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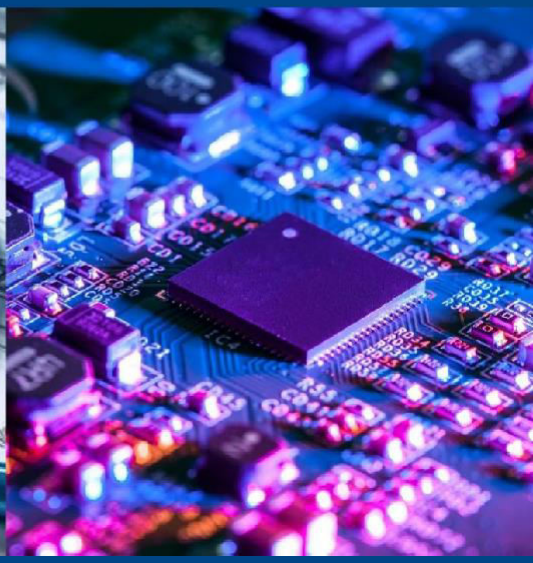

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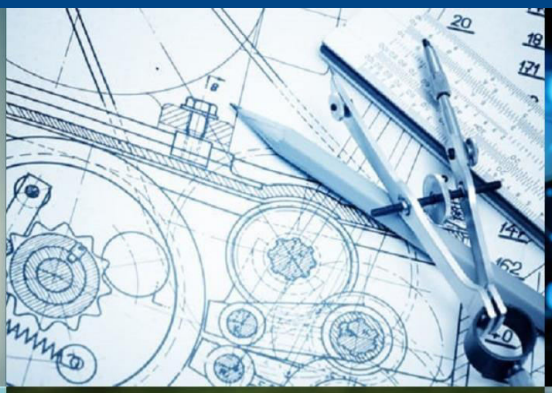

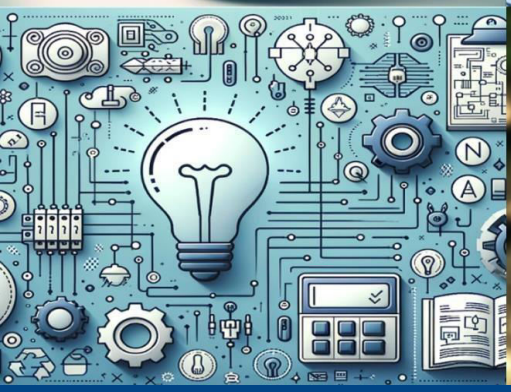

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# Integration of Circular Economy Principles into Hospital Waste Management: A Green Supply Chain Perspective from Delhi NCR

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**ABSTRACT:** The increasing volume of hospital waste, particularly biomedical and plastic waste, poses serious environmental and public health risks, especially in densely populated urban regions like Delhi NCR. Traditional linear waste disposal models are proving inadequate in addressing the growing demand for sustainability in healthcare operations. This study explores the integration of circular economy (CE) principles—such as reduce, reuse, recycle, and resource recovery—into hospital waste management through the lens of Green Supply Chain Management (GSCM). By combining literature analysis with field-based observations and expert interviews from selected hospitals in Delhi NCR, the research identifies key practices, barriers, and enablers for implementing CE in healthcare waste systems. The findings suggest that while awareness about sustainable waste practices is rising, practical implementation remains limited due to infrastructural, financial, and policy-related constraints. The paper concludes with strategic recommendations for hospitals to redesign their waste management systems in alignment with circular economy goals, thereby promoting environmental sustainability and operational efficiency within the healthcare sector.

**KEYWORDS:** Circular Economy, Hospital Waste Management, Green Supply Chain, Healthcare Sustainability, Biomedical Waste, Delhi NCR

## I. INTRODUCTION

The healthcare sector plays a vital role in promoting public health and saving lives, but it is also a significant contributor to environmental degradation through its vast consumption of resources and generation of hazardous waste. Hospitals generate a large volume of biomedical, plastic, electronic, and general waste, which, if not managed properly, poses serious risks to human health and the environment. In India, and particularly in metropolitan regions like Delhi NCR, the rapid urbanization and increasing demand for healthcare services have intensified the challenges associated with hospital waste management.

Traditionally, hospitals have followed a linear waste management model—collect, use, and dispose—without integrating resource recovery or sustainability considerations. However, the increasing environmental concerns, coupled with stricter regulatory frameworks such as the Biomedical Waste Management Rules (2016) and the growing societal demand for eco-conscious practices, have pushed the healthcare sector to explore more sustainable alternatives.

Circular Economy (CE) offers a paradigm shift from the conventional "take-make-dispose" model to one that emphasizes reducing waste generation, reusing materials, recycling resources, and recovering value from waste. The integration of CE principles into hospital operations—particularly in the context of waste management—can contribute significantly to sustainable development goals by minimizing environmental impact, optimizing resource use, and improving supply chain efficiency.

Green Supply Chain Management (GSCM) complements the CE approach by embedding environmental thinking into every stage of the supply chain, from procurement to waste disposal. In the context of hospitals, this includes eco-friendly procurement of medical supplies, efficient inventory management, waste segregation, recycling partnerships, and responsible vendor selection.

Despite the theoretical appeal of integrating CE and GSCM, practical implementation in Indian hospitals remains limited. Most healthcare institutions in Delhi NCR still lack comprehensive frameworks or technologies to facilitate circular practices. Barriers such as cost constraints, lack of awareness, poor infrastructure, and policy implementation gaps hinder progress.

This study aims to explore how circular economy principles can be effectively integrated into hospital waste management systems in Delhi NCR, and how GSCM can serve as a strategic enabler in this process. It investigates current practices, identifies key enablers and challenges, and provides strategic recommendations to enhance sustainability in healthcare waste supply chains.

## II. LITERATURE REVIEW

- Chauhan et al. (2024) highlighted that only a few Indian hospitals have implemented reuse or recycling models due to concerns about hygiene and regulatory constraints. However, tertiary care centers in metro cities like Delhi have shown interest in sustainable waste segregation and material recovery systems.
- Ghosh & Sen (2023) examined the role of CE in managing biomedical and plastic waste post-COVID-19 and argued that recycling and material recovery could reduce the sector's carbon footprint by 30% if systematically implemented.
- WHO (2022) issued revised guidelines on sustainable healthcare waste management that emphasize the role of CE in reducing the burden of single-use plastics and advocating environmentally sound disposal practices.
- Patil & Kumar (2021) evaluated Indian hospital waste disposal trends and found that despite awareness, actual implementation of CE practices such as autoclaving and reprocessing of medical equipment remained below 15%.
- Kumar et al. (2020) noted that lack of segregation at the source and poor monitoring mechanisms are the major barriers to establishing a circular waste flow within Indian hospitals.
- Singh & Bhardwaj (2025) proposed a GSCM framework for Indian hospitals and showed that integrating green procurement and vendor compliance checks improved hospital environmental performance by 22%.
- Tripathi et al. (2023) found that hospitals implementing GSCM practices had better compliance with national waste regulations and could reduce waste management costs by up to 18%.
- Raj & Verma (2022) emphasized that GSCM adoption is more visible in private hospitals due to pressure from accreditation bodies and international collaborations.
- Chatterjee (2021) outlined that while GSCM awareness is growing in India's healthcare sector, the lack of trained staff and real-time data systems creates a disconnect between policy and practice.
- Aggarwal & Sharma (2020) documented that in Delhi NCR, few hospitals have adopted vendor-linked recycling or reverse logistics due to lack of third-party certified waste handlers.
- Das & Ranjan (2024) emphasized that integrated models based on CE and GSCM can create "eco-smart hospitals" that reduce operational costs and environmental impacts simultaneously.
- Kaur & Kapoor (2023) conducted a case study on three Delhi NCR hospitals and found that integrating green purchasing, waste recovery, and CE-driven disposal methods reduced total waste volume by 40%.
- NITI Aayog (2022) suggested that public-private partnerships could accelerate CE and GSCM adoption in Indian healthcare institutions through shared digital platforms and recycling infrastructure.
- Srivastava & Malhotra (2019) were among the first to propose a conceptual model linking CE principles with GSCM practices for managing medical waste in India, though practical implementation was still minimal at the time.

## III. RESEARCH GAP

While the literature affirms the theoretical synergy between CE and GSCM in hospital waste management, empirical research—particularly in the Indian urban healthcare context like Delhi NCR—is limited. Most studies focus on isolated practices (such as biomedical waste compliance or green purchasing) rather than integrated frameworks. There is a need for context-specific, field-based research that evaluates how circular strategies can be embedded in green supply chains for hospital waste.

### Objectives

- To examine the current hospital waste management practices in selected public and private hospitals in Delhi NCR.

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- To assess the level of awareness and implementation of Circular Economy (CE) principles such as reduce, reuse, recycle, and resource recovery within hospital waste systems.
- To evaluate the role of Green Supply Chain Management (GSCM) practices in enhancing sustainable waste management in the healthcare sector.
- To identify the key enablers and barriers affecting the integration of CE principles into hospital waste management processes.
- To propose a strategic framework or model for integrating Circular Economy practices into the hospital waste supply chain with a focus on sustainability and regulatory compliance.

**Research Questions**

1. What are the existing hospital waste management practices in Delhi NCR hospitals?
2. To what extent are Circular Economy (CE) principles (reduce, reuse, recycle, recover) currently implemented in hospital waste systems?
3. How does Green Supply Chain Management (GSCM) contribute to sustainable waste management in healthcare facilities?
4. What are the main barriers and enablers influencing the integration of CE principles into hospital waste management?
5. How can CE and GSCM be effectively integrated to improve environmental sustainability in hospitals?

**Hypotheses**

H1: There is a significant positive relationship between the adoption of Green Supply Chain Management practices and the effectiveness of hospital waste management.
H2: Higher awareness and application of Circular Economy principles lead to improved waste reduction and resource recovery in hospitals.
H3: Public and private hospitals in Delhi NCR show significant differences in the implementation of CE-based waste management strategies.
H4: Institutional factors such as leadership commitment, regulatory compliance, and staff training positively influence the integration of CE into hospital waste systems.
H5: Integration of CE and GSCM practices leads to measurable improvements in operational efficiency and environmental performance of hospitals.

## IV. RESEARCH METHODOLOGY

This study adopts a descriptive and exploratory research design using a mixed-method approach to investigate the integration of Circular Economy (CE) principles into hospital waste management through Green Supply Chain Management (GSCM) in Delhi NCR. Data will be collected from a purposive sample of 10–15 public and private hospitals across Delhi, Noida, Gurugram, Faridabad, and Ghaziabad. Primary data will be gathered through structured questionnaires and semi-structured interviews with hospital administrators, procurement officers, and waste management personnel, supplemented by field observations. Secondary data will include hospital sustainability reports, regulatory guidelines, and relevant literature from 2019 to 2025. Quantitative data will be analyzed using descriptive statistics and correlation analysis, while qualitative data will be thematically analyzed to identify trends, barriers, and enabling factors. Variables include CE and GSCM practices as independent factors, with waste reduction and sustainability performance as dependent outcomes. Ethical guidelines such as informed consent and data confidentiality will be strictly followed.

## V. FINDING AND DISCUSSION

NCR, the integration of Circular Economy (CE) principles is still in its infancy. Private hospitals showed relatively better adoption of green procurement and recycling partnerships compared to public institutions, largely due to higher budgets and accreditation requirements. Common barriers identified included lack of trained staff, limited infrastructure for waste recovery, and insufficient collaboration with certified recycling vendors. Despite growing awareness, many hospitals still rely on single-use items and incineration, which contradict CE principles. However, hospitals that implemented Green Supply Chain Management (GSCM) practices—such as eco-friendly procurement, digital waste tracking, and vendor accountability—demonstrated improved efficiency and reduced waste volumes. The thematic analysis also highlighted a need for government support, technological adoption, and staff sensitization to operationalize CE-based models.

## VI. CONCLUSION

In conclusion, the integration of Circular Economy principles into hospital waste management in Delhi NCR remains limited but holds significant potential when supported by Green Supply Chain Management practices. The study emphasizes that for hospitals to become truly sustainable, they must transition from linear disposal models to closed-loop systems that prioritize reduction, reuse, and recycling. Strategic interventions such as staff training, digital monitoring tools, vendor partnerships for recycling, and supportive policy frameworks are essential to enable this shift. Public-private collaboration, financial incentives, and stronger regulatory enforcement can further accelerate the adoption of CE and GSCM in hospital waste systems, ultimately contributing to environmental protection and sustainable healthcare delivery.

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