in substantial volumes of plastic and microfiber waste. Polyester also causes plastic pollution in the form of microfibers, which are too small to be captured by water treatment plants, are dumped into water bodies, and become part of the food chain [48]. Being non-biodegradable, polyester persists in ecosystems and continues to pose environmental hazards, including pollution of oceans and harm to wildlife, if not recycled. It is worth noting that although polyester recycling technologies have been developed, we still do not have the technology to recycle plastics indefinitely. With each cycle, the quality of the material degrades, making it usable only for products with lower economic value downcycling. However, in the case of banner production, the use of recycled polyester can be an advantage.

3.2. Upcycling, Reuse, Repurpose

The term 'upcycling', which originated in the 1990s, denotes the practice of repurposing discarded objects or materials in a manner that yields a product of enhanced quality or value compared to the original [49]. The approach to upcycling is significantly influenced by the specific social, economic, and political circumstances prevailing at the time. Two distinct paradigms of upcycling can be identified: one driven by necessity, where discarded materials are repurposed to fulfill fundamental human needs, such as the construction of shelters in informal settlements; and another where upcycling is regarded as an artistic or craft endeavor, producing utilitarian and aesthetically pleasing artifacts. Although the underlying motivations between artistry and survival differ significantly, it is noteworthy that

necessity-driven reuse can still exhibit remarkable skill and aesthetic appeal [50]. The economic, cultural, and geographical contexts exert a profound influence on the dynamics of upcycling, including the availability of raw materials, the intended purpose of the process, and the creative techniques employed in handling and repurposing these materials [51,52].

Flex banners serve a functional role in both realms. They continue to find utility in agricultural settings and household applications, serving as roof covers, grain protectors, and ground covers. Disposed banners can be repurposed to shield buildings and crops from moisture, particularly in regions lacking direct sunlight [10]. While such utilitarian uses are prevalent in disadvantaged areas globally, they are relatively uncommon in Europe. Consequently, the objective of this article is to propose an upcycling solution that creatively and practically reuses discarded banners. The upcycling of banners into functional raincoats is an integrated process within the remanufacturing process, where material utilization optimization and design innovations are refined to create durable and eco-friendly products.

In addition to the specific scenarios where used flexible banners are directly reused, there are methods for their indirect reuse, such as incorporating them into concrete used in the construction industry. Despite the observed improvements in the compressive properties of concrete [53,54], the quantities of waste banners used are insignificant, and the production process requires increased consumption of water and various additives.

3.3. Remanufacturing

In the context of the circular economy, remanufacturing not only facilitates the recovery of end-of-use products but also adds value. Within the literature, recycling and remanufacturing emerge as the predominant product recovery strategies employed in the operations management of Closed-Loop Supply Chains [55]. Remanufacturing is typically a more efficient means of material recirculation compared to recycling, as it retains a higher energy content associated with the original conversion of raw materials into finished products [56].

The existing literature commonly emphasizes that the remanufacturing process typically involves two main components: (i) effective reverse logistics and (ii) product development [57]. Reverse logistics begins with retrieving discarded banners from completed advertising campaigns, such as those used in sports or cultural events. These banners are then sorted based on type and size and optionally cleaned. The next step involves utilizing the advanced features of Gemini CAD software to design patterns for functional products such as raincoats, optimizing material use and aesthetics. Prototypes of these products are created using CAD-generated patterns and upcycled banner materials, tested for functionality and durability. The finalized designs are then manufactured, incorporating the optimized material usage. The remanufactured items, such as raincoats, are included in the final distribution, marketing, and retailing processes, serving as sustainable and eco-friendly advertising materials.

4. Case Study—Transforming a Banner into a Raincoat

In the context of sustainable practices within the outdoor advertising industry, upcycling and remanufacturing emerge as primary methods for repurposing discarded banners and optimizing material utilization in operational management. The presented case study illustrates an approach to organized banner recycling using CAD Gemini software. This remanufacturing process serves as a foundation for addressing challenges related to optimizing consumption, aiming to minimize waste generation and ensure that final products do not include images that could infringe upon customer rights.

As part of its sustainable development strategy, a Romanian advertising firm aimed to extend the lifespan of banners used in client advertising campaigns. To achieve this objective, the company explored methods that could fulfill its advertising needs while also reducing waste. Among the solutions adopted was repurposing banners to create seating cushions for various outdoor events (concerts, film screenings, etc.), as well as producing

various souvenirs (tote bags and pouches) and raincoats. Given the complexity of the initiative, the selected case study specifically focused on the production of raincoats.

The integration of CAD/CAM systems in the garment industry has greatly improved the efficient utilization of fabrics [58,59]. Various management software tools are utilized to streamline and coordinate all operational aspects, from style design to product sales. Over the last two decades, these systems have been continuously enhanced with new features. Challenges related to the inherent variability in fabric structure can be addressed with different levels of effectiveness based on the cutting method employed: manual, semi-automated, or fully automated. Advanced technologies now offer a seamless single-ply automated cutting process, where adjustments to pattern shapes within markers can accommodate imperfections in fabric structure, ensuring precise cutting (as demonstrated by systems such as Mosaic by Lectra, AutoMatch by Gerber, the Multi-array scanner (MAS) system by Bullmer, VisionCut by Gemini, Match++ by Optitex, and VisionPRO by Eastman).

To identify the most effective recycling solutions for used banners, a series of lay plans were developed for a specific order in the cutting section, aiming to achieve optimal efficiency. It is well-established that markers can be created in two distinct ways: manually, by tracing master patterns onto fabric or paper, or digitally, by manipulating and plotting computerized pattern images. Computer-aided pattern-making refers to the digitalization of hand-drawn patterns. The comprehensive CAD package encompasses various functions, including pattern making, pattern digitization, pattern grading, marker making, and plotting. In this study, the second method of marking was employed, with the software utilized being Gemini CAD (including Gemini Cut Plan, Gemini Nest Expert or Gemini 20x). Gemini Cut Plan enabled the planning of size combinations on markers and the planning of lays to obtain the requisite quantities, the calculation of input and efficiency, the setting and printing of the order report, the printing of markers on a plotter, and the saving and management of data in files on the computer hard disk or databases for cutting plans. Gemini X20 is an advanced CAD software solution for pattern design, grading, and marker making. It features a user-friendly interface, customizable views, and detailed visual tools to understand complex geometrical elements. The software includes functionalities such as pattern drafting, alteration, grading, seam and hem allowance management, and technical pack creation, aimed at enhancing productivity and precision in pattern development and production planning. The Gemini X20 application was employed to optimize the markers (see Figure 2).

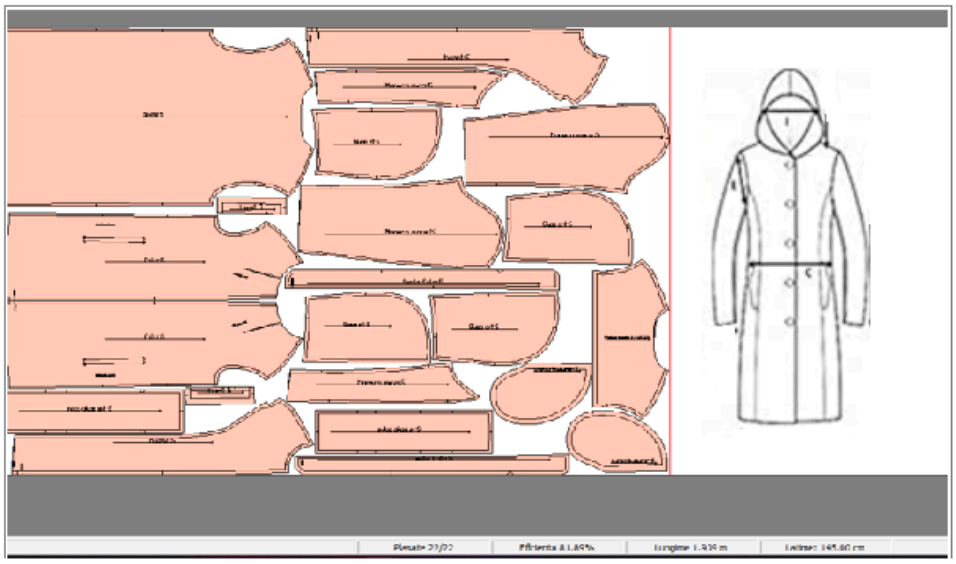


Figure 2. Pattern marker layout for a one-size-fits-all raincoat.

A single cutting order may necessitate the creation of multiple markers to achieve optimal operational efficiency. The efficiency of these markers is determined by fabric utilization, defined as the proportion of total fabric utilized in garment components [59]. The unused fabric area is considered waste. Waste within markers leads to losses and hinders our efforts to reduce it from an ecological standpoint. It is widely recognized that increasing the number of garments and sizes within a marker can improve marker utilization [59]. Additionally, incorporating markers of various dimensions aligns with our goal of creating a puzzle from the printed image on the banner (see Figure 3).

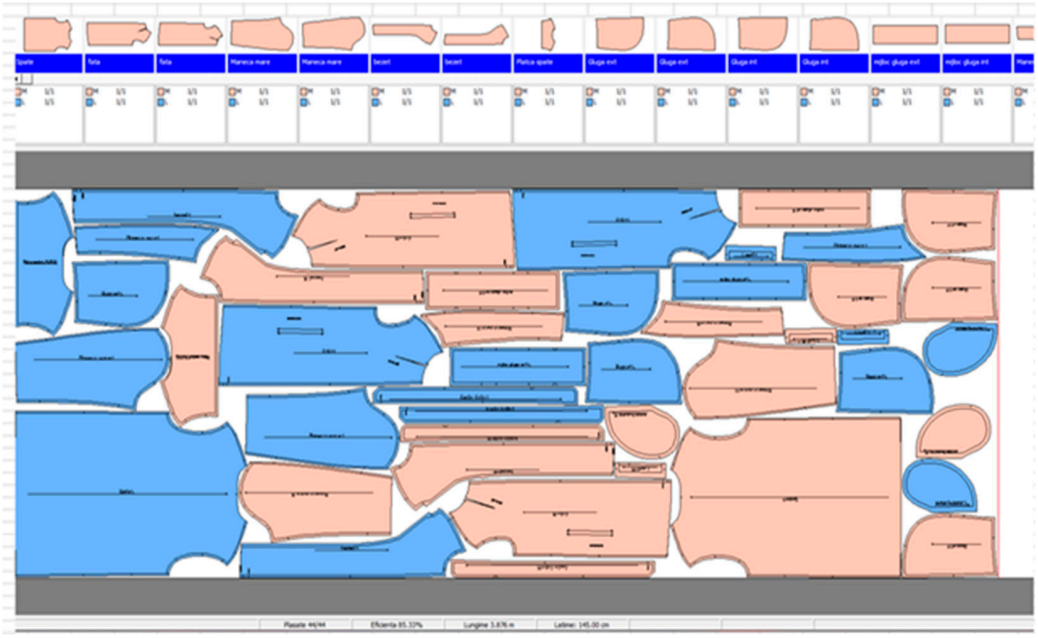


Figure 3. Pattern marker layout for different sizes of raincoats.

However, expanding the range of sizes complicates achieving an optimal cut order plan, particularly when relying on manual calculations. By adopting the fully automated single-ply processing approach, the cutting procedure becomes immune to distortions caused by fabric structure or pattern inconsistencies during cutting, thereby ensuring a consistently precise outcome [60].

In addition, it is essential to bear in mind that the resulting garments must not reproduce all symbols, images, or photographs to avoid possible infringements of intellectual property rights. This is of significant importance in ensuring compliance with legal standards and respecting the limits of intellectual property, including in products obtained through remanufacturing. The effectiveness of the marking is influenced by the degree of matching between the pattern parts within the marking. This is assessed by comparing the total area of the pattern pieces with the total area of the marker, which leads to the calculation of the percentage of fabric used.

$$\text{Percentage of fabric used} = (\sum \text{Area of pattern pieces} / \text{Total area of marker}) \times 100\% \quad (1)$$

Formula (1) quantifies the efficiency of fabric utilization by comparing the actual area of pattern pieces used to the total available area on the marker [59]. In our investigation, this calculation is automated by using a marking software, Gemini CAD (see Figure 4).

Key parameters contributing to heightened efficiency include the minimization of marker length, reduction in the number of markers used, and optimization of fabric length for each marker. Enhanced efficiency in marker usage leads to significant cost savings [61].

Marker efficiency, a crucial aspect of cut planning, receives considerable attention due to its quantifiable nature in terms of fabric consumption percentage. While fabric consumption reduction is an integral element of cut planning, it is just one facet among

many [62]. Eight spans were tested, with the standard sizes of the banners and the objective of obtaining a cross-section for the raincoat taken into account. This was done in order to ensure that the efficiency and image fragmentation requirements were respected, thus reducing the risk of presenting an integral image on the finished product. The dimensions of the banner (width of 145 cm or 138 cm and length of 3900 cm or multiples of 50 cm or 70 cm) and the complexity of the printed image allow the user to select from one of the eight proposed options.

RAPORT CUT PLAN

GEMINI CAD SYSTEMS

Nr. order: **PELERINA**
Client:
Observatii:

Data: **05.04.2024**
Timp: **8:03:51 AM**
Utilizator Cut Plan:

Produs: **PELERINA**
Tip Produs: **MOSTRARE**
Pagina: 1

Cut plan

Span	Marker index	Marimi pe incadrare	Foi	Tip	Latime (cm)	Lungime* (m)	Total material ** (m)	Consum total de material (kg)**	Perimetru taiere (m)	Contractie latime	Contractie lungime	Adaos piese (cm)	Nr. produse in span	Numerotare produse
Span1	M1	S(x1)	1 S1	Simpla	145.00	1.939	1.939 S1	0.000 S1	32.094	0.00%	0.00%	0.30	1	1 - 1
Span2	M2	M(x1)	1 S1	Simpla	145.00	1.958	1.958 S1	0.000 S1	32.405	0.00%	0.00%	0.30	1	2 - 2
Span3	M3	L(x1)	1 S1	Simpla	145.00	2.037	2.037 S1	0.000 S1	32.771	0.00%	0.00%	0.30	1	3 - 3
Span4	M4	XL(x1)	1 S1	Simpla	145.00	2.069	2.069 S1	0.000 S1	33.137	0.00%	0.00%	0.30	1	4 - 4
Span5	M5	S(x1)-XL(x1)	1 S1	Simpla	145.00	3.888	3.888 S1	0.000 S1	65.231	0.00%	0.00%	0.30	2	5 - 6
Span6	M6	M(x1)-L(x1)	1 S1	Simpla	145.00	3.876	3.876 S1	0.000 S1	65.176	0.00%	0.00%	0.30	2	7 - 8
Span7	M7	S(x1)-M(x1)-L(x1)-XL(x1)	1 F1	Simpla	138.00	0.494	0.494 F1	0.000 F1	6.502	0.00%	0.00%	0.10	4	9 - 12
Span8	M8	S(x2)-M(x2)-L(x2)-XL(x2)	1 F1	Simpla	138.00	0.758	0.758 F1	0.000 F1	13.005	0.00%	0.00%	0.10	8	13 - 20

Figure 4. The cutting plan for 8 spans with different fittings.

5. Discussion

The case study illustrates a feasible method for manufacturing raincoats from the material of recycled banners using the Gemini CAD process. The selected design incorporates multiple strategically arranged components to prevent the replication of unsuitable or copyrighted images, thus enhancing material efficiency and minimizing residual waste. However, a downside is the heightened complexity of the garment, leading to higher labor costs.

The production cost (PC) can be calculated with Formula (2):

$$PC = (MCost \times MC) + (AC \times \sum_{i=1}^{n} A_I) + (LC \times \frac{WT}{60}) \quad (2)$$

where:

MCost—Material cost, the cost of the main material per square meter (in local currency). In our case, it is the recycled banner.
MC—Material consumption, calculated with Formula (3)

$$MC = (L \times W) + \sum_{i=1}^{n} A_i \quad (3)$$

where length (L) and width (W) of the material needed for one raincoat (in meters) and
A—Quantity and types of accessories required (e.g., zippers, snaps, drawstrings)
AC—Accessories Cost: cost of accessories per piece (in local currency)
LC—Labor Cost per hour (in local currency)
WT—Work Time: total work time for one raincoat (in hours). It is calculated with Formula (4)

$$WT = MCut + AS + F \quad (4)$$

where:
MCut—Material Cutting: time needed to cut the material (in minutes)
AS—Assembly: time needed to assemble the pieces (in minutes)
F—Finishing: time for final touches and inspections (in minutes)

The three main cost categories for garment manufacturers are direct materials, which account for about 50% of total costs, direct labor, which accounts for about 20% of total costs, and overheads, which account for about 30% of total costs [63]. In the presented case, the

direct material costs are minimal, primarily encompassing accessories, as the raw material is the recycled banner material itself. Indirect costs associated with the procurement of raw materials are also reduced, given that the advertising company oversees the installation, dismantling, and disposal of advertising banners. Additionally, selecting small local workshops helps to lower overhead and indirect manufacturing costs. Therefore, the major component of the total production cost is given by the labor cost. Labor costs are typically assessed using a labor minute rate, derived from multiplying the estimated time required for either an individual or a group of workers to finish manufacturing a garment by the actual labor cost per minute. This cost is determined based on either the minimum wage or the prevailing wage (inclusive of additional wage components in the specific factory), expressed in terms of minutes.

The production of raincoats is not intended for commercial sale. Advertising companies that commission them aim primarily to reduce the waste they generate. At the same time, these companies seek to promote their image as sustainable businesses, thereby demonstrating their commitment to environmental protection and social responsibility. These initiatives not only help reduce the ecological impact of their activities but also enhance the public's perception of the company, strengthening its reputation and attracting clients who value sustainability. The funds for these projects typically come from the companies' marketing and social responsibility budgets, reflecting a strategic investment in the company's image and sustainable future.

The criteria for comfort in raincoats encompass a number of factors, including waterproofing, breathability, lightweightness, a comfortable fit, a soft lining, and adjustability [64,65]. When utilizing banners as the material for crafting raincoats, the essential criteria of waterproofing and durability are effectively met, given the inherent resistance of banner material to water and wear. Nevertheless, limitations in breathability, lightweightness, and a lack of a soft lining may arise due to the nature of the banner material, which is typically not designed for prolonged wear or ventilation against moisture build-up. However, the use of banner material for raincoats may still be considered justified by the context of intended usage, particularly in the case of brief, intermittent wear for outdoor events or advertising campaigns where unexpected rain may occur. In such scenarios, the immediate need for waterproofing and protection against rain showers takes precedence over long-term comfort considerations. Therefore, while banner-based raincoats may not fully meet all comfort criteria, their functionality in providing immediate protection during short-term rain events justifies the comfort compromise for practicality and cost-effectiveness.

Utilizing banner material for raincoats not only meets the functional criteria of waterproofing and durability but also serves as a statement of the company's commitment to environmental sustainability and adherence to circular economy principles. By repurposing banners that would otherwise be discarded as waste, the company demonstrates a proactive approach towards reducing environmental impact and promoting resource efficiency.

Although there may be some compromises in certain comfort criteria, the use of recycled banner material aligns with the principles of the circular economy by extending the lifespan of materials and reducing waste generation. This approach showcases the company's environmental consciousness and commitment to responsible practices, contributing positively to its brand image and corporate social responsibility efforts. Consequently, while banner-based raincoats may be less comfortable than other options, their status as a sustainable and environmentally friendly product aligns with the company's broader objectives of promoting environmental stewardship and embracing circular economy principles.

6. Conclusions

This study has critically examined outdoor advertising, with a specific focus on the environmental impact of banners, proposing strategies to enhance sustainability within the sector. Through an evaluation of both the advantages and disadvantages of banners in outdoor advertising, the research has highlighted environmental concerns such as material waste and pollution associated with their production and disposal. The findings

underscore the potential benefits of adopting circular economy models, which emphasize eco-friendly materials and sustainable production practices not only during production but also throughout the post-production lifecycle. This approach aims to minimize waste generation, optimize resource use, and enhance the economic viability of materials beyond their initial use in outdoor advertising campaigns.

The literature review conducted in this study established a comprehensive foundation by scrutinizing existing research on banners in outdoor advertising, encompassing market reports, academic journals, and case studies. It analyzed environmental issues related to banner production and disposal, emphasizing the need for integrated solutions that promote circularity in the use of materials. Synthesizing these findings supports the proposition that sustainable banner management can benefit significantly from upcycling and repurposing strategies. The findings highlight that the role of street advertising companies can be expanded from polluters to advocates for promoting sustainable practices within the industry. By embedding circular economy principles into their operations, these companies mitigate their environmental impact and contribute to local economic development. The research highlights the importance of innovation and responsibility in achieving a more sustainable future for the outdoor advertising sector.

Illustrated through a practical case study, this research demonstrates the transformation of banners into raincoats using advanced CAD technology, specifically Gemini CAD software. This approach not only showcases the technical feasibility of upcycling but also highlights its economic and environmental advantages. By extending the utility of banners beyond their initial advertising campaigns, companies can bolster their sustainability credentials while minimizing waste generation. Furthermore, integrating these upcycled products into future advertising initiatives expands the scope and versatility of outdoor advertising media. This practical application not only exemplifies the potential of upcycling but also suggests that such raincoats can be reused in companies' marketing campaigns, thereby enhancing their utility and visibility and illustrating the expansion of promotional media from outdoor to alternative Out-of-Home (OOH) advertising media (see Figure 1).

However, despite the comprehensive exploration of sustainable practices in outdoor advertising, this study has certain limitations. Firstly, the focus on a specific case study of upcycling banners into raincoats using CAD technology may limit the generalizability of findings to other contexts or materials. Secondly, the study primarily relies on theoretical frameworks and a single case study, potentially overlooking the diverse range of challenges and opportunities present in the global outdoor advertising industry. Future research could benefit from broader geographic and industry-specific comparisons to enhance the robustness and applicability of identified sustainable practices. Additionally, further exploration into consumer perceptions and market acceptance of upcycled advertising materials would be beneficial to understanding their adoption and scalability in practice.

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