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Open loop alternatives for recycling PET straps in construction products: a PESTEL analysis

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ABSTRACT

Polyethylene terephthalate (PET) straps cannot be mechanically recycled in certain regions where the required technology is unavailable or where the scale of operations is insufficient to ensure economic viability. They tend to be accumulated in the recycling chain, from industrial generators, to waste separation plants and even recycling plants and landfills. However, PET straps could be used in construction as aggregates for concrete paving blocks or in panels with epoxy resin binder. This study evaluates two open-loop alternatives for recycling discarded PET straps into construction products considering Political, Economic, Social, Technological, Environmental, and Legal factors of the PESTEL framework. The political, social, and legal conditions were comparable for both alternatives, whereas the economic and environmental assessments favoured the panel-based solution. However, the technological analysis indicated that panel production remains at an early stage of development, introducing uncertainty and potentially delaying its large-scale implementation. In contrast, the manufacturing process for paving blocks is based on established and readily available technology, allowing for immediate implementation under current conditions.

1 Introduction

Plastic waste pollution is a major environmental problem, mainly because it takes a long time to decompose [1]. The amount of plastic pollution has grown to unsustainable levels, polluting land, waterways, and oceans, causing harm to wildlife and ecosystems [2].

Polyethylene terephthalate (PET) straps can be considered single-use plastic products since once used to secure goods, they are usually discarded rather than reused in their original form. This aligns with the definition of single-use plastics, which are intended for one-time use before disposal [3]. PET straps are strong enough to withstand outdoor environmental conditions such as humidity, solar exposure and high temperatures. Although there are many literature reviews regarding the problem of plastic waste and PET waste [4], no specific data on PET straps waste management as a separate waste stream were found, apart from case studies related to valorisation alternatives.

In some places such as Mendoza, Argentina, PET straps are used in construction and wineries, but this province has no facilities for its complete mechanical recycling [5]. Although recycling PET helps to reduce environmental impact, conserve resources, and minimize landfill accumulation, the recycling rate for PET remains relatively low, and much of it still ends up in landfills or the environment, where it can persist for hundreds of years [4].

Mechanical recycling is not always available due to the lack of appropriate technologies or economies of scale to process PET straps. In those cases it could be considered transporting them to other regions, but it is often economically infeasible and environmentally inconvenient [6]. Two valorisation alternatives related to construction materials have been studied before by the authors: to shred PET straps and use them as aggregates for concrete paving blocks [7], and to mix shredded PET straps with epoxy resin binder to obtain panels [5]. Other alternatives identified in literature are to make welded geogrids [8], to build mechanically stabilized soil structures [9], to reinforce columns with a pre-stressed system [10] and to produce PET strap fibers for concrete reinforcement for pull-out tests [11, 12].

The construction industry could take advantage of the strength and homogeneity of this waste material [12]. Recycling plastic waste can generate environmental benefits in the construction sector, as it supports the transition toward a circular economy in which waste is valorized as a secondary raw material for new products [13]. Circular economy helps to reduce the need for virgin materials, to decrease the environmental impacts associated with their

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extraction and production, and to decouple the economic development from resources consumption [14].

Recent developments regarding the circular economy focus on their relationship with sustainable development through its aims to generate environmental quality, economic development and social equity [15]. Influence of politics, legal and technological developments are also considered relevant for circular economy strategies. Authors have studied some aspects of PET straps waste valorisation, but until now, no systematic and comprehensive analysis has been conducted for this waste stream. The aim of this paper was to analyse and compare two innovative open loop valorisation alternatives for construction applications in terms of political, economic, social, technological, environmental, and legal characteristics. By integrating these dimensions within a single analytical framework, this study provides a structured basis to compare technological maturity, economic feasibility, environmental performance and social conditions, thereby supporting decision-making regarding these alternative pathways for PET straps waste valorisation.

2 Materials and methods

The methodology used in the present study is presented in Figure 1 and described in the following sections.

2.1 PET straps characterization

The PET straps analysed in this study were collected as post-industrial packaging waste from a local company, typically employed for securing industrial loads. According to the manufacturer, the material exhibits a tensile strength ranging from 380 to 500 MPa and an elongation at break exceeding 12%. The elastic modulus of PET ranges between 2,8 and 3,1 GPa [16]. PET typically presents a density of approximately 1,39 g/cm³ and negligible water absorption, which is characteristic of this polymer and relevant for both cement-based and epoxy-based composite applications. For their use as aggregates in paving blocks and panels, the straps were mechanically shredded by a local industry to produce a material with the granulometric distribution shown in Figure 2 [5].

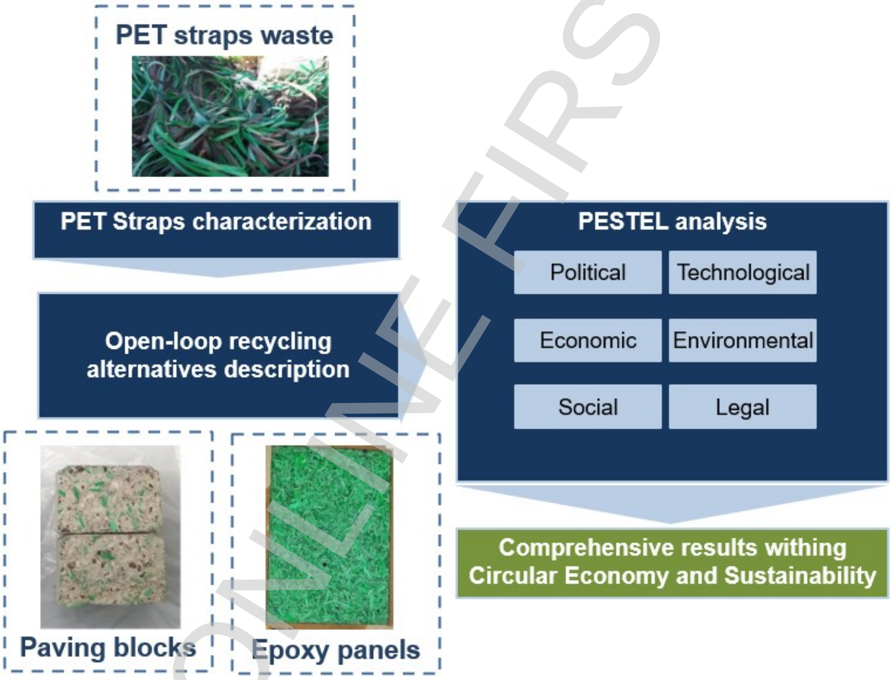

Figure 1. Study design for the PESTEL comparison of construction applications of recycled PET straps

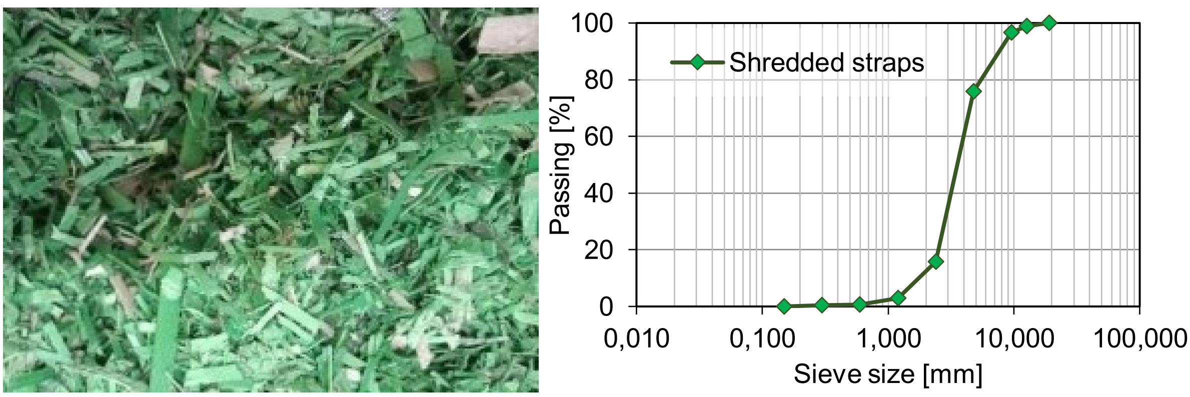

Figure 2. Shredded PET straps (left) and granulometric analysis of shredded PET straps (right)

2.2 Open-loop recycling alternatives description

Two valorisation alternatives were considered from previous studies developed by the authors:

- to use shredded PET straps as aggregates for concrete paving blocks [7],
- to mix shredded PET straps with epoxy resin binder to obtain panels [5].

Many different dosages could be used in both alternatives, but only optimal dosages reported by the authors were considered in this study. Composites for paving blocks were prepared using Portland cement, natural sand, tap water and shredded PET straps. A 1:2 ratio of cement to natural sand aggregates was used, together with a water-to-cement ratio (w/c) of 0,40, and 5% of shredded PET straps by weight of the paving blocks. Paving blocks were demoulded after 24 hours and cured for 28 days submerged at a controlled temperature of 20 ± 2°C [7]. While technical and environmental analyses were carried out, the political, legal, social, and economic evaluations were not performed.

Meanwhile, panels were manufactured under a fume hood and demoulded after 24 hours of curing to ensure complete crosslinking of the polymer network. The selected dosage was 23% of shredded PET strap relative to the total mass of the manufactured panel, with epoxy resin binder [5].

2.3 PESTEL analysis

A PESTEL (political, economic, social, technological, environmental, legal) analysis provides a comprehensive view of the factors that influence the viability of different options. It has been successfully used to evaluate recycling alternatives in various sectors, such as plastics [17], construction and demolition waste [18], municipal waste [19], and healthcare waste [20]. This approach allows the identification of opportunities, risks, and external barriers that affect the implementation and success of different recycling strategies. Each dimension was described for the recycling alternatives, including qualitative and quantitative indicators and criteria, such as:

- Political: included waste policies, incentives for recycling, and circular economy goals.
- Economic: Life Cycle Costing (LCC) and complementary analyses of the impact of each alternative's costs on the market value of the resulting product. The objective was to calculate the costs of waste valorisation alternatives. These alternatives considered both the technical valorisation processes and the associated transport, since this has a significant influence on reverse logistics. The functional unit used for the research was 1 ton of shredded PET straps.

The LCC of paving blocks alternative considered transport from the shredding plant to the paving blocks manufacturing plant. The process included materials consumption, mixing in an automated electric mixer, moulding on a moulding line, and curing the blocks, which consumes fuel to maintain a stable temperature. For the panels it was considered transport to the manufacturing plant and materials consumption. Data on panels fabrication is not available since they were handmade at laboratory. Finally, the panels were cured at room temperature. An efficiency of 95% was assumed, as some material is lost in the process.

Both primary and secondary data were used to build the inventory. Primary data came from measurements, interviews, and documents from the stakeholders involved, while secondary data was obtained from databases and other studies. The quantification of material inputs and outputs for the processes was obtained from primary data from technical trials and from estimates based on interviews and measurements at the PET shredding plant. The market values of the products were estimated from secondary data, specifically using similar products available online. Costs were considered in Argentinian pesos calculated in 2022.

- Social: labour requirements and education levels were described for each alternative. The social dimension is descriptive, since neither alternative has been implemented in practice to date. Therefore, actual social conditions cannot be measured.
- Technological: Technology Readiness Level (TRL), technology availability, pre-treatment requirements, and specific performance indicators related to tests were considered.
- Environmental: midpoint indicators using method CML-IA baseline V3.06, were considered to assess the environmental impact in a Life Cycle Assessment (LCA) following ISO standards 14040 [21] and 14044 [22]. The functional unit of analysis was 1 ton of shredded PET straps. Indicators were abiotic depletion potential (ADP), global warming potential (GWP), ozone layer depletion potential (ODP), photochemical oxidation potential (POCP), acidification potential (AP) and eutrophication potential (EP). These indicators are recommended for LCA of construction products [23].
- Legal: considered environmental permits or restrictions, waste laws and Sustainable Development Goals (SDG) alignment.

3 Results and discussion

3.1 Political and legal dimensions

In Argentina, the political and legal framework related to the circular economy and the management of recyclable waste is still being consolidated, with limited and fragmented progress across jurisdictions. The circular economy agenda in Argentina is mainly implemented through municipal solid waste management programs and guidelines. However, unlike other Latin American countries, there is no national strategy supported by a comprehensive framework law. Current regulations are structured around sectoral laws and are complemented by municipal initiatives focused on source separation, differentiated collection, and strengthening recycling. This still-dispersed regulatory framework reflects a process in transition toward more sustainable production and consumption models, in which extended producer responsibility and the recovery of materials are beginning to position themselves as central pillars of the country's contemporary environmental policy [24].

In Mendoza there are increasingly favourable conditions for the development of waste recycling. The province has recently implemented a new waste management law [25], which promotes waste reduction, separation at source, material recovery, and the creation of waste separation centres. The law mandates municipal participation, establishes sanctions, and aligns provincial objectives with the UN Sustainable Development Goals, particularly SDG 12 on responsible production and consumption. The executive regulation for this law is currently under development.

However, no specific extended producer responsibility schemes for plastics are available, and PET straps have not been included in specific waste policies, while there are no incentives for recycling them yet. In municipal waste separation plants, PET straps are discarded since it is not economically feasible to transport them for mechanical recycling. This is why they are perceived as worthless waste. In conclusion, both alternatives are subject to a similar political and legal context.

3.2 Economic dimension

Regarding the national economic context of the recycling industry, recent resolutions have reduced barriers to import recyclable waste. This situation has had a significant impact on the materials market, leading to a drop in the price of cardboard and plastic of up to 60% [26].

The LCC analysis showed that the cost of producing 93,4 tons of paving blocks from 1 ton of shredded PET straps was $700000, while 1,3 tons of panels were produced with the same amount of shredded straps, demanding $205000. The cost of producing paving blocks was made up by materials consumption, electricity consumption and fuel consumption of associated machinery and transport. The cost of the panels considered transport and materials consumption. The materials included aggregates and cement for the paving blocks and polymer resin for the panels alternative.

Using a net cost-to-market ratio of the resulting product, since the products obtained from each alternative are different and have different market prices, shows the impact of the costs of shredded PET straps on the final product price for each alternative. The use of ratios to complement LCC analyses is very common in literature [27]. The ratio of net costs for paving blocks was 20% while for panels it was 1%. This low value can be explained because the panel price is high, they have very good mechanical properties and can be used for a wide variety of applications. On the other hand, the lack of data on the panels cost inventory excluded costs of an industrial production such as electricity consumption for mixing the resin.

3.3 Social dimension

Both alternatives require collecting, transporting, and shredding PET straps. After that, the material is transported to the production plant, where it is mixed, poured and cured for making paving blocks, and mixed with epoxy resin, pressed and cured to produce panels. All these stages require operators.

Collection, transport and shredding operations could be performed by non-qualified operators. In Mendoza, waste pickers are grouped in recycling cooperatives who collect diverse recyclable waste streams such as plastic, glass, metals. Those cooperatives work together with some big waste generators such as industries and large commercial facilities and receive support from municipalities. National encouragement to those cooperatives has recently declined, reducing the number of beneficiaries of subsidies as salary complements for members of recycling cooperatives [26].

Production of paving blocks can be largely automated, while panels do not have specific technology for their production yet. The required educational level in those activities is medium, and operators can be trained internally to perform their tasks.

3.4 Technological dimension

The present dimension combines an analysis of products properties with the study of the actual production processes available in Mendoza and their TRL.

The studied properties of paving blocks were flexural strength (6,77 MPa), dry density (2027 kg/m^3) and water absorption (3,18%) [7]. Flexural strength is an essential mechanical property for a traffic load-resistant pavement and the acceptance requirement for the modulus of rupture is 4.2 MPa according to standard IRAM 11656 [28]. Density can be used as indicator of uniformity between different paving blocks and water absorption is related to long-term durability, which must be below 5% [28]. Apart from these specific performance indicators, the production of paving blocks has available technology with a maturity level of TRL 9. Existing equipment can be used to produce paving blocks with shredded PET straps, in fact, some automated plants in Mendoza have the technology to produce these products.

Until now, the analysed panels were manufactured at a laboratory scale, using hand tools. While other existing machines could be adapted to increase production, the current TRL is 3, as only proof-of-concept testing exists. Tensile tests were performed on ten flat type I tensile specimens with rectangular section. The mechanical tests were carried out using an Amsler universal testing machine with a maximum capacity of 60 tons and a sensitivity of 10 kg. The maximum average load was 14 N, with a tensile strength of 1,35 kg/mm² [3] according to standard D-638 ASTM [29].

3.5 Environmental dimension

Recycling materials reduces the amount of waste disposed in landfills and raw materials and energy consumption. However, recycling could also have negative environmental impacts [30], so LCA is useful to analyse in more detail the environmental impacts of both studied recycling alternatives. LCA allowed to obtain the midpoint indicators of both alternatives. In panels, a larger quantity of shredded PET straps is used in comparison to paving blocks. Therefore, the functional unit of 1 ton of shredded PET straps defined before, results in 93,4 tons of paving blocks, but just 1,3 tons of panels (Figure 3).

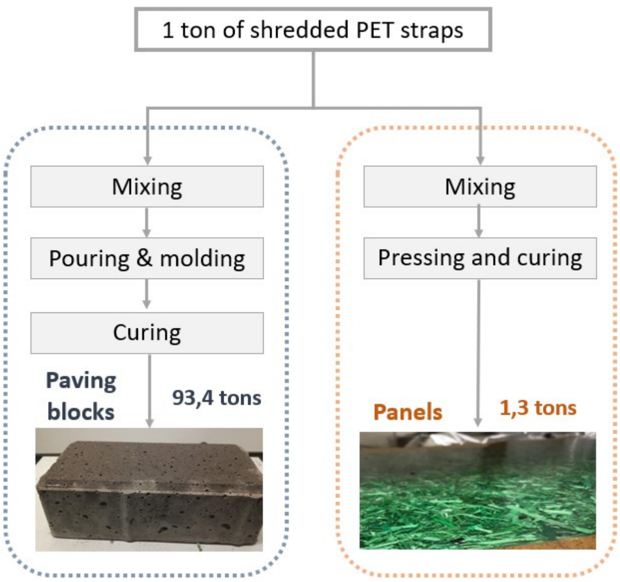

Figure 3. System boundaries for paving blocks and panels with shredded PET straps

The life cycle inventory was constructed for the functional unit using primary data, some based on laboratory studies and others from companies in the sector, and secondary data from international databases [31]. Table 1 shows the inputs required to recycle 1 ton of shredded PET straps.

The life cycle impact assessment results for the functional unit are presented in Table 2.

Results show higher impacts for recycling 1 ton of PET straps in paving blocks than in panels. However, it must be considered that they are different products with distinct functions. Additionally, as mentioned, 1 ton of shredded PET straps produces 93,4 tons of paving blocks, but just 1,3 tons of panels. Both alternatives require transporting and shredding the PET straps before starting the new production cycle.

While producing panels incorporates larger quantities of PET straps per ton of final product, from a wider environmental perspective, the results shown in Table 1 can be reinterpreted. For example, to manufacture 1 ton of paving blocks, an impact of 276 kg of CO_2 eq. is produced, while 925 kg of CO_2 eq. are emitted per ton of panels. The final product will also have a specific lifespan, approximately up to 50 years for paving blocks and up to 20-30 years for panels. End-of-life management is complex in both cases, since they are composite materials containing concrete in paving blocks and epoxy in panels. Therefore, recycling these products may be a challenge that must be further studied.

3.6 Summary

Table 3 summarizes the main findings obtained for each PESTEL dimension when comparing the two recycling alternatives. The analysis shows that both products operate under the same emerging political and regulatory framework for circular economy and waste management in Argentina. However, relevant differences arise in the economic, technological, and environmental dimensions.

4 Conclusions

This study evaluated two open-loop recycling alternatives for waste PET straps: paving blocks and epoxy panels, using the PESTEL framework. Results indicate that both options may represent potential pathways to recover this waste stream in regions lacking closed-loop mechanical recycling infrastructure.

From the political and legal perspectives, PET straps are not yet included in specific waste policies or incentive schemes, which limits their recovery potential. Economically, paving blocks show higher production costs relative to their market value, whereas panels show a more favourable ratio. However, the available data for the panel alternative remain

Table 1. System inputs for both alternatives

Input	Paving blocks	Panels
Materials	61,6 tons of fine aggregates 30,8 tons of cement	333 kg of epoxy resin
Water	15400 litres of water	-
Energy	110 litres of fuel 477 kWh of electricity	9,3 kWh of electricity

Table 2. Midpoint impacts for both alternatives

Midpoint indicator	Units	Paving blocks	Panels
ADP	kg SB eq.	0,0006235	0,0001366
GWP	kg CO_2 eq.	25759	1230
ODP	kg CFC-11 eq.	0,0013795	0,0001309
POCP	kg C_2H_4 eq.	3,2526907	0,6663755
AP	kg SO_2 eq.	49,3	4,1
EP	kg PO_4^{3-} eq.	10,8	1,6

Table 3. PESTEL summary for both alternatives

Dimension	Paving blocks	Panels
Political & Legal	Operates within an emerging regulatory framework for waste management and recycling in Argentina, without specific incentives for PET strap recycling.	
Economic	Production cost: $700000 for 93,4 t of blocks. Net cost-to-market ratio: 20%.	Production cost: $205000 for 1,3 t of panels. Net cost-to-market ratio: 1%.
Social	Production can be largely automated; medium qualification required for plant operators.	Production currently manual at laboratory scale; operators require internal training.
Technological	Mature technology (TRL 9) with existing industrial equipment available.	Early-stage technology (TRL 3) with proof-of-concept laboratory testing.
Environmental	Lower environmental impacts per ton of product, larger lifespan, but incorporates small quantities of PET straps.	Higher impacts per ton of product, shorter lifespan, but incorporates larger quantities of PET straps.

preliminary and correspond to laboratory-scale production. Socially, both alternatives could generate local employment with low to moderate training requirements. Technologically, paving blocks benefit from industrial-scale readiness, while panels are currently at a proof of concept stage and would require further technological development for large-scale implementation. Environmental impacts differ due to material requirements and product outputs, and end-of-life management remains a challenge for both composite materials.

Overall, both alternatives could contribute to reducing PET strap disposal in landfills and supporting regional circular economy initiatives, although further research is needed to validate the technical and economic performance of the panel alternative at industrial scale. The present work highlights the value of integrating political, economic, social, technological, environmental and legal perspectives to inform decision-making and policy discussions regarding emerging recycling pathways.

CRediT authorship contribution statement

JPO: Conceptualization; Formal analysis; Investigation; Methodology; Writing - original draft.

CA: Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Visualization; Writing - review & editing.

IM: Formal analysis; Investigation; Methodology; Funding acquisition; Project administration; Resources; Supervision; Writing - review & editing.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Zhang, K., Hamidian, A. H., Tubić, A., Zhang, Y., Fang, J. K., Wu, C., & Lam, P. K. (2021). Understanding plastic degradation and microplastic formation in the environment: A review. *Environmental Pollution* 274, 116554. https://doi.org/10.1016/j.envpol.2021.116554

[2] Kibria, M. G., Masuk, N. I., Safayet, R., Nguyen, H. Q., & Mourshed, M. (2023). Plastic waste: challenges and opportunities to mitigate pollution and effective management. *International Journal of Environmental Research* 17(1), 20. https://doi.org/10.1007/s41742-023-00507-z

[3] Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of the total environment*, *752*, 141772.

[4] Raj, B., Rahul, J., Singh, P. K., Rao, V. V. K., Kumar, J., Dwivedi, N., ... & Strzałkowski, K. (2023). Advancements in PET packaging: driving sustainable solutions for today's consumer demands. *Sustainability*, *15*(16), 12269. https://doi.org/10.3390/su151612269

[5] Alejandrino, C., Giaroli, C., López, R., Ninago, M., Mercante, I., Llamas, S., & Ojeda, J. P. (2023). *Reciclado de flejes PET en placas compuestas con resinas poliméricas comerciales*. In *Actas del X Simposio Iberoamericano de Ingeniería de Residuos "Hacia la circularidad y el residuo cero"* (Castelló de la Plana, España, 20–22 de junio de 2023).

[6] Ojeda, J. P., Alejandrino, C., & Mercante, I. (2024). *Análisis ambiental de alternativas de logística inversa y valorización de flejes plásticos*. In *Libro de actas XII EnIDI: Décimo Segundo Encuentro de Investigadores y Docentes de Ingeniería* (EnIDI 2023, San Rafael, Mendoza, Argentina).

[7] Ojeda, J. P., Alejandrino, C., & Mercante, I. T. (2024). Recycling PET straps in paving blocks: experimental testing and life cycle assessment. *International Journal of Environmental Studies*, *81*(6), 2725-2734. https://doi.org/10.1080/00207233.2024.2417620

[8] Voskamp, W. (2000) Index and performance testing a new geogrid made of highly oriented straps. *Advances in Transportation and Geoenvironmental Systems Using Geosynthetics* 360-372. https://doi.org/10.1061/40515(291)24

[9] Miyata, Y., Bathurst, R. J., and Allen, T. M. (2018). Evaluation of tensile load model accuracy for PET strap MSE walls. *Geosynthetics International* 1–36. https://doi.org/10.1680/jgein.18.00032

[10] Si, J. H., Chen, J. B., Feng, S. Y., and Qiu, S. X., 2021, Experimental research on eccentric compression of reinforced concrete columns strengthened by prestressed PET straps and angle steel. *Structures* 31, 1254-1264. https://doi.org/10.1016/j.istruc.2021.02.052

[11] Ojeda, J. P., Mercante, I. T., de Borbon, F. M., Zerbino, R., Torrijos, M. C., & Giaccio, G. (2025). Pull-out performance of plastic and steel fibers recycled from waste. *Journal of Reinforced Plastics and Composites*, *44*(19-20), 1955-1963.

[12] Khatab, H. R., Mohammed, S. J., & Hameed, L. A. (2019). Mechanical properties of concrete contain waste fibers of plastic straps. In *IOP conference series: materials science and engineering* (Vol. 557, No. 1, p. 012059). IOP Publishing. https://doi.org/10.1088/1757-899X/557/1/012059

[13] Norouzi, M., Chàfer, M., Cabeza, L.F., Jiménez, L., & Boer, D. (2021). Circular economy in the building and construction sector: A scientific evolution analysis. *Journal of Building Engineering* 44, 102704. https://doi.org/10.1016/J.JOBE.2021.102704

[14] European Commission. (2020). A new circular economy action plan for a cleaner and more competitive Europe. (Brussels: Publications Office of the European Union).

[15] Kirchherr, J., Yang, N. H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the circular economy (revisited): an analysis of 221 definitions. *Resources, conservation and recycling*, *194*, 107001. https://doi.org/10.1016/j.resconrec.2023.107001

[16] Foti, D. (2019). Recycled waste PET for sustainable fiber-reinforced concrete. In *Use of recycled plastics in eco-efficient concrete* (pp. 387–410). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-102676-2.00018-9

[17] Torkelis, A., Dvarionienė, J., & Denafas, G. (2024). The Factors Influencing the Recycling of Plastic and Composite Packaging

Waste. *Sustainability*. https://doi.org/10.3390/su16219515.

[18] Turkyilmaz, A., Guney, M., Karaca, F., Bagdatkyzy, Z., Sandybayeva, A., & Sirenova, G. (2019). A Comprehensive Construction and Demolition Waste Management Model using PESTEL and 3R for Construction Companies Operating in Central Asia. *Sustainability*. https://doi.org/10.3390/su11061593.

[19] Loizia, P., Voukkali, I., Zorpas, A., Pedreño, J., Chatziparaskeva, G., Inglezakis, V., Vardopoulos, I., & Doula, M. (2020). Measuring the level of environmental performance in insular areas, through key performed indicators, in the framework of waste strategy development. *The Science of the total environment*, 753, 141974. https://doi.org/10.1016/j.scitotenv.2020.141974.

[20] Thakur, V. (2020). Framework for PESTEL dimensions of sustainable healthcare waste management: Learnings from COVID-19 outbreak. *Journal of Cleaner Production*, 287, 125562 - 125562. https://doi.org/10.1016/j.jclepro.2020.125562.

[21] International Organization for Standardization. (2006). *ISO 14040: Environmental management—Life cycle assessment—Principles and framework*. ISO.

[22] International Organization for Standardization. (2006). *ISO 14044: Environmental management—Life cycle assessment—Requirements and guidelines*. ISO.

[23] European Committee for Standardization. (2014). *EN 15804:2012+A1:2013 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products*. CEN.

[24] Conti, M. E., Simone, C., El Awag, N., & Tudino, M. B. (2026). An Overview of the Plastics Sector in the European Union-Italy-and Mercosur-Argentina and Brazil. *Revista Tecnologia e Sociedade*, *21*(67), 361-378.

[25] Gobierno de la Provincia de Mendoza. (2025). *Law 9659: Sistema de Gestión Integral de Residuos Sólidos Urbanos (GIRSU)*. Official Gazette de Mendoza.

[26] Guevara Perez, A. V., Alejandrino, C., Guevara, O. J., Mercante, I. (2025). Análisis territorial de actores en la gestión integral de residuos sólidos urbanos del Área Metropolitana de Mendoza (2023-2025). Cuyonomics ISSN 2591-555X (In Press)

[27] Alejandrino, C., Mercante, I., & Bovea, M. D. (2021). Life cycle sustainability assessment: Lessons learned from case studies. *Environmental Impact Assessment Review, 87*, 106517. https://doi.org/10.1016/j.eiar.2020.106517

[28] IRAM. (2019). IRAM 11656: Adoquines de hormigón para pavimentos intertrabados. Requisitos y métodos de ensayo. Instituto Argentino de Normalización y Certificación. Sixth edition.

[29] ASTM. (2005). Standard D-638 - Standard test method for tensile properties of plastics. American Society for Testing and Materials

[30] Peña, C., Civit, B., Gallego-Schmid, A., Druckman, A., Pires, A.C.-, Weidema, B., Mieras, E., Wang, F., Fava, J., Canals, L.M. i, Cordella, M., Arbuckle, P., Valdivia, S., Fallaha, S., Motta, W. (2021). Using life cycle assessment to achieve a circular economy. *The International Journal of Life Cycle Assessment*. 1–6. https://doi.org/10.1007/s11367-020-01856-z

[31] Ecoinvent. (2021). *Ecoinvent database* (Version 3.7.1). https://www.ecoinvent.org/