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Factors Affecting Truck Payload in Recycling Operations: Towards Sustainable Solutions

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Abstract: *Background*: One of the ongoing challenges in freight transport operations is to balance efficiency, effectiveness, and sustainability through the integration of sustainable practices to minimize the environmental impact. When it comes to truck payload and sustainability, the emphasis is on optimizing space, and minimizing empty miles and the wastage of resources. Ensuring that truck loads meet their targets has many challenges, and our empirical research examines the factors influencing the payloads of recycled fibre across the network in the UK paper industry. *Methods*: A mixed method approach includes interviews, business process analysis, the identification of opportunity areas, a site visit, simulation, and viability analysis to assess factors as part of the sustainable solution. *Results*: The research identified aspects related to processes, data availability and fragmentation, consistent procedures, practices, and operational considerations. Refining cage-loading procedures, enhancing baling processes and the visibility of upstream processes, and establishing robust information-sharing mechanisms improve efficiency and support sustainability. *Conclusions*: The empirical research extends the knowledge related to freight efficiency movements on the road and focuses on practical actions in utilizing recycled fibre's carrying capacity.

Keywords: truck payload; freight transport efficiency; green logistics; recycling sector; pulp and paper industry

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1. Introduction

Reusing, recycling, and converting materials into new commodities extends a product's life, reduces landfill waste, and minimizes the use of raw materials [1]. Paper and cardboard (e.g., from packaging) are used regularly in daily life and are the most common waste that can be recycled. Consumers generally favour sustainable packaging, e.g., with a fibre-based design over plastic due to its connectivity to a circular economy, natural material [2–4], and positive associations with nature and wellbeing [5]. Recyclable paper is a crucial component of a sustainable economy as it replaces wood and natural fibres in paper production [6]. While everyone agrees with paper recycling with tailored strategies in country-specific settings, the global effect of the process on improving net zero targets needs to be understood further [7]. Nevertheless, innovative manufacturing approaches use waste paper instead of virgin fibre in products and packaging and have enormous environmental benefits. The UK paper manufacturing industry has 47 paper mills in England, Wales, Scotland, and Northern Ireland, producing around four million tonnes of product this year [8]. The industry typically uses paper as a recycling base, representing over 70% of the raw material for production [8].

Our research focuses on the distribution and truck payload of cardboard packaging in recycling operations, specifically on recycled fibre bales. Many businesses (e.g., in retail) use integrated recycling services and third-party providers with expertise in sustainable logistics to support the operations. Environmental concerns led towards greener logistics management to minimize the environmental impact of deliveries. Factors such as vehicle speed and load, road conditions, and driver skills influence environmental pollution in freight transportation. The focus has shifted towards understanding how freight-related parameters, influencing factors, and ecological consequences are interconnected [9].

The right balance between vehicle utilization and capacity has a positive impact on the community, traffic intensity, and emissions [10–12]. Efficient space utilization, weight distribution, and packing procedures and foldable packaging maximize the payload and reduce the number of trips [13–16]. Load consolidation through grouping different shipments from suppliers and customers reduces handling costs and time [17–19]. Intermodal transportation (road, rail, sea) and leveraging transport choices based on efficiency and environmental impact can achieve optimal payloads and evaluate trade-off solutions [19,20]. Many companies work together, and share and pool resources, supported by mutual collaboration strategies for sustainable goals [21–23]. Improvements in packaging design, and lightweight and flexible packaging with strategies to transport bulk materials closer to the demand points for final packaging also reduce the overall cargo weight [24,25].

The maximum capacity may require additional time and effort, and driver shortages impact the number of collections/deliveries within the time and business constraints [26]. When planning and optimizing payload capacity, companies consider route planning, load scheduling, and various constraints, including driver availability [27]. It is essential to ensure that the payload is within the legal limits and that drivers have sufficient time for rest and comply with regulations while maximizing the available capacity [28,29]. Technology also allows better payload coordination, planning, and driver assignments [30–32]. Advanced logistics technologies, e.g., real-time tracking systems, route optimization algorithms, predictive analytics, and fill rate monitoring, can ensure efficient capacity utilization [30–32].

Cardboard and paper recycling are vital in promoting sustainability and reducing the negative impacts from excessive resource consumption. Our research into the recycling sector aimed to address the following critical issues widely discussed in the logistics environment—the challenge of truck underutilization, reduction in empty miles, and driver shortage. This paper aims to fill the gaps related to understanding the main factors influencing the truck payload of recycled fibre in the distribution network for diverse customers managed by the company or through third-party logistics providers. The published research on the truck payload and distribution of recycled fibre bales is limited, with some relevant applications, e.g., [33–35], as discussed in Sections 2.2 and 2.3. Furthermore, research in the paper industry mainly focuses on the strategic design of the logistics network with decisions on facility locations–allocations and distribution, e.g., [36–39].

2. Related Literature

2.1. The Paper and Cardboard Recycling Industry

A circular economy (CE) focuses on reducing waste and making the most of resources using sustainable materials, collaborative consumption, reuse, repair, recycling, and closed-loop systems [40]. Circular manufacturing acknowledges the CE capabilities and Acerbi and Taisch [1] point out how those principles lead to the creation of circular manufacturing strategies where recycling, remanufacturing and waste management are among the strategies for converting materials into new commodities. Furthermore, in a manufacturing environment, the life cycle of a product needs to be assessed from the viewpoint of CE [41].

Figure 1 presents a typical cardboard/paper recycling and papermaking process in the retail sector. The recycled fibre is the crucial raw material, and the hydration process disrupts the inter-fibre bonding and splits fibres in the pulp [42,43]. Virgin pulp also plays a vital role, as fibres from recovered paper lose their quality over time and cannot be recycled indefinitely [8]. Paper manufacturing includes various quality grades of paper [44]. Laurijssen et al. [45] note the significant variances in the paper grade and energy consumption during production and other operations. Furthermore, inferior pulp for paper production can introduce harmful substances into the recovery cycle and cause the accidental dispersal of chemicals [46].

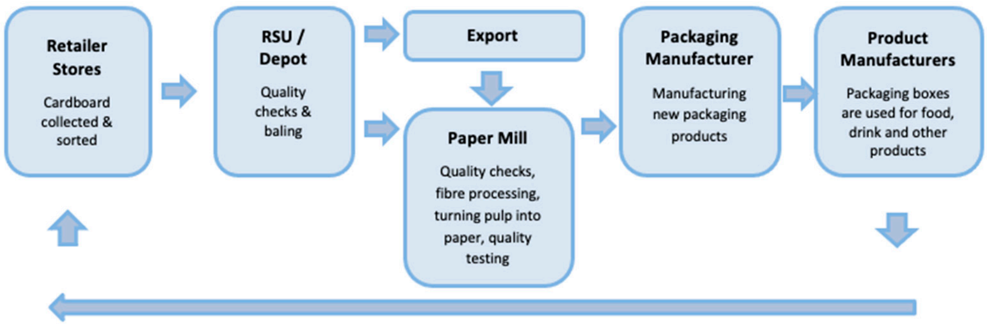


Figure 1. Typical cardboard/paper recycling and papermaking supply chain in retail sector.

Technology is widely integrated into recycling, and sensors (e.g., colour and gloss) are used for sorting paper waste [47] in addition to image processing techniques [48]. Nevertheless, manual grading and sorting are still labour-intensive in some countries, with workers exposed to dust, microorganisms, and bacteria that could lead to health problems [49].

The industry typically uses baling machines (or a balers) to compress and bind waste materials into compact and dense bales. Investing in a baler has several benefits: a great return on investment, saving storage, space, and transportation, improving health and safety, and protecting the environment and branding [50]. On the other hand, some balers are expensive, require regular maintenance and comprehensive training, use a lot of floor space, and are noisy [50]. The machines vary from small manual-tie balers of low compression to modern high-speed, automatic, high-compressed equipment [51].

Depending on the types of fibres, machine settings, and bale properties (e.g., size, weight, density, and stacking characteristics), recycling facilities may receive bales of various sizes/weights/densities [51]. The standardization of bales plays a vital role in operations. The research on balers includes the design of balers for various organizations and businesses [52]; techniques for measuring the moisture in the bales where, due to compliance, bales with higher moisture can be rejected [53]; research into microwaves for measuring the moisture content in bundles of recycled cardboard sheets [54].

When considering the challenges of the waste paper supply and demand market, there are complex connections among environmental policies, regulatory bodies, market dynamics, and technology [55]. They impact price fluctuations, and the key factors include the changes in waste management regulations followed by economic implications, international trade, and seasonal variations in supply and demand [55].

2.2. Freight Transport, Truck Payload, and Environmental Sustainability

The fundamental aspects of logistics services revolve around costs, time, and service. The logistics metrics focus on (1) utilization (e.g., maximize the vehicle capacity, utilize fuel consumption effectively, reduce inefficiency from empty running); (2) productivity (e.g., efficient use of time by the freight); (3) effectiveness of delivery operations (e.g., deviations from the schedule) [56–58]. It is important to note that distribution/collection centres provide value-added services (e.g., storage, delivery, returns, consolidation) that impact freight-related KPIs. The existing literature groups the indicators into four dimensions linked to (1) time (e.g., order lead time, receiving time, queuing time, equipment downtime); (2) cost (e.g., labor, order processing, maintenance costs), (3) quality (e.g., on-time delivery, customer satisfaction, picking accuracy, and scrap rate), and (4) productivity (e.g., labor productivity, throughput, turnover) [59]. These measures dominate in the assessment of logistics performance, whereas other aspects, such as human factors, are also important.

Negative environmental concerns from transportation prompted the development of greener logistics practices covering a green modal shift, green packaging, green warehousing, green logistic systems, and other aspects [60]. Piecyk and McKinnon [9] discuss the freight-related parameters that impact carbon dioxide emissions: transport modes, the amount of cargo transported related to the weight of products, the average distance of transportation, utilization of the vehicle capacity, vehicle movements without cargo, fuel effectiveness, and CO_2 emissions per energy output. Rogerson [61] links these variables with the research on procuring transportation and shipping services. In our study, we engaged with a company contracted to provide recycling services and sustainable solutions for their customers; therefore, coupling purchasing and key variables offers valuable insights.

As we focused on the load factors, overloaded trucks also pose serious safety risks to structural integrity, handling and stability, compliance and legal requirements, and road infrastructure and deterioration [31]. McKinnon and Ge [62] note that it is impossible to eliminate empty running and truck backloading (e.g., in the context of reverse logistics), and they depend on unreliable collections, a limited awareness of scheduled cargo, ineffective communication and coordination between logistics and purchasing functions, unsuitable vehicles for transportation, and restrictions on resources.

Maintaining a proper balance between the vehicle capacity and utilization has many benefits. The measurements of load factor could include weight, volume, and height and cannot be measured in a standardized way [63]. The load factor should be part of the larger system objectives to avoid sub-optimization [11]. Otherwise, it could lead to smaller vehicles with more frequent deliveries of full loads [11]. Different aspects influence the load factor in freight transport that include the types and sizes of loads, variation in the volume, requirements of high loads from providers, delivery/collection windows, demand for frequent deliveries/collections, distance, vehicle rental/ownership, fleet size, inflexibility, limited information sharing, human error, contract requirements, and environmental performance metrics in contracts [61,64,65].

Rogerson and Santén [11] discuss the opportunities to improve the vehicle payload factors and to address the imbalances through capacity adjustment and reallocation. Compromises between higher vehicle utilization and business objectives emphasize the decisions related to the employment environment, unloading procedures, delivery/transit times, and cargo vulnerability in addition to the load factor [11]. McKinnon [66] elaborates on the constraints influencing the load, such as the variations in demand, scarcity of collaboration, and communication between various parts of the business and the network and workplace safety standards.

The technology for monitoring the fill rate ensures efficient capacity utilization [30]. For example, in a typical RFID infrastructure, the data are captured for loading and unloading [32]. Digitalization is expected to reduce the truck kilometers travelled with prospects of setting and monitoring new regulations and improved load factors through data collaboration in interconnected networks [67]. Breschi et al. [68] present a frequency-based method based on the inertial sensors for payload estimation in garbage trucks. Some modern trucks, especially in the mining industry, have onboard payload measurement systems that can improve the productivity, machinery, tyre longevity, and road upkeep [31]. These systems have payload indicators, and Raza [31] provides an overview of the mining industry.

2.3. Design and Analysis of the Recycling Paper and Cardboard Supply Chain

Green waste logistics covers waste management and reverse and integrated logistics themes [69] with reverse logistics having a significant role in the design of CE products to promote sustainable growth [70,71]. Researchers have investigated the various aspects of the paper recycling supply chain using simulation and optimization techniques. Defalque et al. [36] specifically focus on the review of the operation research models, objectives, techniques, and uncertainty approaches for the design of waste paper recycling networks. Zhou and Zhou [37] discuss a strategic network design and location optimization model with decisions related to recycling facilities for office paper recycling in China. Rahmani Ahranjani et al. [38] provide a numerical illustration of a multi-objective stochastic technique for a closed-loop network design for the paper industry. Fleischmann et al. [72] investigate the effect of the return process in a recovery network design that integrated forward and reverse flows in a paper recycling example. Ouhimmou et al. [39] propose a robust optimization approach for a reliable warehouse location problem under demand uncertainty and tested on small problem instances derived from a pulp and paper company in Canada. An illustrative example motivated by a recycling company in Europe is presented by Pazhani et al. [73] to test the proposed closed-loop multi-objective location–production–distribution model with decisions on the manufacturing, distribution, locations of warehouses and multiple services (storage, sorting, and inspection) facilities. Zhang and Chen [74] study the impact of the demand uncertainty of the packaging waste in express outlets in the reverse logistics recovery network, focusing on the location distribution model.

Sauvageau and Frayret [75] use an agent-based simulation to model a recycled pulp supply chain with manufacturing, inventory, and procurement decisions. Modak, Panda, and Sana [76] study a closed-loop supply chain of a manufacturer and retailers to evaluate the impact of cooperative and non-cooperative scenarios. Their example demonstrates that including a recycling facility in the model enhances the interaction between the customer and the retailer and delivers favorable environmental advantages. Abdelli et al. [77] examine collection costs and emissions when optimizing the waste collection processes generated by households and businesses.

The sustainability of waste paper recycling, influencing factors, and potential future trends in Beijing are examined by Yang et al. [78]. Chen and Steuer [79] investigate the material recovery flow, recycling networks, and their partners in Hong Kong regarding the recycling activities that are not fully integrated into the formal systems. They discuss the challenges related to profitability, transaction systems, and policy structures. Mesjasz-Lech [80] analyzes the patterns in municipal solid waste management and the factors influencing the application of reverse logistics solutions.

Through a review of the academic literature, we were surprised to find limited research related to the truck payload, distribution, and recycled bales of fibre, signifying the gap in the literature that we aimed to address in our study. For example, Safaei, Roozbeh, and Paydar [33] study the cardboard circular logistics network using empirical data and focused on identifying inventory, purchasing and location decisions and the optimal amounts of different materials distributed throughout the chain. McCormick [34] presents research into Minas basin pulp and power company, which uses recycled paperboard products. Their key strategy for improving carton quality is to educate suppliers and small recyclers. Soofastaei et al. [35] discuss the truck load variation in the mining industry, where the company can achieve significant cost savings in the analysis of operations, vehicle energy efficiency, carbon footprint, and other rates. An increase in vehicle utilization means reduced transport costs; therefore, the preparation practices before transportation could significantly impact the cost and environmental reduction in a chip supply transport system [81]. The authors also note that outside influences, such as differences in the highway environment, distribution targets, and products for processing, can easily influence the results of their analysis.

3. Methodology

This study was a collaborative research project with a company renowned for its sustainable packaging solutions, paper products, and recycling services. They offer a range of recycling solutions tailored to the business in the UK. Trusted by various clients, including local authorities, retailers, and the food service industry, this company is a go-to for innovative resolutions of recycling challenges. Central to their ethos is the belief that no recyclable materials should ever find their way to landfills or incineration, and a 'closed-loop' solution guarantees materials' recycling. It encompasses the entire process from collecting and processing waste paper from customers to reconstituting it into reusable fibres and working with packaging manufacturers. The research collaboration is with the recycling division that provides logistics solutions for reintegrating paper and cardboard from customers into the manufacturing loop.

The research method applied in our study combines qualitative and quantitative techniques. Qualitative insights were obtained from interviews with logistics managers, which helped identify the practical challenges such as staffing issues and external disruptions like COVID-19. These findings complement the quantitative analysis (statistical investigation), which looked for patterns, trends, and irregular payload performance across various customer sites and haulers, as seen in Figure 2.

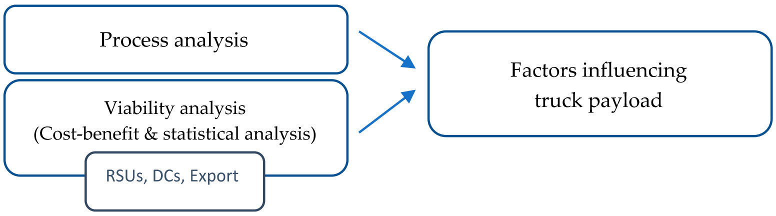


Figure 2. Research overview.

Process analysis and areas of opportunity were mapped and identified through semi-structured interviews with managers engaged with the different process owners in the company and their customers, as well as an on-site visit to a Recycling Service Unit (RSU). An RSU allows the coordination of all cardboard packaging from various stores for baling into recycled bales of fibre which are distributed to processing facilities and manufacturers using a dedicated provider that coordinates all the aspects. Some customers do not have dedicated facilities and use general facilities, with limited space for this operation. One-hour semi-structured interviews were conducted with the commercial manager for one of the retailers, two logistics managers, and a manager with purchasing expertise. During the interviews and observation in an RSU facility, different risks and areas of opportunity were identified, and an implementation plan was discussed with the company based on the improvement of the process analysis.

This project examines the process variability and focused on improvements to create a sustainable solution for recycling cardboard/paper fibre operations. The identified key activities will be pivotal in achieving the desired payload target and overall process optimization. The methodology is based on a business process management (BPM) improvement [82] with benefits in waste and redundancy reduction, cost savings, streamlined workflows, efficiency, tighter process control, upgraded service, and more focused communications through a unified system and processes [83]. The BPM improvement approach can be considered within the Business Process Maturity Model, which entails different levels for improved efficiency, effectiveness, and efficacy and has value propositions for the identification of current strengths, facilitation of informed decisions for prioritizing areas, support of the measurement of progress, and benchmarking [84].

The viability analysis focuses on determining the savings that could be generated and invested in possible solutions. The cost-benefit analysis supports the design of a sustainable solution. It justifies investment in technological solutions for maintaining the payload target in addition to establishing clear communication channels and standardized processes. This was approached through economic and environmental considerations, specifically where the reduction in emissions is achieved through improved resource efficiency. The collection facilities were selected using historical performance and the level of variability in payloads. These improvements were achieved through vehicle routing optimization, improved payload and scheduling planning, and reduction in empty miles.

The method included a statistical analysis and simulation of the payload savings between October 2019 and May 2022. The company provided the payload data for various customers (e.g., larger and discount retailers), their sites (RSU, depots, etc.), collection dates, haulers, source and destination points, KPIs, and other attributes. There can be multiple truckloads from a location on a specific date, and if a target payload is achieved or surpassed, there is no slack. The slack is defined as the difference between the target payload and collected tonnes per specific load. The payload target was set at 23 tonnes and then increased to 24 in May 2021 for RSUs and Export RSUs, whereas for DCs, the target increased from 20 to 21 tonnes. The yearly savings were derived by summing the monthly savings for each month and site using Equation (1).

$$T_m - Target\ pyload\ for\ month\ \text{“m”}$$

$$L_{ndmy} - Load\ number\ \text{“n” in day “d”}\ of\ month\ \text{“m” in year “}y\text{”}$$

$$C - Average\ cost\ per\ load$$

$$S_{my} - Savings\ in\ month\ \text{“m” in year “}y\text{”}$$

$$\sum_{m=1}^{12} S_{my} = \frac{\sum_{d=1}^{31}\sum_{n=1}^{10} max\left(T_m - L_{ndmy},\ 0\right)}{T_m} \times C\ for\ each\ month\ and\ site \quad (1)$$

As part of the viability analysis, a Monte Carlo simulation was conducted to analyze the payload variation for freight suppliers (haulers). In this paper we present only the analysis for two suppliers using the 2020 standard deviation (2.34, 2.46) and mean (21.9, 22.45). The simulation used the payload data with the outputs of the average of 10 rounds using 1000 randomized payload iterations following a normal distribution (Equation (2)).

$$\text{Payload(x)} = \mu + Z \cdot \sigma \quad (2)$$

where μ represents the mean payload, Z is the random variable from the standard normal distribution, and σ is the standard deviation of payloads.

The statistical analysis and Monte Carlo simulation strengthen the viability analysis and serve as a model to replicate other logistics operations. The analysis uses historical data and randomized simulations and provides a comprehensive view of potential savings, risks, and areas for improvement across different sites and haulers. Further discussions are presented in Section 4.3. Subsequent research may consider real-time data and other external variables that impact the payload efficiency.

The final stage of the research outlines the identified payload variation factors and proposes the solutions to effectively manage and address the variability based on the previous stages. A comprehensive examination of those variables that are interlinked with the distribution, operations, and multiple stakeholders will support the design of customized strategies for improved overall performance in recycling paper and cardboard operations.

4. Findings

4.1. Process Analysis

The research analyzed the various sources of process variability affecting truck payloads to support the design of a sustainable solution. The emphasis in this stage was on process analysis, as outlined in Figure 3. The collection–recycling process involved various stakeholders, their facilities, and resources (the company, customers (e.g., retailers), freight suppliers, and paper manufacturers) with possible conflicting objectives, power imbalances, and different levels of investment and commitment.

The key activities for payload improvement are concentrated within the following subprocesses: (0) setup and scheduling of collections; (1) grading, sorting, and baling; (2) load collection and monitoring; and (3) inspection and quality assurance (Figure 3). Each task is associated with a process owner, description, inputs, resources, outputs or deliverables, areas of opportunity, and proposed improvements to enhance the efficiency.

Subprocess 0: setup and scheduling of collections. The customer determines the contract length during the tendering stage. It is typically around three years but can range from 1 to 5 years. The existing customer has some flexibility in negotiations due to the access to historical information to improve the process visibility. There is a possibility for both parties to create more connected and advanced services by utilizing the company's experience in logistics and recycling services.

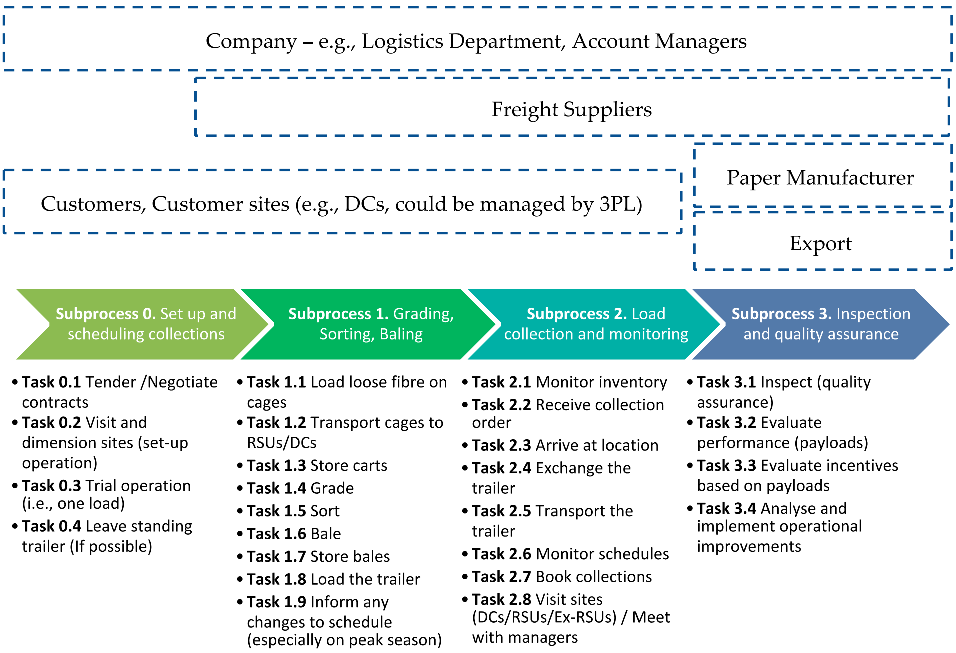


Figure 3. Business process modelling.

A data knowledge sharing clause can complement the evaluation process, which includes site visits, collection trials, and dimensioning to assess competencies, processes, and opportunities for operational enhancements. It could be included or extended during contract negotiations to allow future performance improvements. If both parties agree and document additional information sharing, it supports further improvement in the collection process and resource visibility with regard to the key performance targets, such as the target payload, to address limitations and optimize efficiency.

Subprocess 1: grading, sorting, and baling. The visibility of the upstream processes is of utmost importance since any changes in the packaging requirements by customers can significantly impact the downstream collection schedule. The cages used to transport fibre/cardboard from the customer's stores to the processing facilities are occasionally contaminated with plastic. To standardize the operations and ensure that the bale quality (e.g., bale contamination and moisture) and payload weight/volume meet the target, a trial load collection would be beneficial. Implementing training programmes and incentives for employees involved in cage loading operations would improve the space utilization, separation of materials, and proper elimination of contamination. It is vital to focus on sorting and grading at the baling facility (typically managed by another third-party provider) and emphasize complete removal of any contamination at the retailer's outlet (e.g., store) before cages are transported for baling. Tracking cage sources also helps to identify any errors that may occur at specific stores. Some locations have limited storage space; therefore, improving the utilization of the cages can reduce the overall space needs. Moreover, reviewing the facility layout and introducing suitable signage will enhance health, safety, and productivity. The operational challenges are consistent across different sites, e.g., problems with plastic contamination during loading and empty spaces in the bales.

Various customers have different baling machines and optimizing their performance and weighing the bales on site help achieve the desired payload and correct load distribution within the trailers. Overweighting could be another consideration, as the bale sizes may vary considerably, and the information feedback can address this issue. Moreover, the visibility of a maintenance schedule for the balers is critical for planning collections, and the load distribution can be optimized based on the known and tested bale sizes. The bales can be stored only for a limited time to prevent increased moisture content, and timely collections should be prioritized if the trailers are full. By monitoring "underperforming" facilities to improve the target payload, measures such as weighing, measuring, and pre-organizing bales can be implemented or further improved before loading.

Subprocess 2: load collection and monitoring. Information-sharing systems for contracted haulers can provide the company with timely updates through automated alerts or emails to enhance the collection process. The overall operations can be optimized further through the improved exchange of information among businesses and using other data (e.g., market demand) to enhance the forecasting. Smooth implementation depends on communication, approval of changes, and application of critical controls related to schedule changes. The seasonal demand and additional information are important to consider in the planning activities of the collection schedules.

Machine breakdowns can impact the collection process with inevitable cancellations and bottlenecks. Those operational failures also impact mill processes, as the facility proactively monitors the fibre stock levels and communicates with the logistics team regarding the need for cardboard or other resources. A review of the maintenance planning system can reduce breakdowns and improve the efficiency.

Once the collections are scheduled, the hauler receives a collection order or a series of bookings and dispatches the truck and trailer to the designated location. The booking and collection process could be improved through advanced planning and timely communication regarding the changes to collections and procedures. Other environmental sustainability-related variables (e.g., travel distance, empty running) may be included as part of the KPIs for this process to evaluate the consequences of the trucks' journeys.

When a standing trailer is available, the hauler exchanges it, leaving the empty trailer on site and removing the loaded trailer. However, having fewer standing trailers would be a more efficient use of resources. The hauler can additionally confirm the quality and integrity of the load because they are responsible for meeting the required arrangement regulations. The transportation process can be improved further if several factors are considered. They include trailer availability and an appropriate number of trailers on the customer site; truckload distribution and capacity for the optimal load distribution; optimization of the collection planning for improved resource management and scheduling; payload distribution investigation to analyze the distribution patterns and assist the better planning and allocation of resources.

The review of load collection schedules, cancellations, and additions is managed by account managers through their communication with the retailers. Planning typically commences in the autumn, with peak seasons requiring more in-depth analysis and frequent adjustments. Simple forecasting techniques are utilized, and additional collections are requested based on customer expectations. Any amendments to the schedule are tracked and then communicated (e.g., via email) and updated by the team. The issues are addressed as they arise due to a lack of real-time tracking rather than by proactively preventing them. The visibility of cancellations remains low, as they are currently only available through requested reports. Under-forecasting is less common in planning, and over-forecasting leads to collection cancellations.

The logistics team books the collections of bales from the customer sites, and there are differences between the initial planning and actual collection, with seasonal factors also influencing the planning process. Businesses can further review the contracts to include various challenges and incentives for contracted haulers and customers, including economic and environmental incentives (e.g., to reduce their carbon footprint) as part of the payment process. The life cycle evaluation and overall effectiveness and efficiency could enhance the information quality and KPIs for future decision making. Different contract-related incentives can support every partner in improving their sustainability and performance goals.

The communication between the logistics team, customers (e.g., retailers), and account managers is crucial for effective operations. Authorizing additional loads is typical for frequent revisions of collections, and further indicators can improve the decision making and information sharing with the logistics team. The customer demand should be considered in the planning process of the schedules to minimize unplanned changes. Proactive monitoring, visibility, and communication can improve the performance and service levels while streamlining operations.

Subprocess 3: inspection and quality assurance. The bales are checked at the manufacturing facility (e.g., mill) for compliance with specific standards (i.e., a maximum 15% of contamination) and the inspected bales are either accepted or rejected in line with the practices at the customer facilities discussed in Subprocess 2.

The logistics managers evaluate and analyze the payload performance, which could lead to contract changes with suppliers. Regular meetings and visits with site managers allow the team (including the account manager) to present and discuss payload performance data to identify the potential issues. An additional improvement in information sharing can include automated communication with customers and suppliers to reflect the changes required to daily operations. A timely response to requests for adjustments can lead to more agile operations.

4.2. Viability Analysis

This section aims to provide a detailed financial and operational assessment of the economic benefits of the proposed enhancements. Table 1 outlines the results for a major customer with RSUs, depots, and export facilities. The analysis focused on projecting payload savings (October 2019–May 2022) and was conducted in Excel.

Table 1. Payload variation and potential savings for a major customer.

Site	Payload Variation			Percentile Category (for % Payloads < Target)				Savings (Lowest Value = 100)			
				Year							
	Avg.	St. Dev.	Range	2019	2020	2021	2022	2019	2020	2021	2022
RSU											
L1	0.13	0.56	13.42	5th to ≤10th	10th to ≤25th	10th to ≤25th	≤5th	0	100	0	0
L2	0.69	2.08	22.56	25th to ≤50th	50th to ≤75th	25th to ≤50th	25th to ≤50th	900	5000	1900	2000
L3	1.36	2.38	23.11	50th to ≤75th	>90th	25th to ≤50th	50th to ≤75th	1700	9800	1600	1100
L4	0.53	1.23	16.22	10th to ≤25th	50th to ≤75th	25th to ≤50th	50th to ≤75th	100	2200	1100	1300
L5	1.63	2.3	19.3	75th to ≤90th	>90th	50th to ≤75th	75th to ≤90th	2200	8800	3700	4100
L6	2.03	3.22	23.43	75th to ≤90th	75th to ≤90th	50th to ≤75th	>90th	2900	11,400	3200	4100
L7	0.22	0.76	17.44	10th to ≤25th	25th to ≤50th	25th to ≤50th	10th to ≤25th	0	600	500	0
Export											
Ex1	1.65	2.15	24.00	>90th	>90th	50th to ≤75th	50th to ≤75th	5300	14,200	6000	600
Ex2	0.94	1.91	16.83	75th to ≤90th	75th to ≤90th	25th to ≤50th	50th to ≤75th	1900	6000	1400	700
Ex3	0.26	0.73	7.94	5th to ≤10th	25th to ≤50th	50th to ≤75th	10th to ≤25th	0	400	1400	200
Ex4	0.50	1.55	24	10th to ≤25th	50th to ≤75th	25th to ≤50th	10th to ≤25th	300	2600	1700	300
Depots											
D1	0.87	1.61	16.68	25th to ≤50th	50th to ≤75th	25th to ≤50th	50th to ≤75th	100	500	100	200
D2	2.08	1.95	20.00	>90th	75th to ≤90th	50th to ≤75th	50th to ≤75th	400	1100	300	200
D3	10.36	1.55	3.03					0	0	0	0
D4	0.07	0.19	1.12	10th to ≤25th	10th to ≤25th	10th to ≤25th	10th to ≤25th	0	0	0	0
D5	1.03	2.23	18.04	10th to ≤25th	50th to ≤75th	25th to ≤50th	75th to ≤90th	0	0	0	100
D6	3.96	3.69	23.16	>90th	>90th	>90th		0	100	100	0
D7	0.59	1.27	7.12	10th to ≤25th	25th to ≤50th	25th to ≤50th	10th to ≤25th	0	0	0	0
D8	1.01	2.04	11.90	25th to ≤50th	50th to ≤75th	25th to ≤50th	25th to ≤50th	100	1200	100	0
D9	5.75	5.10	17.06	50th to ≤75th	75th to ≤90th	50th to ≤75th	50th to ≤75th	800	5600	1700	600

L—RSU; Ex—export; D—depot.

Among the RSUs, for the overall observed period, locations L2, L3, L5, and L6 presented opportunities for higher savings and L3, L5, and L6 had a higher percentage of loads not achieving the target (minus 1 tonne for tolerance). The facilities L3, L5, and L6 had higher average, standard deviation, and range variation variability. Moreover, L2 demonstrated a notable range of variation even though it was less frequent.

Figure 4 presents a more detailed examination of the variation to understand further the annual trends. Three sites with the highest variation were still L3, L5, and L6 from 2019 to 2021, but L2 and L4 increased, with L3 presenting a lower value. Regarding the standard deviation, the analysis is similar to the investigation conducted over the three years for L3, L5, and L6, whereas L2 had an increased standard deviation. Related to the payload variation range, L6 presented a high range, although it improved in the 2022 year, whereas L2 and L5 continued to present a high range of variation.

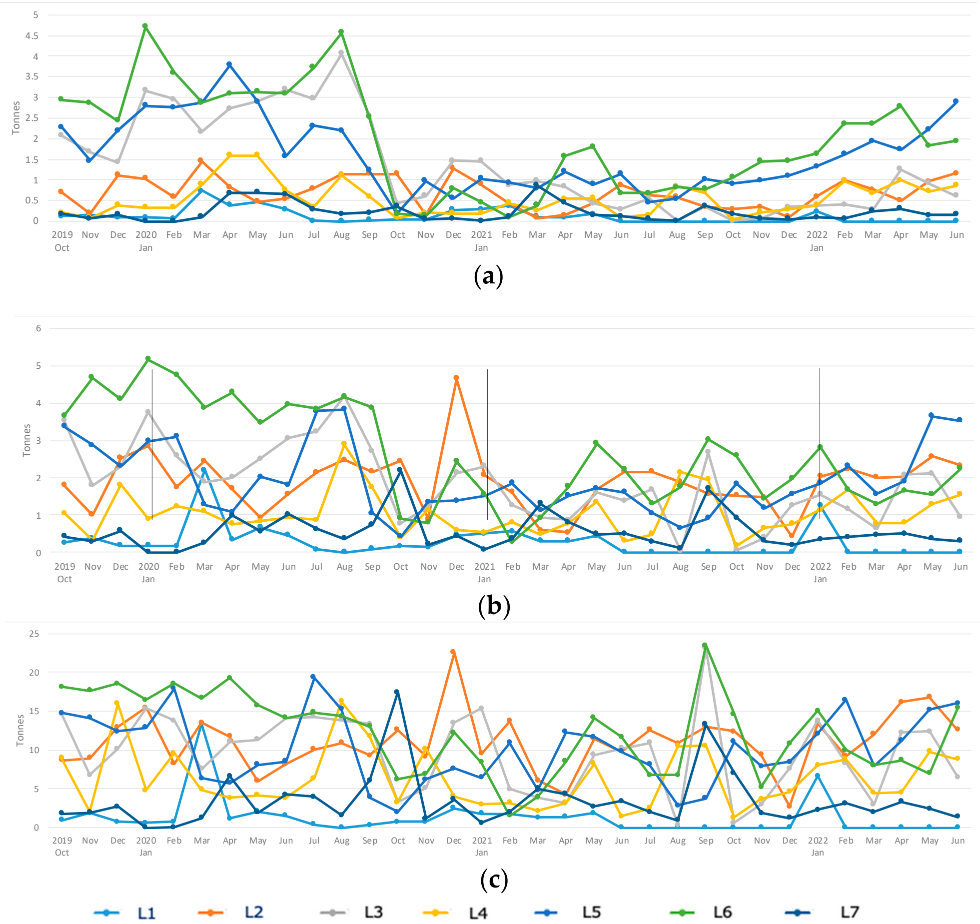


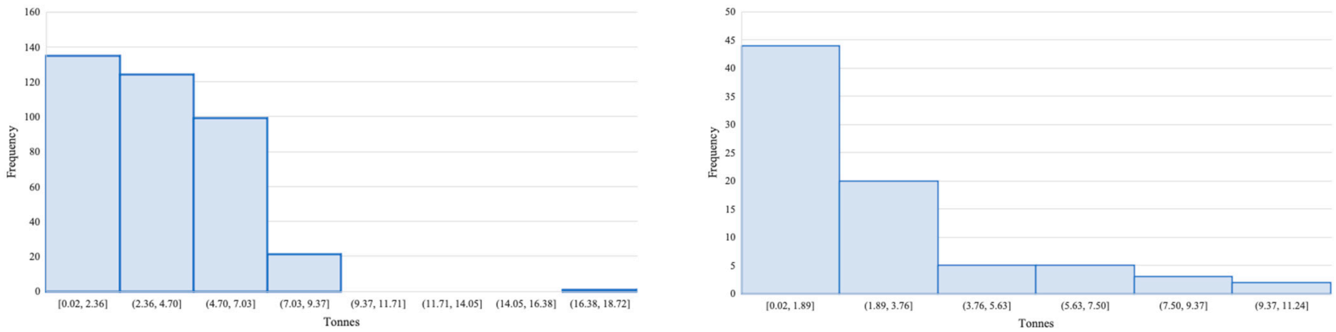
Figure 4. RSUs' payload seasonality analysis (2019–2022): (**a**) average payload variation; (**b**) payload standard deviation variation; (**c**) payload variation range.

As discussed, seasonality negatively contributes to efficient collection planning and truck payload performance. Some seasonality was observed from February to May and towards the end of the year in November and December due to the high season and, subsequently, higher loads (Figure 4). During the summer, there was an increase in the standard variation (Figure 4b), and it may be related to holidays, resulting in potential staffing challenges or a high personnel rotation. Similar observations were made for DCs, where locations D2 and D9 had a higher monthly average payload variation, with noticeable seasonality observed in March–April and July–September.

An increase in payload variation range can be seen during some periods, for example, during the COVID-19 lockdowns from August to September 2021 (Figure 4c). This investigation provides further insights into the effects of external factors, e.g., national lockdown restrictions, seasonal variations, and holidays, on the data trends for a more comprehensive understanding of the data patterns.

A statistical analysis of each site was conducted to analyze the payload variation sources in different periods. The benchmark for each site could be taken from their group type (i.e., RSU, Export, or DC) to ensure consistency and compare it to their own site historical performance, for example, in the last 12 months. Some facilities (e.g., L6) in 2020, had a higher range of variation compared to 2021 when it reduced and appeared to be skewed to the left. These examples allow a greater understanding of the reasons for the variation.

Another analysis focused on freight suppliers (haulers) to determine the suppliers with a higher variation (difference between the target and actual payload) based on the availability of information as few sites had comparable and representative supplier samples. For example, suppliers LSP1 and LSP2, in 2020, had an average payload variation of 3.6 and 2.4 tonnes, a standard deviation of 2.3 and 2.5, and a range between 0–18.7 and 0–11.2 tonnes, respectively. The LSP1 fleet analysis presents a larger range of variation compared to LSP2, which had a higher frequency of variation from 1 to 4 tonnes, while LSP2 had repetitive variations of around 1–2 tonnes (Figure 5).



(**a**) LSP1 (2020) (**b**) LSP2 (2020)

Figure 5. Export site (EX1) analysis by supplier and payload variation.

The results of the simulation demonstrate a mean value for the payload as 21.81 for LSP1 and 22.18 for LSP2, with standard deviations of 2.35 and 2.47, respectively. These findings indicate that LSP1 has less variability in the long term and is a reliable provider of the service for consistent payload performance. This supports the company's strategic objectives linked to the environmental goals and improvements to payload targets.

The viability analysis demonstrates that advanced simulation techniques and qualitative insights can identify actionable insights for improving the payload planning and reducing the variability. The facilities and carriers with better consistency in the payload can be used in the analysis as benchmarks for comparison with other locations and services. Moreover, those sites should be comparable, e.g., like-for-like facilities with similar balers' performance and assets in those locations. Furthermore, our methodology offers a replicable framework for future logistics analysis.

4.3. Factors Influencing the Payload

The business must understand the factors influencing the truck payload variation to design a sustainable solution in the context of the recycling sector. As part of the contractual arrangement, customers, shippers, and carriers must work together to ensure that the truck payload meets its target. Those factors were identified from the qualitative and quantitative analysis in Sections 4.1 and 4.2 and are summarized in Figure 6. The primary factors affecting the truck payload variation are discussed in this section in order of importance and include fragmented process information, operational performance variations, and human factors. Other aspects include the baler maintenance and driver shortages. The key factors are associated with three core processes: "setup and scheduling of collections", "grading, sorting, and baling", and "load collection and monitoring". The study draws on their results to propose actionable measures (see Figure 6) to ensure consistent and optimized payload performance in the recycling industry.

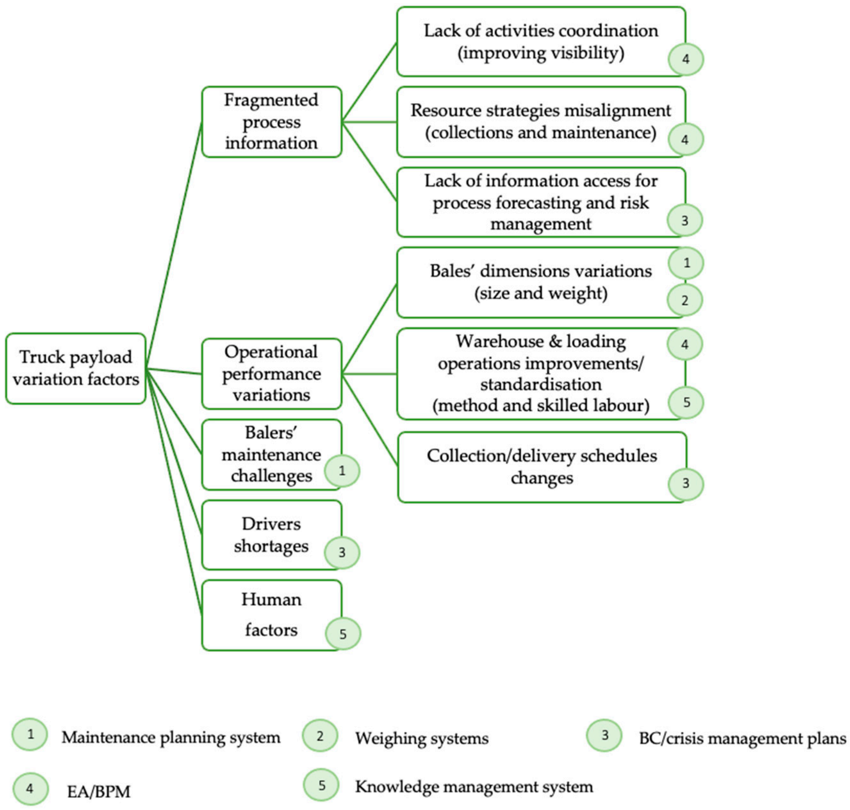


Figure 6. Factors influencing truck payload and proposed measures.

Fragmented process information factors cover limited communication channels and real-time data, data silos, process visibility, uncoordinated risk management, and lack of standardization. Lack of visibility and coordination leads to forecasting and risk management issues, such as scheduling changes or drivers' availability and supply variability. Ineffective coordination and limited insights into meaningful, timely data and processes can cause disruptions in operations and inefficiencies. Misalignment in resource planning strategies specifically concerns collections and maintenance and can create inconsistencies and hinder the overall efficiency. The coordination effort and efficient use of resources are central to effective operations from cost, productivity, and sustainability perspectives.

Reviewing and enhancing information-sharing systems and utilizing automated alerts/emails with haulers and customers can streamline the collection process. Given the complexity of the current IT systems, companies often require the development of interfaces to integrate systems for internal and third-party communications. Enhancing this aspect would need an IT systems point-to-point integration, with the development of an Enterprise Architecture (EA). The process mapping identified risks and opportunities that could be effectively addressed through system integration. The company can gain knowledge of the current systems and its communications through the EA, and different stakeholders should facilitate the process to determine the required data, information, and technology. Digitization may be essential for specific data or information that has not been converted to digital format, prompting the investment in technology that captures the requirements. This strategy will lead to more cohesive and efficient information exchange and facilitate seamless communication and collaboration in companies.

Developing historical data and expert-informed scenario analysis can support business continuity (BC) and crisis management plans for specific risk events, particularly during peak seasons when there is a possibility of a driver or trailer shortage. Various risk management structures can be investigated and applied to establish the procedures for frequent and high-impact risks, including those suggested by the Business Continuity

Institute. Furthermore, those standards can satisfy the requirements of a management system that protects and reduces the possibility of disruptive events and supports recovery. Effective continuity planning policies and the business impact analysis of various scenarios can help the company to be more resilient and manage unexpected events.

Addressing the operational performance variation through human-related factors that affect the load quality (e.g., cage contamination and loading operations) and the optimization of the baling processes can be managed by implementing effective information-sharing mechanisms that can collectively enhance the efficiency, reduce waste, and improve the performance. Through further improvements in the baler's maintenance planning, environmental measurement standards, communication, and the visibility for critical stakeholders, the overall logistics can be significantly optimized, disruptions can be reduced, sustainability can be promoted, and resource utilization can be improved. Further improvements and load analysis allow the shipper to enhance their transportation, cost-effectiveness, and service.

The use of weighing scales after the baling and possibly being complemented with a video camera could be a solution for load size measurements/weights, as part of the proposed measures. This combined approach will allow the company to determine the weight and measurement of all loads in advance. A trial phase can evaluate the performance in various locations and compare the resulting benefits. Once the viability of the solution has been tested and evaluated, then full-scale implementation can further improve the efficiency.

Enhancing the visibility of the baler's maintenance schedule and integrating a maintenance planning system can proactively reduce or prevent machine breakdowns. This suggestion can be proposed as a contract clause to support a commitment to the maintenance plan and to reinforce the equipment's reliability and operations.

Finally, human factors can lead to inconsistent practices and affect the overall performance. Examples include insufficient training and limited knowledge exchange among the team. A skill management system can address these challenges, offer further training opportunities, and motivate employees to develop their skills, competence, and efficiency. Alongside an Enterprise Architecture, it is important to recognize a variety of skills and expertise required for effective process management. These capabilities can be integrated into the business maturity model as a systematic approach to skills development and management. Six Sigma and agile system methodologies can enhance the quality and address these issues. Communication and discussions are essential components to support an operational knowledge management system that uses various tools for knowledge depository and collaborative platforms. It should support a learning-oriented and cooperative environment and encourage knowledge exchange and continuous development.

4.4. Comparative Analysis

The findings show that supply chain visibility and coordination are prominent for the company, its customers, and shippers to address variation, fragmented processes, and other factors. The challenges associated with reverse logistics are also discussed by Sonar et al. [85], where insufficient plans for a reverse logistics strategy and limited visibility of recycling and reuse are the most significant barriers, in addition to demand uncertainty and limited movement information available to stakeholders. Our study highlights these factors but also identifies the issues related to the contract, equipment, and human factors in the paper recycling industry, and extends the research in other sectors, e.g., [61,64–66,81].

The process variability and variation in demand and supply contribute to the uncertainty, and Sarkar et al. [86] point out that the unpredictable nature of returns impacts the production choices that depend on returns. Green product innovation using remanufacturing improves the waste management, and when there is a high uncertainty in the demand and supply, cutting-edge products outperform less innovative ones [86]. The lack of information on returns found in our research could also impact the product design and paper mill production planning, where product innovation could be stifled.

Although Garai and Sarkar [87] suggest gradual updates to the latest machinery in the bio-manufacturing environment, our research also does not emphasize the urgent need for upgrading the equipment (e.g., balers). Furthermore, our study focuses on the standardization of the processes related to bale sizes to reduce the variation in size/weight and optimize the truck payload. We emphasize the importance of an investment in information systems/technology to facilitate effective communication, data sharing, and collection planning and scheduling.

Our research focuses on the transportation payload efficiency and further investigations into the inventory decisions, such as the economic order quantity for remanufacturing, could optimize the logistics decisions further. Increasing the remanufacturing rate leads to a higher ordering quantity and reduces the setup and ordering costs [88]. As a result, an increased rate would enable consistent material movement and help with the truck payload utilization. This could be achieved through the collaboration among the customers in the network.

5. Conclusions

Sustainable logistics strategies aim to minimize freight deliveries' environmental concerns and balance the efficiency. The findings of this collaborative research of industry provide useful insights into the paper recycling sector in the UK and propose strategies that improve the truck payloads. An important contribution of this study is that, to the best of the authors' knowledge, it is the first investigation with a distinct focus on the truck payload, the distribution of recycled fibre bales, and operational considerations. It complements and extends the academic literature on the environmental factors that impact the freight transport sustainability and efficiency, e.g., [9,61,64–66,81]. The research brings attention to the optimization of the vehicle load and extends our understanding of the road freight efficiency in the paper recycling sector.

The empirical research examined the diverse origins of process variability that impact payloads, ultimately formulating actionable policies. The study identifies customers and their sites where enhancements in the payload efficiency are needed. Influencing payload factors relate to process aspects, data accessibility and fragmentation, processes' uniformity, and various operation considerations. Starting with the load quality concerns such as cage contamination, refining the cage loading procedures, optimizing the baling processes and the visibility of the upstream processes, and establishing robust information sharing mechanisms contribute to waste reduction and overall performance. Optimization of the truckload capacity and conducting comprehensive payload distribution analysis also provide new opportunities for actions.

Managerial implications. The results of this research provide logistics managers with an overview of the practical strategies on how to manage the sources of variability to improve the vehicle load and a comprehensive understanding of the influencing factors. The multifaceted nature of the payload optimization emphasizes the importance of a collaborative environment with far-reaching implications and creates and sustains effective and clear communication channels with customers and suppliers. This aspect of enhancement involves technological integration and an effective coordination ecosystem with mutual understanding and shared goals. Consequently, there is an opportunity to improve the productivity and effectiveness considerably due to the operational integration.

The results further indicate that the supply chain visibility would allow managers to detect disturbances to business as soon as possible and proactively respond. The sector must focus on improving the visibility with haulers and customers to enhance the scheduling and maintenance planning. Moreover, the research emphasizes the role of contractual arrangements with all stakeholders to support not only service provision and meeting targets but also the commitment to changes, economic and environmental objectives, incentives, effective exchange of data and information, and the coordination of activities.

Limitations and future research. This study focuses on one logistics case study in the paper recycling sector in the UK context, with an organizational setup involving 3PLs, different types of retailers, and scattered data. Some presented factors and proposed strategies can be specific to the sector. Nevertheless, similar dynamics can be found in other businesses, and the analysis could be extended to different products, sectors, and geographies, which will allow for the generalization of the model. Moreover, there could be some limitations related to the implementation of the proposed actions due to the market power, tensions, and stakeholders' dependence on the current contracts which should be reviewed in the future based on suggestions with further discussions. Further research could also investigate the trade of solutions (proposed strategies) related to the influencing factors and various pooling strategies for the baling and logistics among competing customers, where sharing resources and facilities could bring further advantages to operations. Also, the impact of forecasting techniques and data sharing on collection planning and influencing factors should be explored. Other aspects include investigations into the conflicts and misalignment in customer and supplier relationships and strategic partnerships to support the development of optimized logistics processes and green logistics innovations in recycling.

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