

Circular Warehouse Operations: ESG-Driven Optimization through Reusable Pallets

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Received: Nov 19, 2025, **Revised:** Nov 19, 2025, **Accepted:** Dec 2, 2025, **Published Online:** Dec 26, 2025

Reviewers: Anonymous Peer Review

Citation: Paida, V.R. (2025). Circular Warehouse Operations: ESG-Driven Optimization through Reusable Pallets. *International Journal of Supply Chain Management*, 14(6), 1-11, <https://doi.org/10.59160/ijscm.v14i6.6363>

Abstract— Sustainability, a key concept being implemented in all aspects of commercial activities around the world, aligns with nations' objective of transition to a greener and cleaner world. A key facet of this transition is "circular flow" or what is commonly understood as recycling. This article establishes the benefits of integrating the same principles in logistics, through a comprehensive analysis of an Environmental, Social, and Governance or ESG aligned circular warehouse model implemented across six GoBolt warehouses in North America. Combining reusable plastic pallets and Gaylords, waste compaction and corrugated recycling, and 5S-based (Sort, Set in Order, Shine, Standardize, Sustain) workflow redesign yielded an average annual savings of \$54,100 per warehouse, with an estimated 139 tons per year of CO₂ avoided per warehouse. Additionally, there was 12% productivity enhancement due to reduced picker walking and standardized 5S practices. Comparison with benchmarks of CHEP, iGPS, IFCO, and IKEA indicates that an in-house circular model can deliver competitive carbon reductions and attractive payback periods.

Keywords— Warehouse, logistics, transportation, pallet, pooling, sustainability, supply chain, supply chain management.

1. Introduction

Global logistics has rapidly evolved under the dual pressures of e-commerce growth, fueled by rapid development in information and communication technologies (ICT), and accountability for sustainable business practices. Logistics has now come to be regarded as the indispensable infrastructure that supports carrying out of e-commerce transactions [1]. Explosion in consumerism has already put a lot of pressure on the limited natural resources while elevating pollution levels. In countries all across the globe,

growing severity of environmental pollution alongside natural resource constrictions have resulted in the pressing need to resort to sustainable operational practices that ensure efficient natural resource utilization while taking care of environmental protection [2]. Growing environmental pollution and rapidly depleting natural resources have made environmental protection as well as sustainable use of natural resources a critical issue that warrants immediate attention and must be solved without much delay [3, 4]. This paper focuses on improving storage and packaging, an indispensable segment of supply chain of every product, especially for e-commerce businesses. Circular economy model, an economic model based on the principle of repair-reuse-recycle, can be effectively applied to create a supply chain that is better in terms of sustainability and can strive to achieve maximum efficiency, without compromising the quality of the finished product. Throughout the process, the focus remains on keeping the products at their highest utility and value [5]. In an efficient supply chain, logistics encompasses sustainable warehousing that incorporates development of strategies relating to the reuse of packaging, materials recycling, and waste management optimization in the context of storage and distribution [5].

Warehouses — the central nodes in supply chains — historically depend on single-use packaging materials and fragmented processes that increase cost and carbon intensity. Circular economy principles when integrated into logistics, marks a step forward in the direction of achieving sustainable warehousing. The key focus of circular economy is on effective waste management which stems from the principle of drawing the maximum possible benefit from the available limited resources. A circular economy, therefore, looks at minimizing waste while maximizing benefit from resources by way of closed material loops through

recycling, regeneration, and reuse [6]. Reusable Packaging Containers (RPCs) are doled out by the company and reused to create a more sustainable supply chain. [7].

This paper investigates a practical circular operations framework composed of three levers:

- 1) Reusable transport items (RTIs) such as plastic pallets and Gaylords (enormous, heavy-duty cardboard boxes, also referred to as bulk boxes or skid boxes, that are used for shipping and storing large or bulk items);

- 2) Waste compaction and closed-loop corrugated recycling; and

- 3) 5S-driven process standardization to reduce unnecessary movement and defects.

This research article enumerates the financial, environmental, and productivity outcomes from a six-warehouse pilot and compares these results against the data available on global leaders pertaining to pooling and circular logistics. The paper also articulates a technology roadmap that entails dock appointment scheduling, labor forecasting, and inventory cycle-count modules and can strengthen adoption and improve the efficiency of reporting under ESG frameworks. ESG-driven optimization refers to integration of Environmental, Social, and Governance (ESG) factors into decisions, both strategic and operational, for improving performance, managing risks, and creating value such as optimization of a company's supply chain or a portfolio through consideration of factors such as carbon emissions, labor relations, and corporate governance. This study scrutinizes the ways in which logistics will be able to contribute to circular economy objectives using advanced material recovery practices, packaging solutions that can be reused, and storage systems that have high levels of energy efficiency.

2. Literature Review

The subjects of green transition and circular economy are widely researched and a plethora of research material and articles are easily available on the subject matter. The topic of sustainability is also well covered. However, sustainability in logistics management, especially warehousing and recyclable packaging are topics that are relatively less discussed. This area still remaining relatively unexplored, innovative ideas are still developing. Sustainability in warehousing bestows environmental, economic, and operational benefits, upon the business practicing it, through the reduction in generation of waste material, reuse of packaging materials, and recycling of resources [5].

2.2 Pallets in Packaging

Pallets form a key component of the global supply chain of a product and are also among “the most used return-able transport items (RTIs)”, that finds application in approximately 80% of all world trade [8]. Having substantial environmental and economic impacts, throughout their entire life cycle, pallets act as an important asset for a product's supply chain. These are apparently simple products having an uncomplicated and standardized design structure that supports the carriage and storage of commodities. They enable the development of an efficient and harmonized material handling and logistic system that finds worldwide application [9]. Presently, the application of transport pallets being ubiquitous in the distribution of an extensive range of products globally, more than 80% of the entire global trade is now carried out using pallets – either wooden or plastic [8].

2.3 Plastic Vs Wooden Pallets

The preliminary cost involved in using plastic pallets is quite high compared to wooden pallets. However, over the longer term, the cost savings generated from their use make them a cost-effective and hence better option.

Wooden pallets are utilized for transporting products across categories, from electronics to groceries, and ensure that the products reach their respective destinations safely, timely and efficiently. Nevertheless, often the lifecycle of a wooden pallet would end prematurely in a landfill, and would contribute to ever-growing volume of waste, adding to environmental degradation [10]. The wood block pallets, conventionally used for product packaging and transportation, frequently finish up in landfills post the completion of approximately twenty-five trips. A plastic pallet, on the other hand, can complete up to a hundred trips in the supply chain and once it reaches the end of its lifespan, a plastic pallet can be molded into a new one [11].

Plastic pallets, moreover, offer several benefits such as including better hygiene, higher durability, and safety in comparison to wood [12, 13]. They are not only resistant to pests, moisture, and rot, but also do not need the application of splinters or nails which makes them safer for a company's labor to handle [14, 13]. Additionally, they are much lighter compared to wood, which helps to cut down the cost of shipping. Plastic pallets are also easier to handle being lightweight and stackable, and in general have a longer lifespan, which helps to rationalize logistical costs over time as a

consequence of lower need for replacement [12]. These are the key principles of sustainable supply chain management that always concentrates on economy and efficiency aspects of a supply chain [15].

From the perspective of hygiene too, the plastic pallets are superior. Wooden pallets, because of their porous nature, have the tendency of harboring pests and bacteria. Whereas plastic pallets provide a surface that is smooth and non-absorptive which improves hygiene [16]. They being non-absorbent, reduce the possibility of biological and chemical contamination of the products [17]. In addition, these pallets are easy to clean which reduces maintenance costs, and at the same time are compatible with automated systems. These pallets are frequently manufactured utilizing recycled materials and are, in general, completely recyclable at the end of their lifespan [18, 19].

By virtue of being durable, reusable, and requiring low maintenance, these pallets help the businesses reduce their expenditure on repairs and replacements, which in turn leads to a better return on investment (ROI) [14].

2.4 Environmental Footprint of Pallets

Pallet-related CO₂ emissions are generated by the manufacturing of new pallets, their transportation, and their eventual disposal. Compared to plastic pallets, wooden pallets exhibit lower initial carbon footprint, due to the fact that wood stores biogenic carbon. However, the overall impact is dependent on such factors as the sourcing and reuse. Efforts are being made to reduce emissions that include promotion of reuse, optimization of transport logistics, and use of alternative materials such as cardboard or bio-based plastics. However, plastic demonstrates higher durability which increases the number of reuses thereby reducing the frequency of manufacturing. Compared to wooden pallets, cumulative emissions caused by the transport and replacements of pallets are lower, generating lesser carbon footprint, when plastic pallets are used [20].

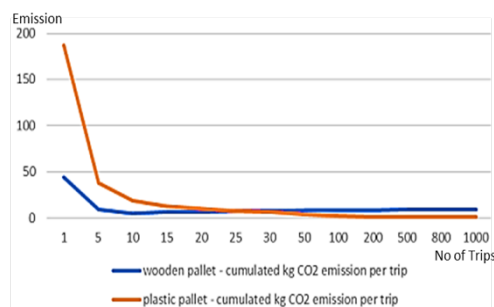


Figure 1: Cumulated Kg CO₂ emission [20].

According to the above study, opposed to common feeling, plastic pallets can be an appreciated alternative to wooden pallets from the perspective of environment. Plastic pallet has lower cumulative emission after approximately two years. The average lifespan of a plastic pallet is better. Substantially lower carbon footprint due to higher durability and lower need for replacement coupled with the fact that it does not generate solid waste unlike wooden pallets that end up in landfills at the end of their life span, should at least create interest and encourage research pertaining to wider implementation and greater adoption of plastic pallets. According to research, multiple use, of both the product and the material they are being made of, are the key factors that lead to the reduction of the burden on the environment [20].

2.5 Sustainable Practices

Logistics is that indispensable segment of a product's supply chain, where efficiency and cost-effectiveness are held supreme, and hence the thrust on sustainability is gaining significant impetus. One of the areas that is often overlooked and also where the companies can make a significant environmental impact, is reuse and recycling, that also aligns with the principle of circular economy. This refers to the area of recycling of pallets and reuse of pallets. Pallets are ubiquitous platforms, made out of wood or plastic, that play a crucial role in the transportation of goods across the globe, and the manner in which these are managed can have extensive implications for the businesses, their day-to-day operations and the Earth [10].

Pallets are different from other packaging products, designed specifically to be repaired repeatably and reinjected for usage. Compatibility with automated systems, ease of maintenance and the fact that they are often manufactured using recycled materials make plastic pallets an easy and preferable choice despite the debate on their environment friendliness.

Recycle-ability, while being environmentally beneficial due to its ability to reduce waste, can result in complex interactions among the various stakeholders involved such as manufacturers, pallet providers, users and recyclers [9]. This has resulted in the growing practice of repairing the pallets for reuse, which has now gradually become a common practice. Environmentally, this practice looks quite promising but at the same time gives rise to further complexities pertaining to logistics and management.

2.5.1 Pallet Pooling

In logistics management, an important leg of supply chain management, pooling refers to the sharing and reuse of assets used in the supply chain. As opposed to rental or proprietary systems in which such assets are expended or operated by a single party, pooling makes fuller and more efficient use of the available resources by ensuring that the resources are kept in use constantly and remain in unceasing circulation [21]. CHEP (Brambles) demonstrated through its European operations that pallet pooling can reduce pallet-related CO₂ by 55–60% in European networks while eliminating hundreds of thousands of empty truck miles [22, 23]. Pooling entails sharing and reuse of pallets based on the circular economy principles. Pallets are not bought or exchanged but are rented and the entire pallet management is outsourced. Instead of being commodity, pallets become a 'Pallet as a service.' All supply chain participants generally work towards achieving their common objective of avoiding empty miles. Transportation organizations, independent logistics and transport operators, and the retailers and manufacturers – everyone is affected by empty miles as all of them lose money on “dead leg trips” [24].

As demonstrated by iGPS Logistics, the life-cycle benefits of RFID-enabled plastic pallets, often exceed 100 reuse cycles and deliver significant carbon footprint reductions. IFCO (International Food Container Organization) and Euro Pool System (EPS), both operate extremely efficient, closed-loop pooling systems for Reusable Packaging Containers (RPCs). These are designed for a constant cycle of "share and reuse", and the packaging products circulate swiftly amongst producers, retailers, and service centers [21]. IFCO / Euro Pool's reusable crate systems underscore high-cadence closed loops with traceable washing, inspection, and redeployment [25]. Accorsi et al. provide modeling evidence that optimized pooling networks can reduce transport distances by approximately 65% and bring down emissions by nearly 60% [26]. Circular packaging initiatives undertaken by IKEA Europe demonstrate substantial reduction in packaging waste and optimization of transport at retail scale [27].

2.6 Challenges of Sustainable Logistical Practices

While sustainable logistics and warehousing are extremely essential for an efficient and clean supply chain, the processes and procedures are often countered due to the need for upfront

investment outlay, inadequate standardization, and low degree of awareness among the stakeholders. However, these drawbacks are far outweighed by the long-term benefits, including enhanced brand image, better compliance, and higher operational efficiency [5]. It is possible for businesses to achieve sustainability and at the same time drive economic growth through alignment of logistical operations with the principles of circular economy

3. Research Methodology

This study examines several literary works on logistics segment of supply chain management. The study involves both qualitative and quantitative methods. The qualitative part of the study makes generous use of publicly available information to explain the theories of circular economy, sustainability and other concepts in this discipline. The literature review had been constructed from materials obtained from books, reports, journals and other online publications. The article also makes use of charts and diagrams to exhibit important observations and results.

The article has adopted the case study methodology to establish the merits of application of the principles of circular economy in logistics management and quantify the benefits that are generated from it. The later segments of the article highlight the results achieved when the practices are applied to real life business operations. The study was carried out at six GoBolt warehouses located across North America - two in the U.S.A. and four in Canada. GoBolt Operations and Sustainability teams had provided access to operational data that helped champion 5S and ESG initiatives.

Interventions: The intervention has been carried out in the following order.

1. Swapping wooden pallets for reusable plastic pallets and Gaylords;
2. Either install or contract for waste compaction
3. Set up corrugated box resale
4. Application of 5S (Sort, Set in Order, Shine, Standardize, Sustain) to reduce picker walk distance and defects through the optimization of the physical layout and creation of disciplined, consistent processes within a warehouse. The key to enhancing efficiency and productivity in a modern fulfillment center is reducing pickers' walking distance. It is pivotal for and helps to maintain timeliness of delivery [30].

Data Collection: Data was gathered, pre/post panels over consecutive months, using supervisor logs, waste hauler tickets, recycling invoices, and productivity time-studies.

Key Metrics: The study used the following key metrics to arrive at the results - pallet reuse savings (USD), waste compaction savings (USD), CO₂ avoided (tons), productivity change (%), ROI/payback (months).

CO₂ Estimation: The study has used an EPA-aligned factor of ~37 kg CO₂ that is avoided per pallet-reuse cycle for a standard reusable plastic pallet system. For a representative site reusing ~3,760 pallets per year, this equates to ~139 tons per year of avoided CO₂ per warehouse, or ~834 tons per year across the six sites where the studies were conducted. This study also employs a sensitivity analysis that varies the reuse volume by $\pm 20\%$ to test the robustness of the estimates.

4. Results

The study combines reusable plastic pallets and Gaylords, waste compaction and corrugated recycling, along with the 5S-based workflow redesign.

Empirical results demonstrate that the initiative is able to generate an average annual savings of \$54,100 per warehouse. This brings the estimated CO₂ avoided per warehouse to approximately 139 tons per year.

Productivity showed improvement by 12% aided by reduced picker walking and standardized 5S practices. Comparative benchmarks with CHEP, iGPS, IFCO, and IKEA show that an in-house circular model is capable of delivering competitive carbon reductions and offer attractive payback periods [27]. This approach, by emphasizing on the reuse, recycle, and optimization of available resources, benefits not only the environment but also the business by being bottom line accretive through the transformation of the conventional linear model of "take, make, dispose" into a more closed-loop system of reuse and recycle, that is more sustainable.

Financial Outcomes: The study resulted in average yearly total cost savings of \$54,100 per warehouse. It can be broken down into \$30,100 cost saving ensuing from pallet reuse and \$24,000 from waste compaction and recycling. Across the six facilities under study, the total network-wide cost savings stand at \$324,600 per year.

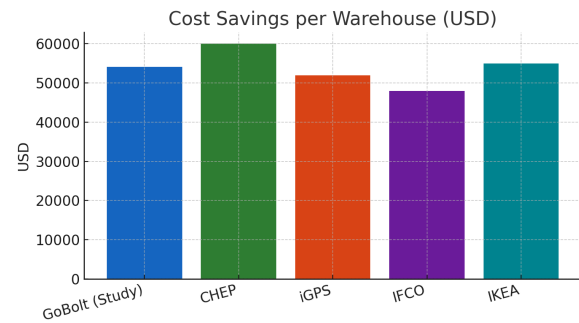


Figure 2. Cost savings per warehouse by entity (Values represent annualized averages per facility in USD).

Environmental Outcomes: The CO₂ avoided was estimated at ~139 tons per year per site which totals to ~834 tons per year for the six facilities under study, taken together.

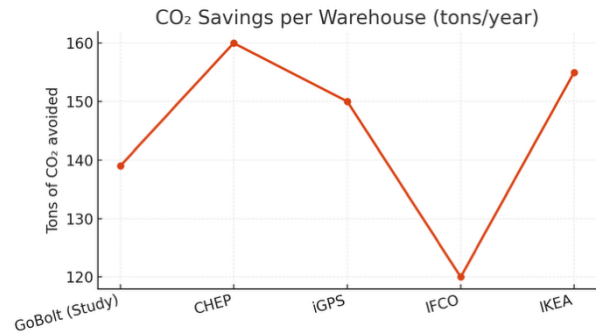


Figure 3. CO₂ savings (tons/year) per warehouse by entity. - Values approximate life-cycle avoidance per facility.

Operational Outcomes: Picker productivity increased by 12% following 5S implementation and aisle - level layout redesign.

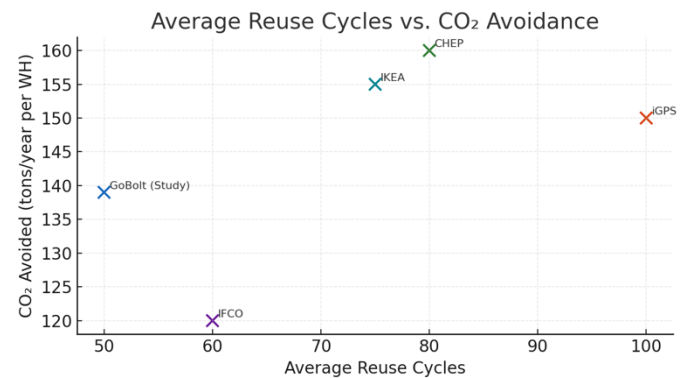


Figure 4. Relationship between average reuse cycles and CO₂ avoidance. Higher cycle counts correlate with greater annual CO₂ savings.

Comparative benchmarks with CHEP, iGPS,

IFCO, and IKEA indicate that an in-house circular model can deliver competitive carbon reductions and attractive payback periods.

4.2 Benchmarking

The study compares five entities - GoBolt (Our Case Study), CHEP, iGPS, IFCO, and IKEA – across five criteria: cost savings, CO₂ savings, reuse cycles, ROI / payback, and ESG (Environmental, Social, and Governance) maturity. Results indicate that GoBolt's in-house circular model competes well in terms both cost and CO₂ avoidance while offering faster payback compared to typical third-party pooling in certain contexts.

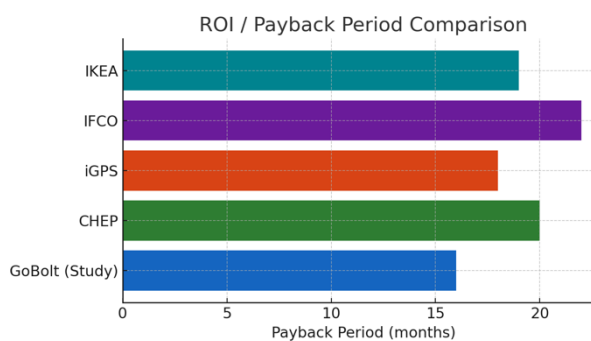


Figure 5. Payback period (months) comparison by entity. Lower values indicate faster ROI from circular interventions.

iGPS excels in traceability due to RFID ubiquity. iGPS plastic pallets are equipped with RFID tags on all 4 corners which allows the customers to track and trace shipments. iGPS (Intelligent Global Pooling Systems) has always used an all-plastic pallet pool where each single pallet has more than one (four, for redundancy) embedded passive RFID tags. It is a standard feature for every pallet and not an extra cost.

On the other hand, CHEP's network scale provides both suppleness and buoyancy but can result in longer paybacks depending on structure of the contracts. IFCO's reuse of crates (vs. pallets) fits high-turnover fresh supply chains while IKEA demonstrates strong packaging circularity integrated with retail logistics.

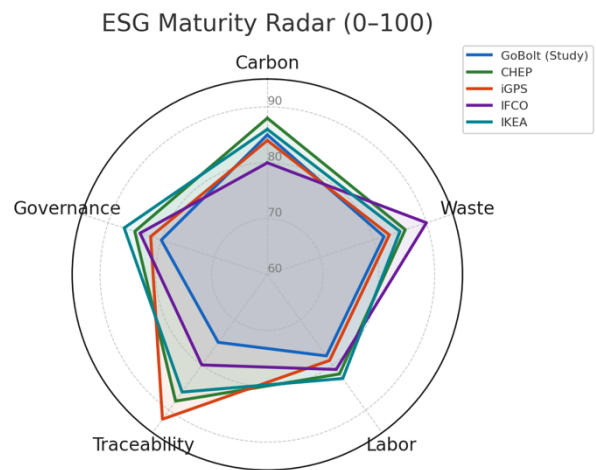


Figure 6. ESG maturity radar across five dimensions and five entities (0–100 scale).

5. Discussion

As is evident from the preceding paragraphs, pallets are indispensable for a product's supply chain with respect to physical movement of the finished products. They are an absolute necessity for moving commodities, transporting everything be it everyday essentials like groceries or more sophisticated items such as electronics, auto parts and pharmaceuticals. Plastics are preferred to wooden pallets and Gaylords due to durability, longevity, ease of use and hygiene factors.

Due to growing environmental concerns, corporations face the persistent challenge regarding the ways and means to source, track, refurbish or restore and recycle the overwhelming number of pallets that transition through warehouses every day. Herein lies the importance of pallet pooling. A system of pooling pallets allows businesses to have shared access to a centralized system of reusable pallets, rather than bearing the costs and headache of owning and managing its own stock. This makes it easier for companies to keep goods in transition while rationalizing costs, moderating waste and simplifying logistics [28]. This also helps the businesses align their operations in a manner that better aligns with the environmental, social and governance principles.

5.2 Integration of Operations and ESG:

Incorporation or amalgamation of Environmental, Social, and Governance (ESG) principles into business operations can be considered a strategic approach that propels value creation over the long-term, improves risk management, expands and develops a company's competitive advantage. It goes a step further than

simple compliance or philanthropy and moves towards imbedding sustainability into the core decision-making processes, supply chains operations and management, and work culture. Operational levers are the explicit, actionable techniques or systems applied within operations management that can enable and expedite integration of these principles to enhance efficiency, productivity, and overall performance. 5S, layout, and scheduling are three vital operational levers that work in tandem to optimize a work environment through the elimination of waste, organization and management of physical space, and effective coordination of various relevant activities.

The 5S stands for Sort, Set in Order, Shine, Standardize, and Sustain - guiding principles that form the backbone of this technique [29]

Sort: The first step in the 5S methodology is to sort which involves identification of the essential items within the business operation or workspace and elimination of any excess or redundant items. This helps to remove the clutter, minimize distractions, and lead to streamlining the workspace.

Set in Order: The second step is to set the process in order. This step entails organization of the essential items following a logical and systematic method. This comprises assignment of the precise location for each item and labeling them for the ease of identification which helps to reduce search time and in turn eliminate the necessity to maintain excess inventory.

Shine: The following step in the 5S methodology is to shine which encompasses cleaning and maintenance of the workspace. This includes consistent and systematic cleaning, inspection, and maintenance of the pallets to ensure everything remains in working condition and is free of any defect. This eliminates potential delays.

Standardize: The last but one step in the 5S methodology is to standardize. This step engages activities to create a set of rules, parameters and procedures for maintaining the workspace. This step is particularly important because it sets the parameters within which the company needs to function with respect to various legs of the supply chain and any deviation should get detected promptly to avoid cost overruns. This step also involves documentation of the previous three steps and the setting up of a regular schedule for their implementation.

Sustain: The last step in the 5S methodology is to sustain. A change in operations, the adoption of

new business process or a novel and sophisticated technology will be meaningless if it cannot be sustained. This step, therefore, involves creation of a culture and environment that fosters continuous development and improvement, in which the previous four steps are followed unswervingly, and the workspace optimization is a continuous process.

The case study illustrates that operational levers (5S, layout, scheduling) and circular assets (pallets, Gaylords) jointly amplify ESG outcomes. The critical observation here is that, 5S contributed to productivity increase by 12% that supported the financial case for the reuse programs. This dual perspective – lean business operations and its alignment with ESG principles, converted sustainability from an essentially a cost-center narrative into a crucial performance driver. Plastic pallets enable warehouse optimization strategies and integration with automated systems that achieve the goal of reducing picker walking distance. Their key characteristics facilitate efficient warehouse design and order picking methods that minimize picker travel time.

5.3 GHG Protocol Mapping:

The CO₂ savings primarily affect Scope 3 (purchased goods and services; waste) with ancillary impacts on Scope 1/2 if compaction reduces on-site energy or hauls. Scope 3 emissions, also referred to as value chain emissions, frequently contribute to the lion's share of total greenhouse gas (GHG) emissions by any organization [30]. Scope 3 emissions take into account the sources that are not within the scope 1 and 2 boundary of an organization.

For reporting, organizations can attribute avoided emissions to material reuse, reduced waste hauling, and optimized transport. To strengthen audits, we recommend maintaining chain-of-custody logs for RTIs and recycler receipts. Supply chains comprise an important part of comprehensive climate action strategies. For instance, in 2019-20 every one of the new Pixel and Nest products were designed using recycled substance, and presently shipping of Google hardware to and from the direct customers is carbon neutral [31].

5.4 Carbon Credit Monetization:

The price of voluntary carbon credits in the US and Canada varies extensively depending on the type and quality of the project. However, on an average, price of around \$10-15 per ton is considered to be a reasonable estimate for a larger

variety and type of lower-cost credits. Prices garnered in the voluntary market in general range from less than \$5 to more than \$500 per ton [32].

At conservative voluntary market prices of \$10–15 per ton, 834 tons per year CO₂ avoidance across the six sites under study hold the potential to generate \$8.3k–\$12.5k in annual credits. This cannot be recorded as a primary revenue stream, but can definitely be construed and recorded as an ancillary benefit that offsets program costs. However, the crediting feasibility is dependent on certain factors such as – methodology, eligibility and verification costs. The price per ton is majorly dependent upon the project, its location, certification, and the co-benefits it offers. Firms also need to evaluate standards such as Gold Standard or Verra (Verified Carbon Standard – VCS). Both Verra and Gold Standard are battling climate change using verifiable emissions reductions, but they are quite different from each other with respect to their core focus, operational scope, and approach to sustainable development [33].

5.5 Limitations and Risks

Asset loss and dwell time can erode ROI: Misappropriation and misplacement of pooling pallets can lead to operational inefficiencies and higher need for replacement, both of which will ultimately result in increased costs and hence lower return on investment [33]. Thus, asset loss and excess dwell time results in significant erosion in the return on investment (ROI) in pallet pooling through the escalation of operational costs, reduction in asset utilization, and creation of the need for greater capital expenditure for replacements. Sensitivity analyses suggest that a 20% drop in reuse volume can yield positive ROI, though payback gets extended by 3 – 5 months.

RFID (Radio-Frequency Identification) and QR (Quick Response) codes are crucial for modern pallet pooling because they provide enhanced visibility and real-time tracking, which directly deters theft and minimizes accidental loss or misplacement. Service Level Agreements (SLAs) are highly effective in mitigating losses within pallet pooling systems. SLAs are designed to establish clear, measurable guidelines that ensure both parties have the exact expectations regarding the quality, scope, and timing of the service delivered [34].

Incorporating new supply chain practices entail significant changes in long existing business operations and conventional practices. The success depends on effective change management. Change management is nontrivial—training and incentives

are pivotal. Undeniably, change management involves a complex process in which training and incentives takes the central stage, playing a pivotal, yet frequently underrated part in successful adoption of new process or technology and in ensuring sustained success.

6. Conclusion & Future Work

This article discusses the merits of the circular economy and its usability in supply chain management, especially the logistics segment of it. The article also establishes the rationale behind the use of plastic pallets in place of wooden pallets and Gaylords in transportation of finished products and also establishes the merit of pooling pallets. The key outcomes include cost rationalization, higher efficiency of the supply chain, lower waste generation and shrinkage along with higher CO₂ avoidance leading which aligns perfectly with the goal of sustainability pursued by businesses all across the globe. Though results were obtained after studying 6 warehouse operations in the US and Canada combined, they are applicable to all companies across the globe for whom transportation of products is a key performance metric.

This article examines and explores the manner in which logistics will be able to support a circular economy through the application of sustainable warehousing practices. It explores strategies such as recycling materials, reusing packaging, sharing resources and reducing waste that is generated in the process of storage and distribution of products. In addition, it examines real-life examples and best practices to illustrate the tangible benefits of these approaches.

This study provides the evidence that circular warehouse operations have the potential to deliver economic savings, CO₂ reductions, and productivity enhancement simultaneously to the organization incorporating the principles in their logistics practices. The benefits combine economic viability with sustainability.

The article presents studies carried out in six warehousing facilities in North America. The results are scalable and can be applied to other warehouses. Scaling to 50 warehouses could generate approximately \$2.7M in annual cost savings and nearly 6,900 tons per year of CO₂ avoidance.

This article sets the floor for future work towards digitization of asset tracking via QR/RFID, integrate ESG dashboards, dock scheduling, and labor forecasting, and formalize GHG accounting to enable third-party assurance and potential carbon-credit issuance. The model aligns with UN SDGs 9, 12, and 13.

Traditional wooden pallets, despite being the backbone of global logistics, represent a hidden sustainability and efficiency challenge. Each year, over two billion pallets circulate globally, with nearly 90% being wood-based and over 25 million discarded after limited use. This article proposes study into ReLoop PAAS (Pallet-as-a-Service) — a circular, IoT-enabled logistics platform that transforms pallet usage from a consumable model to a service-based, trackable, and environmentally accountable ecosystem. ReLoop integrates Bluetooth Low Energy (BLE) tracking, QR-based identification, and cloud based platform.

References

- [1] Z. Teng, Y. He and R. Wu, "E-Commerce: Does Sustainable Logistics Development Matter?," MDPI - Sustainability, Vols. 15, 579, 2023.
- [2] M. Donner, A. Verniquet, J. Broeze, K. Kayser and H. D. Vries, "Critical success and risk factors for circular business models valorising agricultural waste and by-products," Resources, Conservation & Recycling, Vols. 165, 105236, 2021.
- [3] M. Song, R. Fisher and Y. Kwoh, "Technological challenges of green innovation and sustainable resource management with large scale data," Technological Forecasting and Social Change, Vols. 144, July 2019, pp. 361-368, 2019.
- [4] W. N. Osman, M. N. M. Nawi, R. Saad and R. Ismail, "Factors Affecting Systematic Implementation of Reduce and Recycle in Construction Industry," Int. J. Sup. Chain. Mgt, vol. 6, no. 1, pp. 270 - 278, 2017.
- [5] H. Rashid, "Integrating Circular Economy Principles in Logistics to Drive Sustainability," International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences, vol. 7, no. 6, pp. 1-9, 2019.
- [6] European Parliament, "Circular economy: definition, importance and benefits," 24 May 2023. [Online]. Available: <https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits#:~:text=The%20circular%20economy%20is%20a, reducing%20waste%20to%20a%20minimum..> [Accessed 29 Oct 2025].
- [7] IFCO, "IFCO SmartCycle - A circular approach," 2024. [Online]. Available: <https://www.ifco.com/the-ifco-way/ifco-smartcycle/>. [Accessed 29 Oct 2025].
- [8] V. Kočí, "Comparisons of environmental impacts between wood and plastic transport pallets," Science of The Total Environment, vol. 686, pp. 514-528, 2019.
- [9] F. Tornese, M. G. Gnani, B. K. Thorn, A. L. Carrano and J. A. Pazour, "Management and Logistics of Returnable Transport Items: A Review Analysis on the Pallet Supply Chain," MDPI Sustainability, vol. 13, no. 22, 2021.
- [10] A&M Pallets, "Sustainability in Logistics: The Role of Pallet Recycling and Reuse," 29 Jun 2024. [Online]. Available: <https://www.palletsforhouston.com/sustainability-in-logistics-the-role-of-pallet-recycling-and-reuse/>. [Accessed 01 Nov 2025].
- [11] iGPS, "Benefits of Circular Supply Chains," 19 Dec 2024. [Online]. Available: <https://igps.net/circular-supply-chains/#:~:text=The%20Circular%20Supply%20Chain%20in%20Action,-The%20optimal%20circular&text=Our%20automation%2Dfriendly%20plastic%20pallets,undoubtedly%20evolve%20with%20the%20industry..> [Accessed 31 Oct 2025].
- [12] E. Wilhelmus, "The Benefits of Plastic Pallets: An Eco-Friendly Solution for Efficient Material Handling: Bulk Container Express," 14 Aug 2023. [Online]. Available: <https://www.bulkcontainerexpress.com/blog/the-benefits-of-plastic-pallets-an-eco-friendly-solution-for-efficient-material-handling#:~:text=One%20of%20the%20key%20advantages,savings%20in%20the%20long%20run..> [Accessed 31 Oct 2025].
- [13] TriEnda Holdings, LLC., "7 Hygienic Benefits of Plastic Pallets for the Grocery Industry," 13 Dec 2019. [Online]. Available: <https://www.triendaholdings.com/industry-news/hygienic-benefits-plastic-pallets-grocery-industry/#:~:text=The%20hygienic%20benefits%20of%20plastic,one%20way%20to%20address%20it..> [Accessed 31 Oct 2025].
- [14] Rehrig Pacific Company, "Elevate Your Supply Chain: The Game-Changing Benefits of Plastic Pallets," 20 Dec 2024. [Online]. Available: <https://www.rehrigpacific.com/about/news/elevate-your-supply-chain-the-game-changing-benefits-of-plastic-pallets#:~:text=Plastic%20pallets%20are%20a>

- so%20safer, reap%20these%20long%20term%20benefits.. [Accessed 31 Oct 2025].
- [15] B. Thakre, "Use of Generative Artificial Intelligence to Create Sustainable Supply Chain Management: An Online Retail Perspective," *Int. J. Sup. Chain. Mgt*, vol. 14, no. 2, pp. 55-65, 2025.
- [16] ORBIS Corporation, "Rackable Plastic Pallet Benefits: Why Choose Plastic?," 29 Apr 2025. [Online]. Available: <https://www.orbiscorporation.com/en-us/supply-chain-insight/rackable-plastic-pallet-benefits-why-choose-plastic/>. [Accessed 31 Oct 2025].
- [17] iGPS, "Supply Chain Automation: Why Pallets for Automated Storage and Retrieval Systems Should Be Plastic," 26 Jun 2018. [Online]. Available: <https://igps.net/why-pallets-for-automated-storage-and-retrieval-systems-should-be-plastic/>. [Accessed 31 Oct 2025].
- [18] Go Plastic Pallets, "Why use plastic pallets instead of wooden pallets for exports?," 03 Apr 2023. [Online]. Available: <https://www.goplasticpallets.com/news/why-use-plastic-pallets-instead-of-wooden-pallets-for-exports#:~:text=In%20fact%2C%2093%25%20of%20our,agriculture%20and%20pharmaceuticals%2C%20favour%20them..> [Accessed 01 Nov 2025].
- [19] Y. Royer, "Optimizing Industries with Durable Plastic Pallet Solutions: Flat Cargo," 20 Jun 2024. [Online]. Available: <https://flatcargo.com/plastic-pallet/>. [Accessed 01 Nov 2025].
- [20] K. Witos, A. Wójcik-Czerniawska and P. Z. Grzymała, "Environmental impact of using EUR-size wooden and plastic pallets measured by generated carbon footprint and solid waste.," in 4th Symposium on Agri-Tech Economics for Sustainable Futures, Harper Adams University, Newport, U.K., 2021.
- [21] IFCO SYSTEMS, "Bringing the benefits of pooling to your value chain," 23 Feb 2023. [Online]. Available: <https://www.ifco.com/bringing-the-benefits-of-pooling-to-your-value-chain/#:~:text=IFCO%20RPCs%20automatically%20reduce%20the,IFCO%20RPCs%2C%20there's%20zero%20waste..> [Accessed 01 Nov 2025].
- [22] J. Hartzfeld, "Why CHEP-Brambles Prioritizes Sustainability as an Important, Ongoing Imperative: LinkedIn," 09 Jun 2021. [Online]. Available: <https://www.linkedin.com/pulse/why-chep-brambles-prioritizes-sustainability-ongoing-jim-hartzfeld#:~:text=In%202010%2C%20CHEP%20knew%20it,regenerative%2C%20nature%20positive%20business..> [Accessed 02 Nov 2025].
- [23] CHEP, "Coca-Cola reduces its pallet related CO2 emissions by 60%," 2025. [Online]. Available: <https://www.chep.com/be/en/coca-cola-reduces-its-pallet-related-co2-emissions-60>. [Accessed 02 Nov 2025].
- [24] iGPS, "Reducing Empty Miles: How the Right Pallet Can Make Shipping More Efficient," 11 Aug 2020. [Online]. Available: <https://igps.net/reducing-empty-miles-how-the-right-pallet-can-make-shipping-more-efficient/>. [Accessed 02 Nov 2025].
- [25] IFCO SYSTEMS, "Pooling reusable packaging is the smart choice," 14 Aug 2024. [Online]. Available: <https://www.ifco.com/pooling-reusable-packaging/>. [Accessed 01 Nov 2025].
- [26] R. Accorsi, G. Baruffaldi, R. Manzini and C. Pini, "Environmental Impacts of Reusable Transport Items: A Case Study of Pallet Pooling in a Retailer Supply Chain," *MDPI Sustainability*, vol. 11, no. 11, pp. 1-13, 2019.
- [27] IKEA, "IKEA Sustainability Report FY23," 2023. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ikea.com/global/en/images/IKEA_SUSTAINABILITY_Report_FY_23_20240125_1b190c008f.pdf. [Accessed 01 Nov 2025].
- [28] Supply Chain Brain, "The Tech-Enhanced Future of Pallet Pooling," 14 Oct 2025. [Online]. Available: <https://www.supplychainbrain.com/articles/42616-the-tech-enhanced-future-of-pallet-pooling>. [Accessed 04 Nov 2025].
- [29] B. Griffiths, "10 Steps for effective 5S implementation in your Industry | Lean Transition Solutions," 25 Jul 2023. [Online]. Available: <https://leantransitionsolutions.com/5S-Process/10-Steps-for-effective-5S-implementation-in-your-Industry>. [Accessed 11 Nov 2025].

- [30] U.S. EPA, "Scope 3 Inventory Guidance | United States Environmental Protection Agency," 23 Apr 2025. [Online]. Available: <https://www.epa.gov/climateleadership/scope-3-inventory-guidance>. [Accessed 05 Nov 2025].
- [31] R. Porat, "CDP 2020 Global Supply Chain Report : CDP AFRICA REPORT TRANSPARENCY TO TRANSFORMATION: A CHAIN REACTION BENCHMARKING PROGRE," Feb 2021. [Online]. Available: https://cdn.cdp.net/cdp-production/cms/reports/documents/000/005/554/original/CDP_SC_Report_2020.pdf?1614160765. [Accessed 05 Nov 2025].
- [32] D. Grasveld, "Voluntary Carbon Market - Latest Prices and Developments- Regreener | B Corp," 03 Oct 2025. [Online]. Available: <https://www.regreener.earth/blog/voluntary-carbon-market-update>. [Accessed 05 Nov 2025].
- [33] Aqualia , "Knowledge Hub: Verra vs. Gold Standard: Which Certification is Right for Your Project?," 2025. [Online]. Available: <https://aquila.is/2025/verra-vs-gold-standard-which-certification-is-right-for-your-project/#:~:text=and%20administrative%20costs-,Key%20Differentiators:,directly%20into%20its%20certification%20process..> [Accessed 05 Nov 2025].
- [34] M. F. Pro, "Pallet Pooling Market: Key Insights, Drivers, Trends, and Challenges Shaping the Future | LinkedIn," 14 Aug 2025. [Online]. Available: <https://www.linkedin.com/pulse/pallet-pooling-market-key-insights-drivers-trends-raq1f/>. [Accessed 05 Nov 2025].
- [35] M. Jameela, "Understanding the SLA Full Form and Its Importance in Logistics and Fulfilment," 26 Jun 2024. [Online]. Available: [https://wareiq.com/resources/blogs/sla-service-level-agreement/#:~:text=Service%20Level%20Agreements%20\(SLAs\)%20in,in%20today's%20fast%20paced%20market..](https://wareiq.com/resources/blogs/sla-service-level-agreement/#:~:text=Service%20Level%20Agreements%20(SLAs)%20in,in%20today's%20fast%20paced%20market..) [Accessed 05 Nov 2025].
- [36] L. Marketing, "Reducing picker travel time: Enhancing warehouse efficiency with automation and smart slotting," 25 Jun 2025. [Online]. Available: <https://www.logiwa.com/blog/reducing-picker-travel-time-to-enhance-warehouse-efficiency>. [Accessed 11 Nov 2025].