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The role of software in reverse logistics and effect on oily waste management

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Background: The oil and gas industry faces significant challenges in the management of oily waste, which requires effective reverse logistics practices. The incorporation of software in reverse logistics can potentially enhance the management of oily waste in the industry, but their effectiveness and implementation require exploration.

Objectives: The aim of this research was to explore the role of effective software in managing oily waste within the reverse logistics processes of the oil and gas industry, highlight their importance and identify industry-specific software.

Method: A literature review was conducted, and industry-specific software was identified through website analysis.

Results: Specific software solutions were found to be effective in managing oily waste in reverse logistics, and their use promotes sustainability in the supply chain.

Conclusion: The use of software in reverse logistics is an effective approach for managing oily waste and promoting sustainability in the oil and gas industry. Incorporating technology into reverse logistics practices can help to address the challenges of oily waste management.

Contribution: This study contributes to the literature by providing insights into the potential of software in reverse logistics for effective oily waste management in the oil and gas industry.

Keywords: reverse logistics; oily waste management; supply chain management; software; Industry 4.0; digital transformation.

Introduction

Reverse logistics has become an increasingly important aspect of supply chain management in recent years. It is the process of managing the return of products and materials from the end point to the place of production or recovery. Rogers and Tibben-Lembke (2001) defined reverse logistics as the planning, implementation and management of the efficient, cost-effective movement of raw materials, in-process inventories, completed items and related information from the point of consumption to the point of origin with the aim of recapturing or producing value or correct disposal. Reverse logistics cover collection, inspection, sorting, recycle and disposition operations of used or end-of-life products, wastes and materials (Agrawal, Singh & Murtaza 2015).

Fleischmann et al. (1997) indicated that reverse logistics helps companies to cut their costs, especially spent on materials, increase their profit and aid phenomena of scarce resources. The main objective of reverse logistics is to enable the return of resources in the productive cycle and add value. Coelho and Mateus (2017) state that reverse logistics plays a relevant role in sustainable management by effectively managing waste through appropriate processing or disposal, in a way that is socially acceptable. This process helps to recover the value of products, both economically and ecologically, and reduces the amount of waste generated.

Despite the fact that reverse logistics plays a crucial role in the sustainable development of companies and in circular economy, improper disposal of wastes and inefficient management of reverse logistics flow can have a negative impact on both environment and society. Furthermore, this leads to the economic loss for the companies and whole supply chain, and decreases the competitiveness of a business (Julianelli et al. 2020). All these factors urge the need for efficient reverse logistics network design and management.

Another driver for companies to implement reverse logistics is the involvement of government by legislations, green regulations, and incentive programmes (Laosirihongthong, Adebanjo & Choon

Tan 2013). Implementing efficient reverse logistics aid organisations avoid getting financial penalties for not complying with legal regulations and rules.

The process diagram in Figure 1 provides a general overview of the reverse logistics activities in the oil and gas industry. It begins with the extraction of oil and gas, followed by the collection and transportation of oily wastes. These wastes undergo treatment and processing, with the option of recycling and reuse. Additionally, there are pathways for disposal, inventory management and remanufacturing. Distribution to the second market is also highlighted, along with the transportation back to the oil field. This diagram visually represents the complex flow of reverse logistics activities in the oil and gas industry, encompassing waste management, resource optimisation and sustainable practices.

The growth of e-commerce and the increasing concern for sustainable business practices have both contributed to this trend. However, the efficient management of reverse logistics remains a challenge for many companies (Fleischmann et al. 1997), especially in petroleum industry. The oil and gas industry generates a significant amount of oily waste during their operations, which poses environmental and economic challenges for reverse logistics (Shahbaz et al. 2023). The traditional approach of managing this waste is often inefficient and unsustainable. Therefore, the use of software has emerged as a potential solution to address these challenges (Sun, Yu & Deng Solvang 2022).

Several studies have investigated the use of software to improve reverse logistics processes. However, there is still a gap in the literature regarding the specific types of software that are most effective for managing reverse logistics and wastes in the oil and gas industry. This study aims to address this gap by exploring the role of software in reverse logistics and identifying industry-specific software solutions provided by some companies. To achieve this aim, the study has the following objectives: firstly, to review the existing literature on reverse logistics and software used in the management of oily waste in this field, and secondly, to identify different types of industry-specific software solutions that can be used in reverse logistics for managing oily waste in oil and gas industry and give description for each of them.

The conceptual framework for this study is based on the theory of supply chain management, which emphasises the importance of efficient and effective management of all aspects of the supply chain, including reverse logistics (Rogers & Tibben-Lembke 2001). The study will contribute to the existing literature by providing insights into the role of software in reverse logistics and its impact on the management of oily waste which will be valuable insights for practitioners and researchers.

Literature review

The role of software in reverse logistics

Companies can benefit from using Industry 4.0 tools in reverse logistics operations. Dev, Shankar and Swami (2020) point out that reverse logistics relies on inventory and production planning, additive manufacturing, well-coordinated transportation system and information transparency, and integration of Industry 4.0 could help companies to improve those operations. Radio-frequency identification (RFID) technology improves inventory and

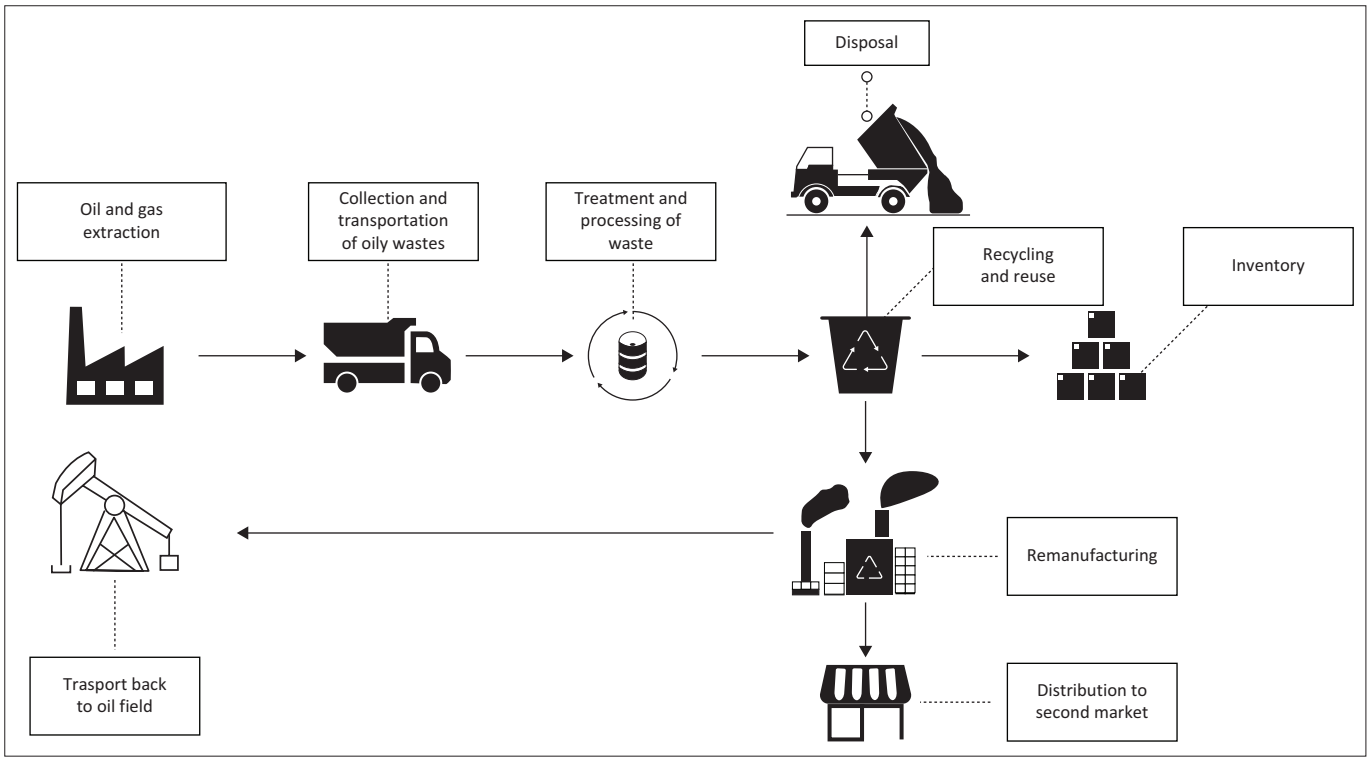

FIGURE 1: Process diagram about reverse logistics activities in oil and gas industry.

production planning in the reverse logistics system. Furthermore, cloud technology provides a single platform from which data and information may be exchanged across all organisations engaged in a supply chain. Specifically, real-time information ensures the availability of the appropriate method of transport for the timely delivery of green products.

The development of technology has led to the implementation of digital and intelligent solutions that have transformed the landscape of reverse logistics in three key areas: data, services and operations. The utilisation of Internet of things (IoT), smart devices, artificial intelligence (AI) and big data analytics has revealed the unprecedented value of data, allowing for more effective and timely planning of resources and operations. The implementation of a cloud-based, interactive and intelligent digital platform connects various service providers and customers, leading to optimal resource sharing and the creation of innovative services. The incorporation of Industry 4.0 principles into reverse logistics enables the utilisation of data and smart technologies to create innovative services and helps to achieve sustainable development, economic efficiency and environmental sustainability and fulfil social responsibility.

Agrawal et al. (2015) summarised reverse logistics processes as collection of used products or wastes, inspection and sorting, repairing, remanufacturing, recycling, reusing or final disposal after taking the decision. Industry 4.0 tools are enablers to make all these processes more sustainable and smarter.

The importance of Industry 4.0 software in managing oily waste in the oil and gas industry

The integration of Industry 4.0 technologies, such as automation, IoT and big data analytics, has the potential to significantly improve the management of oily waste in the oil and gas industry. One of the key benefits of Industry 4.0 software solutions is the automation of oily waste management processes. Automation can reduce the need for manual labour and minimise the risk of human error, which is particularly important in the handling of hazardous materials such as oily waste (Cheema, Hannan & Pires 2022). Automated systems can also improve the efficiency of oily waste management by reducing downtime and increasing productivity.

Industry 4.0 software solutions also allow for the collection, analysis and reporting of large amounts of data, and can therefore increase supply chain efficiency and contribute to overall improved business performance. This can provide organisations with valuable insights into the performance of oily waste management processes and identify areas for improvement. By making data-driven decisions, organisations can optimise their operations and reduce costs.

Garcia et al. (2022) highlighted that predictive maintenance is another key feature of Industry 4.0 software solutions that is particularly useful for appropriate maintenance to prevent significant losses of money and time, and managing oily waste in the oil and gas industry. Predictive maintenance uses machine learning and IoT technology to predict when equipment is likely to fail and schedule maintenance accordingly. This helps to reduce downtime and improve the efficiency of equipment, ultimately reducing the costs of operations.

Industry 4.0 software solutions also enable remote management and monitoring of facilities and operations (Mirani et al. 2022). This allows organisations to quickly identify and address any issues that arise, improving the overall efficiency and effectiveness of oily waste management operations.

In addition, Industry 4.0 software solutions are helpful in monitoring and reporting on compliance with regulatory requirements for oily waste management. This helps organisations to ensure compliance with local and international regulations and avoid penalties.

In conclusion, Industry 4.0 software solutions play a crucial role in managing oily waste in the oil and gas industry by providing a range of advanced technologies and capabilities that improve the efficiency, effectiveness and sustainability of oily waste management processes.

Research methods and design

This study employed a qualitative research design that allows for an in-depth exploration of the role of software in reverse logistics and its effect on oily waste management. The study was conducted in the oil and gas industry, focusing on companies that deal with the management of oily waste.

Data collection for this study involved a literature review of published research on the topic and a list of software used in the field. Data from the literature review were collected by searching electronic databases such as Scopus and ResearchGate, and additional papers were found in Google Scholar by implementation of snowballing method to find further literature. Data from the software survey were collected by searching the websites of companies that provide software solutions for reverse logistics and oily waste management.

Given that this study is based on a literature review and the gathering of information on software solutions, the data analysis primarily involved a descriptive analysis of the findings. Organisations providing the software solutions identified for reverse logistics operations were organised in a table, based on the functionality of tools in managing oily waste, and were compared based on their features and capabilities. The analysis provided insights into the different types of software that can be used for effective management of reverse logistics in the context of oily waste.

Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

Results and discussion

Collection and transportation of oily waste

In the oil and gas sector, the collection and transportation of oily waste is a crucial component of reverse logistics as it entails the safe and effective disposal of waste materials from drilling and production sites. Given that they enable businesses to track and monitor the flow of waste materials from the place of origin to the final destination, RFID and global positioning system (GPS) tracking systems are crucial tools for controlling the collection and transportation of oily waste (Namen et al. 2014).

Radio-frequency identification technology uses radio waves in a wireless system to identify and track goods, including waste materials. Radio-frequency identification tags attached to the waste containers may be scanned by RFID readers placed at various points along the transit route. This enables companies to track the location and transit of the waste goods in real time to guarantee compliance with regulations and minimise delays or misroutes (Hannan et al. 2011).

On the other hand, GPS tracking devices employ satellite signals to locate the waste cans. Real-time position information from GPS monitoring devices may be utilised to improve transportation routes and guarantee that waste products are delivered on schedule (Arebey et al. 2009).

Smart sensor technology may also be used to keep an eye on the state of waste during transit and guarantee that rules are being followed. Smart sensors may detect several characteristics, including temperature, pressure, and humidity, and communicate the information to a central monitoring system when they are attached to waste bins. This enables businesses to identify any possible issues, such as leaks or damage, with the waste containers and take immediate action to stop hazardous spills or other accidents (Xu & Yang 2022).

Table 1 presents software solutions that can be used in collection and transportation of oily waste. It includes information on the functionality, software names and descriptions of each technology.

Treatment and processing of the waste

The next step in the reverse logistics process for waste management is the treatment and processing of the waste. This involves the use of automated systems for sorting and separating different types of waste, as well as predictive maintenance software and machine learning algorithms (Agrawal, Singh & Murtaza 2015). These tools are essential for effectively and efficiently handling the different types of waste that are generated by the oil and gas industry and for ensuring compliance with regulations and environmental standards.

Advanced sensor technology is used by automated systems for sorting and separating various waste products, including oil, water and solids. This makes it possible to handle the waste effectively and efficiently, which can assist in lessening the overall amount of waste that has to be moved and disposed of (Gundupalli, Hait & Thakur 2017).

The equipment and machinery used in the waste treatment and processing process are monitored using predictive maintenance software, which may send out alerts for possible faults before they become serious issues (Herve, Moore & Rosner 2019). This increases the general effectiveness of the waste management process while lowering maintenance costs and downtime.

Large volumes of data created by the waste treatment and processing process are analysed using machine learning algorithms, which may spot patterns and trends that can assist to streamline the procedure and enhance overall performance (Chen 2022). They may also be used to forecast

TABLE 1: Collection and transportation of oily waste.

Functionality	Software name	Description	Source (literature)
RFID and GPS tracking systems	RAIN RFID, MotionWorks Asset	The collection and transportation of oily waste can be effectively tracked and managed through the utilisation of Zebra Technologies' software, specifically RAIN RFID and MotionWorks Asset. These software solutions enable businesses to ensure compliance with regulations and enhance decision-making by providing real-time visibility and data. By utilising Zebra Technologies' systems, organisations can track and monitor the location, movement and condition of oily waste throughout the transit process, facilitating efficient waste management practices.	https://www.zebra.com/us/en/products/rfid.html; https://www.zebra.com/gb/en/solutions/intelligent-edge-solutions/rtls.html
	Higgs® RFID ICs	For the collection and transportation of oily waste, Alien Technology offers Higgs® RFID ICs as part of their RFID and IoT solutions. These Higgs® RFID ICs provide businesses with the capability to track and monitor the flow and state of waste, maintain regulatory compliance and gain real-time insights and data for better decision-making.	https://www.alientechnology.com/products/ic/higgs-4/
	Automatic Location Tracking System	Motorola Solutions provides the Automatic Location Tracking System, enabling businesses to track and monitor waste movement during transit. This software, combined with their GPS tracking devices, ensures compliance, real-time visibility and informed decision-making. Efficient waste tracking and monitoring contribute to improved waste management practices.	https://www.motorolasolutions.com/en_xp/application-catalog/alts.html#benefits
Smart sensor technology	Siemens Digital Industries Software	Siemens Digital Industries Software offers smart sensor technology for the collection and transportation of oily waste. Their solutions provide real-time data and analytics, enabling businesses to monitor the status of oily waste during transit and ensure regulatory compliance.	https://www.plm.automation.siemens.com/global/en/industries/energy-utilities/energy-equipment-manufacturing/waste-management.html
	CompactRIO combined with LabVIEW FPGA Module	The collection and transportation of oily waste may be accomplished with the help of smart sensor technology – CompactRIO from National Instruments. Through the provision of real-time data and analytics, the combination with LabVIEW FPGA Module may assist businesses in keeping an eye on the status of waste throughout transit, enhancing productivity and ensuring regulatory compliance.	https://www.ni.com/pl-pl/shop/compactrio.html

GPS, global positioning system; RFID, radio-frequency identification; IoT, Internet of things.

upcoming equipment failures and plan required maintenance, extending the life of the equipment.

Overall, the treatment and processing of oily waste is a crucial step in the reverse logistics process, and the use of these advanced tools and technologies can greatly improve the efficiency and effectiveness of this process, while also helping to minimise the environmental impact of the oil and gas industry.

Table 2 summarises software solutions for the treatment and processing of oily waste. Each software is described along with its functionality area and the benefits are also highlighted.

Recycling and disposal of oily waste

Recycling and disposal of oily waste is a crucial step in the reverse logistics process of managing and mitigating the environmental impact of industrial operations. Cheah et al. (2022) report that the proper disposal of oily waste involves a combination of remote monitoring systems, automated tracking systems and compliance with regulations. These tools are essential for ensuring that the waste is disposed of in a safe and responsible manner, and that the company remains compliant with relevant laws and regulations.

Remote monitoring systems allow real-time monitoring of waste disposal sites, providing valuable information on the status of the waste, as well as any potential issues that may arise (Joshi et al. 2022). Automated systems for managing and tracking the disposal of oily waste, such as SAP EHS, Enablon and Intelex, allow companies to easily monitor and report on their waste management activities and to demonstrate compliance with regulations.

These tools are important for ensuring that the disposal process is carried out in an efficient and effective manner and for minimising the environmental impact of the waste (Namoun

TABLE 2: Treatment and processing of the waste.

Functionality	Software name	Description	Source (literature)
Automated systems for sorting and separating	Autosort™	To manage and treat the waste more efficiently, Tomra offers AutosortTM for classifying and dividing various forms of wastes. Their solution is made to maximise the recovery and recycling of priceless resources while minimising the environmental effects of waste treatment.	https://www.tomra.com/en/waste-metal-recycling/products/machines/autosort
	Oil Filter Shredding Recycling Solution	Oil sludge treatment systems and oil filter recycling machines are just a few of the equipment for processing oily waste that Enerpat has to offer. Oil Filter Shredding Recycling Solution is made to efficiently remove oil and other contaminants from waste streams, guaranteeing legal compliance and minimising environmental damage.	https://www.enerpatrecycling.com/Waste-Oil-Filter-Recycling-Solution-pd40801649.html
	McMRF®	Sorting systems, shredders and separators are just a few of the equipment for processing oily waste that is offered by CP Group. McMRF® is built to be very effective while having little negative environmental impact.	https://www.cpgrp.com/systems/mcmrf
Predictive maintenance software	GE Predix Platform	An IoT-based technology called GE Predix Platform enables remote monitoring and proactive repair of industrial machinery. With the use of this software, oily waste may be treated and processed in a more efficient manner, resulting in less downtime and maintenance expenditures.	https://www.ge.com/digital/iiot-platform
	PTC ThingWorx	Industrial equipment may be monitored and controlled in real-time using the IoT platform PTC ThingWorx. It can be used to guarantee compliance with rules and to improve the operation of machinery used in the handling and processing of oily waste.	https://www.ptc.com/en/products/thingworx
	IBM Maximo® Application Suite	An asset management tool called IBM Maximo® Application Suite enables the tracking and upkeep of industrial machinery. It may be utilised in the handling and processing of oily waste to aid in the early detection of possible problems and the timely scheduling of maintenance.	https://www.ibm.com/products/maximo
Machine learning algorithms	RapidMiner	RapidMiner is a machine learning tool that can be utilised to analyse and spot patterns and trends in enormous volumes of data. It can be used to guarantee compliance with rules and to improve the operation of machinery used in the handling and processing of oily waste.	https://rapidminer.com/
	KNIME Software	A machine learning platform called KNIME enables users to develop, test and employ data science models. It may be used to examine the data produced when treating and processing oily waste and to find strategies to increase effectiveness and lessen the negative effects on the environment.	https://www.knime.com/software-overview
	Alteryx Analytics Cloud	A data science platform called Alteryx Analytics Cloud enables users to develop, test and employ data science models. It may be used to examine the data produced when treating and processing oily waste and to find strategies to increase effectiveness and lessen the negative effects on the environment.	https://www.alteryx.com/products/alteryx-cloud

IoT, Internet of things.

TABLE 3: Remote monitoring systems.

Functionality	Software name	Description	Source (literature)
Remote monitoring systems	SmartWaste	SmartWaste is a remote monitoring system that uses real-time monitoring technology to keep track of waste disposal sites. This software allows businesses to monitor and manage waste disposal activities in order to ensure compliance with regulations and minimise environmental impact.	https://www.bresmartsite.com/products/smartwaste
	Ecowaste Solutions	Ecowaste Solutions is a software company that specialises in providing automated systems for managing and tracking the disposal of wastes. Their software allows businesses to track the movement of waste from collection to disposal, ensuring that waste is handled in an environmentally friendly and compliant manner.	https://ecosolutions.com/
	Enablon	Enablon is a leading provider of environmental, health and safety management software. This software allows businesses to manage and track the disposal of waste, ensuring that it is handled in an environmentally friendly and compliant manner.	https://www.wolterskluwer.com/en/solutions/enablon
Automated systems	SAP EHS	SAP EHS is a software solution that helps businesses to manage and track the disposal of waste. The software allows businesses to monitor and manage waste disposal activities in order to ensure compliance with regulations and minimise environmental impact.	https://www.sap.com/products/scm/ehs-management-health-safety.html
	EHSQ & ESG Management Software	Intelex is a leading provider of environmental, health and safety management software. Their EHSQ & ESG Management Software allows businesses to manage and track the disposal of waste, ensuring that waste is handled in an environmentally friendly and compliant manner.	https://www.intelex.com/

et al. 2022). Furthermore, these tools can also help companies to reduce costs associated with waste management and disposal, as well as to improve their overall environmental performance.

Table 3 illustrates remote monitoring systems which can be used in recycling and disposal processes of oily waste. Software solutions are grouped for their functionality in the table, and description for each is presented.

Inventory management and tracking of oily waste

In inventory management and tracking of oily waste, various tools are used to efficiently manage and track the movement and storage of oily waste. These include: software for inventory management, tracking and tracing of waste, and reporting and compliance management (Liwan, Kasim & Zainal 2013). These tools are crucial for ensuring compliance with regulations and proper handling and disposal of oily waste. They also assist in identifying areas for process improvement, reducing waste and minimising environmental impact. Real-time monitoring, automated data collection, and advanced analytics capabilities are also important features of inventory management and tracking software (Dev et al. 2020). These software solutions help organisations to make data-driven decisions and optimise their waste management processes.

Table 4 provides an overview of software applications for inventory management and tracking of oily waste.

Data analysis and reporting for oily waste management

Data analysis and reporting is a crucial step in the reverse logistics process for oily waste management. It involves using advanced software to analyse large amounts of data related to the collection, transportation and disposal of oily waste. This information is then used to identify patterns, trends and potential issues, and to make informed decisions about how to improve the overall efficiency and effectiveness of the waste management process (Vafeiadis et al. 2019).

One important aspect of data analysis in oily waste management is the use of big data analytics software. These tools are designed to process and analyse large sets of complex data in real time, providing valuable insights that can be used to optimise the waste management process. For example, big data analytics can be used to identify patterns in the data that indicate areas where waste is being generated in large quantities, or where collection and transportation routes are inefficient (Sun 2020).

Another important aspect of data analysis in oily waste management is the use of dashboard and visualisation tools. These tools allow users to view and interact with data in a graphical format, making it easier to understand and analyse the information. For example, dashboards can be used to display key metrics such as waste volumes, transportation routes, and compliance with regulations. This makes it easy to identify areas of concern and take action to address them (Sun et al. 2022).

Overall, data analysis and reporting are critical components of the reverse logistics process for oily waste management. By providing valuable insights into the collection, transportation and disposal of oily waste, it enables companies to improve the efficiency and effectiveness of their operations and ensure compliance with regulations.

Table 5 presents software applications for data analysis and reporting in the context of oily waste management.

Automation of reverse logistics processes for oily waste

An essential step in efficiently handling and disposing of oily waste materials is automating reverse logistics activities.

TABLE 4: Inventory management and tracking.

Functionality	Software name	Description	Source (literature)
Cloud-based inventory management systems	SAP Inventory Manager	A cloud-based solution for managing end-to-end procurement processes, including catalogue management, sourcing and invoice processing. By having real-time visibility into inventory levels, SAP Inventory Manager can help optimise the management of oily waste materials in the oil and gas industry, enabling more efficient and effective reverse logistics operations.	https://help.sap.com/docs/SAP_Inventory_Manager/880c14f9d1f2492486ef8521a1e7d4a4/b482683270a71014882be7f64e204223.html
	Oracle NetSuite ERP	Oracle NetSuite is a cloud-based enterprise resource planning (ERP) system that provides businesses with a unified view of their financials, inventory and operations. The system's inventory management capabilities can aid in the tracking and reporting of oily waste materials, helping organisations in the oil and gas industry to comply with regulations and make informed decisions about waste disposal and recycling.	https://www.netsuite.com/portal/products/erp.shtml
	Infor WMS	Infor is a provider of enterprise software solutions for various industries, including oil and gas. Its inventory management software, Infor Warehouse Management (WMS), can assist with real-time tracking and reporting of oily waste materials, enabling organisations to make data-driven decisions about waste management and compliance.	https://www.infor.com/solutions/scm/warehousing/warehouse-management-system
Automated systems for monitoring and reporting on inventory levels	SAP EWM	A warehouse management system that offers real-time inventory visibility and control. By automating inventory management processes and providing real-time data, SAP EWM can help oil and gas companies optimise their waste management operations and ensure compliance with regulations.	https://www.sap.com/products/scm/extended-warehouse-management.html
	Oracle WMS	A warehouse management system that offers inventory visibility, control and automation. It can assist oil and gas companies in tracking and reporting oily waste materials, enabling them to make informed decisions about waste management and compliance.	https://www.oracle.com/scm/logistics/warehouse-management
	Manhattan Active	Manhattan Associates is a provider of supply chain and omnichannel commerce solutions, including inventory management software. Manhattan Active, which is an inventory management solution, can assist oil and gas companies in tracking and reporting oily waste materials, enabling them to optimise their waste management operations and ensure compliance with regulations.	https://www.manh.com/products/manhattan-active-warehouse-management

TABLE 5: Data analysis and reporting.

Functionality	Software name	Description	Source (literature)
Big data analytics software	Cloudera Data Platform	Cloudera provides a platform for big data analytics and management, with features such as data warehousing, machine learning, and real-time streaming. In the context of reverse logistics and oily waste management, Cloudera Data Platform can be used to process large amounts of data and generate insights into waste streams, allowing for more efficient and effective management and disposal.	https://www.cloudera.com/products/cloudera-data-platform.html
	Hortonworks Data Platform	Hortonworks Data Platform is a big data analytics software that provides data management, governance, and analytics. The platform can be used to store, process, and analyse large amounts of data, including data related to oily waste streams. This can enable more efficient and effective management of waste, and compliance with regulations.	https://www.cloudera.com/products/hdp.html
Dashboard and visualisation tools	Tableau	Tableau is a data visualisation tool that allows users to create interactive dashboards, charts, and graphs. In the context of reverse logistics and oily waste management, this tool can be used to create visualisations of data related to waste streams, enabling more efficient and effective management of waste, and compliance with regulations.	https://www.tableau.com
	QlikView	QlikView is a data visualisation and business intelligence tool that allows users to create interactive dashboards, charts, and graphs. In the context of reverse logistics and oily waste management, this tool can be used to create visualisations of data related to waste streams, enabling more efficient and effective management of waste, and compliance with regulations.	https://www.qlik.com/us/products/qlikview
	Looker	Looker is a data visualisation tool that allows users to create interactive dashboards, charts, and graphs. In the context of reverse logistics and oily waste management, this tool can be used to create visualisations of data related to waste streams, enabling more efficient and effective management of waste, and compliance with regulations.	https://www.looker.com/product/visualizations

TABLE 6: Automation of reverse logistics processes.

Functionality	Software name	Description	Source (literature)
Robotics and automation systems	IRB 120, IRB 2600	ABB Robotics is a company that specialises in providing robotics and automation systems for various industries. IRB 120, IRB 2600 may be utilised for wide range of activities including welding, painting and material handling. These systems may be utilised for automated oily waste sorting, packing and handling in reverse logistics. This may result in a procedure that is more accurate and efficient.	https://new.abb.com/products/robotics/robots/articulated-robots/irb-120; https://new.abb.com/products/robotics/robots/articulated-robots/irb-2600;
	FANUC M-710iC Series, LR Mate Robot Series	FANUC America Corporation is a company that specialises in providing industrial robots and automation systems. Their robots (FANUC M-710iC Series and LR Mate Robot Series) are capable of doing activities including machine maintenance and material handling. These robots can be utilised for automated oily waste sorting, packing and handling in reverse logistics. This may result in a procedure that is more accurate and efficient.	https://www.fanucamerica.com/products/robots/series/m-710; https://www.fanucamerica.com/products/robots/series/lr-mate
	KR AGILUS, KR CYBERTECH	KUKA is a company that specialises in providing industrial robots and automation systems. KR AGILUS and KR CYBERTECH may be utilised for jobs including welding, machine maintenance and material handling. These robots can be utilised in reverse logistics for the automated sorting, packing and handling of oily waste. As a result, the procedure may become more accurate and efficient.	https://www.kuka.com/en-gb/products/robotics-systems/industrial-robots/kr-agilus; https://www.kuka.com/en-gb/products/robotics-systems/industrial-robots/kr-cybertech
Automated systems for scheduling and coordinating reverse logistics processes	SAP TM	SAP Transportation Management is a software that can be used for scheduling and coordinating transportation processes. Reverse logistics can make use of this software to plan and coordinate the collection and delivery of oily waste. This may result in a procedure that is more accurate and efficient.	https://www.sap.com/products/scm/transportation-logistics.html
	Oracle Transportation Management	Oracle Transportation Management is a software that can be used for scheduling and coordinating transportation processes. The collection and transportation of oily waste may be scheduled and coordinated using this programme in reverse logistics. As a result, the procedure may become more accurate and efficient.	https://www.oracle.com/uk/scm/logistics/transportation-management/
	Manhattan Active	Reverse logistics may make use of Manhattan Active software to plan and coordinate the collection and delivery of oily waste. This may result in a procedure that is more accurate and efficient.	https://www.manh.com/products/technology

Various technologies, including robotic process automation (RPA) and warehouse management systems (WMS), can be used to automate processes. Robotic process automation enables the automation of repetitive processes, which decreases the demand for manual labour and boosts productivity (Siderska 2021). Warehouse Management Systems can help track and manage waste products from the moment of collection through final disposal throughout the reverse logistics process. Additionally, including IoT technology can allow for real-time waste monitoring and tracking, giving crucial information for making decisions and adhering to rules (Sun et al. 2022). Automation of reverse logistics procedures can result in cost savings, higher efficiency and safety, and better regulatory compliance.

Table 6 highlights software solutions for the automation of reverse logistics processes for oily waste.

Predictive maintenance and monitoring of equipment used in oily waste management

A key component of guaranteeing the efficient and successful operation of the oil and gas sector is the predictive maintenance and monitoring of equipment used in the treatment of oily waste. With the use of cutting-edge technology and processes, maintenance teams may employ predictive maintenance to schedule repairs and replacements before machinery and other equipment breaks down (Çinar et al. 2020). As a result, unplanned maintenance costs are reduced, downtime is reduced, and safety is enhanced.

Predictive maintenance and monitoring can assist to make sure that the machinery used during drilling operations in oil and gas industry is working properly and efficiently. This aids in lowering the possibility of equipment breakdown, spills and other dangers that might harm the environment and people's health (Herve et al. 2019). The industry may enhance its sustainability practices and lessen the impact of its operations on the environment by employing predictive maintenance solutions, and increase efficiency of waste collection, transportation and storage in the context of managing oily waste. It is critical to select the appropriate technologies and systems for equipment used in the treatment of oily waste to perform successful predictive maintenance and monitoring.

In conclusion, guaranteeing the effectiveness and sustainability of operations in the oil and gas sector requires predictive

maintenance and monitoring of the machinery employed in the treatment of oily waste. It is feasible to lessen the likelihood of equipment failure, save downtime, increase safety and lessen the impact of operations on the environment by employing cutting-edge technologies and procedures. The sector may advance its practices and emerge as a pioneer in sustainability and environmental stewardship with the correct tools and approaches.

Table 7 presents software solutions for predictive maintenance and monitoring of equipment used in oily waste management.

Supply chain optimisation for reverse logistics of oily waste

Managing the reverse logistics process of oily waste in the oil and gas sector requires careful supply chain management. In order to transfer commodities efficiently from the point of origin to the point of consumption, supply chain optimisation seeks to minimise costs, cut waste and increase efficiency (Xie & Chen 2022). The integration of several operations, including such as waste collection, transportation, storage, treatment and disposal, is a key component of supply chain optimisation in the context of reverse logistics for oily waste.

With the help of IoT, reverse logistics of oily waste would benefit from an effective supply chain optimisation strategy that took into account a number of variables, such as the type of waste produced, its volume, the operational environment's physical and regulatory constraints, and the resources available for its management (Parry et al. 2016). It will be possible to create an optimised plan for the management of oily waste after a thorough analysis of these factors. This plan may include the use of specialised machinery, the implementation of effective transportation routes and technology-based solutions to monitor and manage the process in real time.

Additionally, the introduction of digital technologies like telematics and the IoT and the integration of information systems may greatly increase the supply chain's visibility and transparency, giving important insights into its performance and possible bottlenecks (Sun et al. 2022). As a result, decision-making and continuous improvement may be approached more proactively and with more knowledge.

In conclusion, supply chain optimisation is an essential part of a successful reverse logistics plan for handling oily waste in the oil and gas sector. Organisations may save costs, increase efficiency and assure compliance with laws and industry standards by integrating diverse processes, utilising technology, and continually monitoring and upgrading the system.

Table 8 provides an overview of software solutions that support supply chain optimisation in the context of reverse logistics for oily waste management. It highlights various functionalities and corresponding software or tools that can help to enhance efficiency and effectiveness in the supply chain processes.

Remote management and monitoring of oily waste facilities

Utilising cutting-edge technology and software systems, oily waste facilities may be remotely managed and watched over. Real-time data and insights into the state and operations of the facilities are provided by these systems, facilitating effective management and decision-making (Slonecker et al. 2010). In order to ensure the secure and appropriate disposal of waste, the systems are furnished with cutting-edge sensors and algorithms that can track and monitor important parameters, including temperature, pressure and fluid levels.

The openness and accountability of oily waste facilities may be significantly increased by the deployment of remote management and monitoring technologies, which can also lower the risk of human mistake and accidents (Eso & Eseosa 2022). This can therefore result in improved waste management procedures, cheaper costs and an improvement in the sector's overall sustainability.

TABLE 7: Predictive maintenance and monitoring of equipment.

Functionality	Software name	Description	Source (literature)
Predictive maintenance and remote monitoring systems	GE Predix Platform	A platform for managing operations and analysing industrial data is called GE Predix. It offers sophisticated machine learning, predictive analytics and visualisation capabilities to assist businesses in enhancing equipment efficiency and minimising downtime. By offering real-time monitoring and analysis of the state and performance of equipment used in the treatment of oily waste, this software can be helpful for reverse logistics and waste management in the oil and gas sector.	https://www.ge.com/digital/iiot-platform
	PTC ThingWorx	PTC ThingWorx is an IoT platform for industrial companies, providing advanced capabilities for connecting, monitoring and analysing industrial equipment. By enabling businesses to track the operation of machinery used to manage oily waste and anticipate probable breakdowns, this software can be useful for reverse logistics and waste management in the oil and gas sector, cutting downtime and maximising performance.	https://www.ptc.com/en/products/thingworx
	IBM Maximo® Application Suite	IBM Maximo is an enterprise asset management (EAM) software designed to help organisations manage their assets and operations more efficiently. For asset management, maintenance management and preventative maintenance, it offers a complete range of tools. The capacity to track and assess the operation of machinery used to manage oily waste, foresee probable breakdowns and improve maintenance procedures makes this programme useful for reverse logistics and waste management in the oil and gas industry.	https://www.ibm.com/products/maximo
	Insights Hub	Insights Hub is an IoT operating system for industrial companies, providing advanced capabilities for connecting, monitoring and analysing industrial equipment. By offering real-time monitoring of equipment used in the management of oily waste, this software can be useful for reverse logistics and waste management in the oil and gas sector. This enables businesses to swiftly react to possible issues and maximise performance.	https://plm.sw.siemens.com/en-US/insights-hub/

IoT, Internet of things.

TABLE 8: Supply chain optimisation.

Functionality	Software name	Description	Source (literature)
Supply chain management software	SAP SCM	SAP Supply Chain Management (SCM) is a software solution that helps organisations manage their supply chain operations, including procurement, production, transportation and distribution. It gives businesses real-time access into supply chain operations, allowing them to spot bottlenecks and improve their supply chain. SAP SCM may assist in managing the flow of waste materials from the production site to the final disposal destination in the context of reverse logistics of oily waste, optimising the supply chain and lowering costs.	https://www.sap.com/mena/products/scm.html
	Oracle SCM	Oracle SCM is a comprehensive solution for managing all aspects of the supply chain, from procurement and production to transportation and distribution. It gives businesses real-time access into supply chain operations, allowing them to spot bottlenecks and improve their supply chain.	https://www.oracle.com/scm/
	Infor SCM	A software programme called Infor SCM gives complete visibility into all aspects of the supply chain, from purchasing through distribution. By offering real-time data and insights, it aids enterprises in optimising their supply chain, enabling them to make wise decisions and increase productivity. Infor SCM may assist in managing the flow of waste materials, cutting costs and limiting the environmental effect of waste transportation in the context of reverse logistics of oily waste.	https://www.infor.com/solutions/scm
Automated systems for scheduling and coordination	SAP TM	SAP Transportation Management (TM) is a software solution for managing transportation operations, including transportation planning, execution and monitoring. Organisations can optimise their transportation operations and cut expenses because to the real-time visibility it gives them into such activities. SAP TM may assist in managing the transportation of waste materials from the production site to the final disposal destination in the context of reverse logistics of oily waste, lowering costs and limiting the environmental effect of waste transportation.	https://www.sap.com/products/scm/transportation-logistics.html
	Oracle Transportation Management	Oracle Transportation Management is a software solution for managing transportation operations, including transportation planning, execution and monitoring. Organisations can optimise their transportation operations and cut expenses because to the real-time visibility it gives them into such activities. Oracle Transportation Management may assist with managing the transportation of waste materials, lowering costs and decreasing the environmental effect of waste transportation in the context of reverse logistics of oily waste.	https://www.oracle.com/uk/scm/logistics/transportation-management/
	Manhattan Active	Manhattan Active is a software solution for managing transportation operations, including transportation planning, execution and monitoring. Organisations can optimise their transportation operations and cut expenses because to the real-time visibility it gives them into such activities. Manhattan Active may assist in managing the transportation of waste materials, lowering costs and limiting the environmental effect of waste transportation in the context of reverse logistics of oily waste.	https://www.manh.com/active

TABLE 9: Remote management and monitoring.

Functionality	Software name	Description	Source (literature)
Remote monitoring systems	GE Predix Platform	GE Predix is a remote monitoring system that provides real-time monitoring of equipment and facilities. To manage complex industrial processes, it provides powerful analytics, predictive maintenance capabilities, and secure communication. GE Predix may be quite helpful in the context of managing oily waste as it offers real-time data on facility performance, enables early detection of possible problems and enhances decision-making.	https://www.ge.com/digital/iiot-platform
	PTC ThingWorx	PTC ThingWorx is a remote monitoring system that enables real-time monitoring and control of industrial equipment. To assist businesses in making wise decisions, it offers sophisticated visualisation, data analytics and secure communication. PTC ThingWorx may aid in the optimisation of waste management procedures when it comes to managing oily waste as it offers real-time facility performance data and makes it possible to put preventative maintenance plans into action.	https://www.ptc.com/en/products/thingworx
	Insights Hub	The IoT platform – Siemens Insights Hub – allows for real-time monitoring and control of industrial equipment. To assist enterprises in making wise decisions, it offers advanced analytics, predictive maintenance capabilities and secure connection. Insights Hub may aid in the optimisation of waste management procedures when it comes to managing oily waste as it offers real-time facility performance data and makes it possible to put preventative maintenance plans into action.	https://plm.sw.siemens.com/en-US/insights-hub/
Automated systems for managing and monitoring facility operations	SAP EHS	A software programme for managing environmental, health and safety issues is called SAP EHS. It offers resources for organising and keeping track of facility activities, as well as for monitoring and documenting environmental compliance and its effects. SAP EHS may be quite helpful in the management of oily waste by giving real-time data on facility performance, enabling early detection of possible problems and enhancing decision-making procedures.	https://www.sap.com/products/scm/ehs-management-health-safety.html
	Enablon	A software programme for managing environmental, health and safety issues is called Enablon. It offers resources for organising and keeping track of facility activities, as well as for monitoring and documenting environmental compliance and its effects. Enablon may be quite helpful in the management of oily waste by giving real-time data on facility performance, enabling early diagnosis of possible problems and enhancing decision-making procedures.	https://www.wolterskluwer.com/en/solutions/enablon
	EHSQ & ESG Management Software	EHSQ & ESG Management Software of Intelex is a software solution for environmental, health and safety management. It offers resources for organising and keeping track of facility activities, as well as for monitoring and documenting environmental compliance and its effects. Intelex may be extremely helpful in the management of oily waste by giving real-time data on facility performance, enabling early diagnosis of possible problems and enhancing decision-making procedures.	https://www.intelex.com/

IoT, Internet of Things.

The information produced by these systems may also be utilised to spot waste management patterns and trends, as well as chances for process optimisation and development (Sun et al. 2022). Having a deeper understanding of the dynamics of waste management will enable facilities to manage their waste streams more effectively.

Table 9 provides an overview of software applications that enable remote management and monitoring of oily waste facilities in the context of reverse logistics. These solutions allow organisations to remotely track, control and monitor the operations and conditions of the facilities, ensuring compliance with regulations and efficient management of the waste.

Compliance and regulatory reporting for oily waste management

A key component of ensuring the ethical disposal and management of waste produced by the oil and gas sector is compliance and regulatory reporting for oily waste management. According to 'POSOW, Oil Spill Waste Management Manual' by Le Roux (2014), the reporting

TABLE 10: Compliance and regulatory reporting.

Functionality	Software name	Description	Source (literature)
Automated systems for monitoring, tracking and reporting	SAP EHS	For monitoring and reporting on environmental, health and safety standards, SAP EHS provides a complete solution. It offers a unified platform for handling audits and inspections, reporting on issues and tracking compliance requirements. The programme assists businesses in ensuring regulatory compliance and lowering their risk of fines and penalties. Organisations in the oil and gas sector may efficiently manage and report on their compliance requirements for the management of oily waste by utilising SAP EHS. This lessens the possibility of fines and penalties and helps to guarantee that the business is functioning in accordance with legal regulations. This further demonstrates the reverse logistics procedure for oily waste's overall effectiveness.	https://www.sap.com/products/scm/ehs-management-health-safety.html
	Enablon	Enablon has modules for risk management, sustainability reporting and compliance monitoring. The programme assists businesses in monitoring their environmental performance and reporting on their compliance responsibilities. Organisations in the oil and gas sector can increase their compliance with rules governing the management of oily waste by utilising Enablon. This lessens the possibility of fines and penalties and helps to guarantee that the business is functioning in accordance with legal regulations. This further demonstrates the reverse logistics procedure for oily waste's overall effectiveness.	https://www.wolterskluwer.com/en/solutions/enablon
	EHSQ & ESG Management Software	EHSQ & ESG Management Software offers a single platform for managing events, audits, and reporting on environmental performance as well as tracking compliance responsibilities. The programme assists businesses in ensuring regulatory compliance and lowering their risk of fines and penalties. Organisations in the oil and gas sector may efficiently manage and report on their compliance requirements for the management of oily waste by utilising Intelex. This lessens the possibility of fines and penalties and helps to guarantee that the business is functioning in accordance with legal regulations. This further demonstrates the reverse logistics procedure for oily waste's overall effectiveness.	https://www.intelex.com

procedure entails keeping records of how oily waste is produced, gathered, transported, treated and disposed. The waste management process must be carried out in a way that is ecologically sustainable and complies with local, national and international legislation.

The reporting system must be able to trace waste creation, movement and disposal, including hazardous waste management. The systems also need to stop unlawful dumping and inappropriate disposal of the waste and make sure that it is disposed of in accordance with the rules (Namoun et al. 2022). This lessens the harm that greasy waste does to the environment and to people's health. The reporting system encourages sustainable waste management techniques while assisting in lowering the environmental concerns connected to the treatment and disposal of oily waste.

Table 10 presents software applications that facilitate compliance and regulatory reporting in the context of oily waste management in reverse logistics. These solutions help organisations ensure adherence to environmental regulations, streamline reporting processes and maintain transparency in their waste management practices.

Considering the study's findings, it becomes evident that the integration of software plays a crucial role in optimising reverse logistics processes for the effective management of oily waste in the oil and gas industry. These findings underscore the significance of leveraging advanced technologies to address the complex challenges associated with waste management. By incorporating industry-specific software, organisations can unlock a range of benefits, including enhanced tracking and monitoring capabilities, improved regulatory compliance, and real-time visibility for informed decision-making. Additionally, the utilisation of these technologies fosters increased efficiency throughout the reverse logistics process, leading to cost savings and improved sustainability outcomes. Thus, the integration of software should be considered a strategic imperative for organisations aiming to achieve optimal results in managing oily waste.

Key findings

This study identifies the importance of incorporating software in reverse logistics operations in the oil and gas industry to address the challenges of oily waste management and promote sustainability in the supply chain and presents industry-specific software names.

Discussion of key findings

The key findings of this study align with previous research in the field of reverse logistics and sustainability. It supports the notion that technology plays a vital role in improving the effectiveness of reverse logistics operations and achieving sustainability goals. The study contributes to existing knowledge by providing a comprehensive understanding of the software that can be integrated into reverse logistics operations in the oil and gas industry to manage oily waste sustainably.

Strengths and limitations

One of the strengths of this study is the comprehensive review of literature on the topic, which provides valuable insights into the software available for oily waste management. Another strength is the identification and listing of industry-specific software names specifically tailored for the oil industry, which can be effectively implemented and integrated into reverse logistics processes. However, one limitation of this study is the lack of empirical data to validate the effectiveness of the software solutions identified.

Implications or recommendations

The study has several implications for practitioners and researchers in the field of reverse logistics in the oil and gas industry. The recommendations from this study include integrating transportation management systems, WMS and inventory management systems into existing reverse logistics processes to manage oily waste sustainably. Future research could investigate the effectiveness of these software solutions in real-world scenarios and explore the barriers to implementation and integration of these technologies into reverse logistics operations. These findings could be used to

guide policy development and improve sustainability in the management of oily waste in the oil and gas industry.

Conclusion and recommendation

In conclusion, the use of software in reverse logistics has a significant impact on the management of oily waste. This article has identified and discussed industry-specific software that can be used in the management of oily waste in reverse logistics. By leveraging these software solutions, organisations can benefit from enhanced tracking and monitoring capabilities, improved regulatory compliance, real-time visibility and data for better decision-making, and increased efficiency in the management of oily waste throughout the reverse logistics process. The software solutions discussed in this article provide a framework for managing oily waste and may offer cost savings, increased efficiency and improved sustainability. However, it is important to note that each application may have unique challenges, and the practical implementation of these technologies requires careful consideration. Overall, the use of software in reverse logistics should be viewed as a complementary approach to traditional management practices, and organisations should strive to integrate both to achieve optimal results.

The study uncovers the significance of incorporating software into reverse logistics operations in the oil and gas industry for effective management of oily waste. It highlights the utilisation of RFID and GPS technologies for tracking and monitoring waste flow, while sensor technology and automated sorting systems enhance treatment and processing. The integration of remote monitoring systems and automation plays a crucial role in streamlining recycling and disposal processes. Additionally, the implementation of software solutions enables efficient inventory management and tracking throughout the reverse logistics journey. Furthermore, the utilisation of robotics and automation systems optimises various tasks associated with reverse logistics. The study also emphasises the role of predictive maintenance software in ensuring equipment reliability and minimising downtime. Furthermore, the integration of ERP systems aids in optimising supply chain operations, while software applications facilitate remote facility management and streamline compliance reporting.

Future research in this area could focus on the development of more advanced software that can provide real-time monitoring and analysis of the reverse logistics process. This could include the use of machine learning algorithms to analyse data from sensors and other sources, and the development of predictive analytics tools to anticipate changes in demand for waste management services.

Another area for future research is the integration of software with emerging technologies, such as blockchain and the IoT. The use of these technologies could help to improve transparency and traceability in the reverse logistics process and facilitate the exchange of information and data between stakeholders.

Overall, the use of software in reverse logistics has the potential to significantly improve the management of oily waste. By leveraging these technologies, organisations can reduce costs, increase efficiency and improve sustainability in their waste management practices. Further research in this area can help to identify new opportunities for innovation and drive continued improvement in the management of oily waste.

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