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A Scoping Review of Reusable Personal Protective Equipment in Hospitals: Barriers, Facilitators, and Impacts on Environment, Care Safety, Costs, and Supply Chain Resilience.

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Title: A Scoping Review of Reusable Personal Protective Equipment in Hospitals: Barriers, Facilitators, and Impacts on Environment, Care Safety, Costs, and Supply Chain Resilience.

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Abstract

Introduction: Climate degradation poses a significant global health challenge, with healthcare systems paradoxically contributing to this issue while adhering to the principle of "do no harm." Notably, the healthcare sector accounts for a considerable share of greenhouse gas emissions in many industrialized countries, primarily due to the supply chain of pharmaceuticals and disposable personal protective equipment. The COVID-19 pandemic exacerbated this issue, with millions of tons of CO₂ emissions attributed to single-use personal protective equipment. In response to the pandemic, some hospitals have begun adopting and implementing reusable personal protective equipment as a sustainable alternative to reduce emissions, enhance resilience to supply chain disruptions, and achieve cost savings. This scoping review aims to synthesize the available evidence on the adoption, implementation barriers and facilitators, as well as the impacts of reusable personal protective equipment in hospital settings.

Methods and analysis: This protocol is based on the York's five-stage framework outlined by Arksey and O'Malley. We will map evidence on the environmental and economic impacts of reusable versus disposable personal protective equipment, and the associated infection risks. Using an adapted Consolidated Framework for Implementation Research, our scoping review will identify enablers and barriers to implementation across different clinical settings. The methodology will adhere to PRISMA-ScR guidelines and will include a comprehensive search of peer-reviewed articles in 5 databases (Medline, Embase, CINAHL, Web of Science and Global Health) and gray literature. Two reviewers will independently evaluate the eligibility of all identified titles and abstracts for inclusion in

the full-text review, as well as for data extraction. Descriptive data will provide insights into the enablers and facilitators of reusable personal protective equipment adoption and implementation, along with its impacts on patient and staff safety, costs, the environment, and supply chain resilience to disruptions will be reported.

Ethics and dissemination: We expect the results to identify research gaps and generate new ideas for future studies on transitioning to reusable personal protective equipment in healthcare settings. This review will also provide healthcare decision-makers with insights into the factors and impacts of transitioning from disposable to reusable personal protective equipment. The information will be crucial for refining strategies and activities related to PPE management. These refined strategies and activities will help healthcare facilities adopt reusable PPE more effectively while minimizing operational disruptions and maintaining patient and staff safety.

Keywords: reusable personal protective equipment, adoption and implementation factors, impacts, carbon footprint, patient safety, cost control, supply chain resilience.

Registration details: <https://doi.org/10.17605/OSF.IO/DESVU>

Strengths and limitations of this study (max 5 bullet points)

- This will be the first scoping review to map the barriers, facilitators, and impacts of implementing reusable personal protective equipment (PPE) in hospital settings.
- The review employs an adapted Consolidated Framework for Implementation Research, providing a structured approach to understanding the enablers and barriers to implementing reusable PPE.

- The review will not include a formal quality assessment or grading of the evidence, as this is not part of the scoping review methodology.
- The inclusion of diverse study types—both qualitative and quantitative—may result in significant heterogeneity in study designs, data collection methods, and outcome measures. This variability may complicate synthesis, but we will use careful categorization and a narrative synthesis to identify key trends while acknowledging differences between studies.

Introduction

Climate degradation represents a global health challenge with significant implications for both the environment and public health. Paradoxically, healthcare systems contribute to this degradation, contradicting their fundamental principle of "do no harm". The health sector contributes significantly to national emissions in many countries, with hospitals being major emitters. In industrialized countries, healthcare systems are indeed responsible for a significant share of greenhouse gas (GHG) emissions. For instance, in the United States, the healthcare sector accounts for approximately 8.5% of the nation's GHG emissions.¹ In Canada, healthcare contributes around 5% of total emissions, surpassing even the aviation industry.¹ The United Kingdom's National Health Service (NHS) is responsible for about 5.4% of the country's GHG emissions.¹ France also has similar figures, with the healthcare sector contributing between 5% and 7% of the national total¹. A substantial portion of these emissions stems from the supply chain of pharmaceuticals and medical equipment, including personal protective equipment (PPE) such as gloves, masks, and gowns.² Most PPE items are available in both reusable and single-use forms.

Single-use has not been found to reduce infection rates but is almost always associated with higher costs and a worse environmental footprint than its reusable equivalent.³ During the COVID-19 pandemic, it was estimated that PPE was responsible for millions of tons of CO2 equivalent emissions globally, with single-use masks and gloves contributing significantly to these emissions. For example, a study found that the global healthcare sector generated approximately 1.6 million tons of plastic waste per day during the pandemic, a considerable portion of which was attributed to disposable PPE.⁴

In response to these environmental challenges, some hospitals worldwide that previously had single-use PPE have adopted and implemented reusable PPE, driven by the need to reduce GHG emissions, improve PPE quality/protective performance, improve resilience to supply chain disruptions, and achieve cost savings. Life cycle assessments have shown that reusable PPE, including gowns, masks, and gloves, consumes less energy, generates less waste, and produces fewer GHG emissions over its entire lifespan compared to single-use alternatives.⁵ Case studies highlight significant cost savings, with some estimates suggesting up to 75% reduction in costs per usage of reusable PPE compared to disposable counterparts.⁶⁻⁸

However, barriers to reusable PPE implementation persist, including concerns over increased infection risk, high initial investment costs, and the logistical demands of washing, and storing reusable PPE. While these are important considerations, evidence suggests that the benefits of reusable PPE in terms of cost, environmental impact, and infection control outweigh those of disposable PPE, as the latter's purported advantages in preventing infections are not strongly supported by scientific evidence.⁹

While there is growing recognition of the advantages of reusable PPE, the implementation of reusable PPE in hospital settings and its comprehensive impact on the environment, patient and staff safety, and cost-effectiveness remain poorly understood.

Therefore, in this scoping review, we aim to synthesize the available evidence on the adoption, implementation barriers and facilitators and impacts of reusable PPE in hospital settings.

Methods and Analysis

Protocol design

The review started in September 2024 and is expected to be completed by March 2025.

The protocol for this scoping review was registered in the Open Science Framework.¹⁰ To ensure reproducibility, our review will follow the reporting standards outlined in the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (see Appendix 2).¹¹

This protocol is based on the York's five-stage framework outlined by Arksey and O'Malley.¹²

Stage 1: identifying research questions and hypotheses

Through consultation with our team of researchers with diverse expertises (health management, health economics, biostatistics and medicine), the research questions are the following:

- What are the barriers and facilitators towards adopting and implementing reusable PPE in hospital settings? Are these adoption and implementation factors different across various clinical units or sectors (e.g., low risk vs. high-risk surgical units, surgical units vs. other units)?

- What is the environmental impact of reusable PPE vs. disposable PPE in hospital settings?
- What are the differences in patient and staff safety between reusable PPE and disposable PPE in hospital settings? Specifically, how do they compare in terms of infection risk levels and protective performance?
- What is the impact of reusable PPE vs. disposable PPE on the resilience to supply chain disruption?
- What are the economic costs and benefits of reusable PPE vs disposable PPE in hospital settings?

We hypothesize that implementing reusable PPE in hospital settings will result in reduced GHG emissions and plastic waste, maintain comparable infection risk levels, increase resilience to supply chain disruptions, and lead to substantial cost savings, making it a cost-effective solution.

Stage 2: identifying relevant studies

Review conceptual model

The review will be conducted using an adapted version of the updated Consolidated Framework for Implementation Research by Laura J. Damschroder et al.¹³. This framework will facilitate an exploration of various domains related to the implementation of innovations and their outcomes. In this context, "innovations" refer to interventions such as reusable PPE used in hospital settings.

The review will investigate both enablers and barriers to the implementation of reusable PPE through several domains:

1. **Implementation Process:** Examining the activities and strategies employed to adopt and integrate reusable PPE.
2. **Roles of Individuals/Stakeholders:** Assessing factors such as preferences, acceptability, resistance to change, and the influence of individual leadership on the implementation process.
3. **Inner Setting:** Analyzing characteristics of hospital settings, including types of clinical units, institutional culture, and infrastructure.
4. **Outer Setting:** Evaluating the impact of regulatory and policy contexts on the adoption and implementation of reusable PPE.

Additionally, the framework will explore the outcomes of reusable PPE through four domains of impact: financial costs, environmental impact, patient and staff safety, and resilience to supply chain disruptions.

Eligibility criteria

The Population, Concept and Context framework was applied as a guide to construct the eligibility criteria of our scoping review¹⁴. Eligibility criteria are available in Table 1.

Table 1: Inclusion and exclusion criteria

	Inclusion criteria	Exclusion criteria
Study focus	Any type of publication based on primary or secondary research findings focusing on the adoption and implementation of reusable PPE, and/or their impact(s) on the environment, costs, and infection risks	Studies neither focusing on reusable PPE implementation nor impact of PPE on infection risk, environment or costs
Population	Hospital settings, any types of clinical sectors or units	N/A

Study context	Hospital settings	Other settings than hospitals (e.g. nursing homes, primary care).
Intervention	Adoption and implementation of reusable PPE (gowns, gloves, masks, respirators, head covers, shoe covers, eye protection, goggles)	Adoption and implementation of reusable medical equipment or devices, excluding reusable PPE
Outcomes	Environmental impact (greenhouse gas emissions, waste generation, energy and water consumption) Patient and staff safety (PPE protective performance, transmission of pathogens, healthcare-associated infections) Resilience to supply chain disruption Cost reduction	
Study characteristics	Original research articles Reviews of any types Reports Book chapters Conference proceedings Dissertations/theses	Expert opinions or reviews Theoretical frameworks
Timeframe	No constraints	
Publication language	No constraints	Unable to obtain translation

Search Strategy

We will conduct a comprehensive search of several electronic databases, including MEDLINE-Ovid, EMBASE-Ovid, Global Health, Web of Science, and CINAHL (EBSCO), to gather relevant evidence. All searches will be conducted in English and will encompass both qualitative and quantitative study designs. Additionally, we will perform

a thorough search of gray literature through platforms such as Google Scholar, OpenGrey, Scopus, Faculty Opinions, Publons, and governmental websites, including the World Health Organization, Agency for Healthcare Research and Quality, Institute for Healthcare Improvement, and Sustainable Healthcare Coalition. We received support from a librarian in developing and validating our research strategies for the databases. To refine our search strategy, we initially developed it in MEDLINE, utilizing Medical Subject Headings (MeSH) and relevant keywords specific to the implementation and impacts of reusable PPE. We employed the search terms listed in Table 2, which presents a non-exhaustive list of these terms. Following a pilot search on PubMed, we reviewed the titles and abstracts of potential sources to identify additional relevant terms and index terms for incorporation into our MEDLINE search strategy (see Appendix 1). To ensure the accuracy and comprehensiveness of the search strategy, a health sciences librarian meticulously reviewed it in accordance with the Peer Review of Electronic Search Strategies (PRESS) guidelines¹⁵ before adapting it for other databases. Additionally, we will contact authors of ongoing or upcoming studies to request full-text articles or any supplementary information as needed. We will also search for relevant studies based on the reference lists of the included articles.

Table 2: Search terms

Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Reusable PPE	Implementation barriers, implementation facilitators	Environmental impact, sustainability	Care safety	Economic impact, financial impact	Supply chain resilience /vulnerability
Reusable gowns	Organizational challenges, logistic challenges,	GHG emissions	Pathogen transmission, Cross-	Cost-benefit analysis, life-cycle costing	Supply chain vulnerability

	procurement challenges		contamination prevention		
Reusable masks	Adoption, Transition, Switching	Carbon footprint	Laundry process efficacy	Cost saving, financial gain, economic gain	Supply chain resilience
Reusable gloves	Feasibility	Life cycle assessment	Protective performance, protective value	Financial sustainability, economic viability	
Reusable face covers, shoe covers	Acceptability, resistance, preference	Material waste, waste management	Healthcare associated infections, nosocomial infections	Economic evaluation, economic assessment	
Reusable face shields					
Reusable respirators					
Reusable eye protection					

Stage 3: Selecting Eligible Studies

Based on the search strategies developed for each database, all identified studies will be imported into EndNote referencing software to remove duplicates. Two reviewers (NC and CB) will independently assess the relevance of all titles and abstracts using the inclusion and exclusion criteria, facilitated by Covidence. A pilot round involving a randomly selected sample of 10% of the articles will be conducted to evaluate inter-reviewer agreement on the inclusion and exclusion criteria prior to the full screening of all articles.¹⁶

¹⁷ Two additional reviewers (FC and CL) will serve as referees to resolve disagreements between the primary reviewers.

Non-relevant studies will be excluded, and the full texts of selected articles will be assessed to ascertain eligibility for inclusion by the two reviewers. Any disagreements that arise during this process will be resolved through discussion with the third and fourth reviewers.

Stage 4: Extracting Data

At this stage, the two reviewers will extract data from the included articles and conduct the evidence synthesis. We will use a data extraction form adapted from the Joanna Briggs Institute's template. The following key information will be collected from the relevant studies: authors, publication year, country, study design, clinical settings, conceptual framework (if applicable), objectives, methods, findings, and reported limitations. Additionally, the form will capture key findings related to the scoping review questions and outcomes of interest: 1) enablers and barriers to the implementation of reusable PPE, 2) environmental impact of reusable PPE utilization, 2) impact on patient and staff safety, 3) effects on cost, and 4) effect on the supply chain resilience/vulnerability.

Stage 5: Structuring the Data Synthesis

The primary aim of this scoping review is to compile findings and provide an overview of the research rather than evaluate the quality of the studies. We will utilize the PRISMA-ScR checklist to guide the data synthesis process.¹¹ The synthesis criteria will be based on the number of studies reporting outcomes of interest related to the research questions. A narrative synthesis will be employed to present these findings. For quantitative data concerning impacts on one or more dimensions (environment, patient and staff safety, cost, and resilience of the supply chain), descriptive statistics will be reported. Qualitative data will be analyzed using a conceptual model that addresses multiple dimensions of implementation: 1) the process of implementation, 2) roles of stakeholders, 3) inner setting, and 4) outer setting.

Patient and public involvement

Patients and the public were not involved in any way in the development of the scoping review protocol.

Ethics and Dissemination

Since the scoping review methodology involves reviewing and collecting data from publicly available materials, this study does not require ethics approval. We anticipate that the results will highlight research gaps and generate novel ideas for future studies on transitioning to reusable PPE in healthcare settings. The findings will be submitted for publication to relevant peer-reviewed journals and conferences focused on healthcare management and implementation science.

Beyond academic contributions, this scoping review will provide healthcare decision-makers and staff with valuable insights into the implementation factors and impacts associated with transitioning from disposable to reusable PPE. This information will be crucial for refining protocols and practices, enabling healthcare facilities to adopt reusable PPE in a manner that maximizes benefits while minimizing disruptions. Ultimately, the results will not only enhance the effectiveness of reusable PPE implementation within individual hospitals but also contribute to the broader development of best practices that can be shared across the healthcare sector.

Strengths and limitations of this scoping review

The scoping review has several strengths, including its comprehensive approach to synthesizing evidence from diverse healthcare settings and its use of a robust conceptual framework to explore multiple aspects of reusable PPE implementation. By examining key

impacts—such as environmental footprint, cost-effectiveness, patient and staff safety, and supply chain resilience—the review will provide a broad overview of the topic, highlighting both enablers and barriers to adoption. Its rigorous methodology, which includes thorough database searches, multiple stages of data extraction, and adherence to PRISMA-ScR guidelines, enhances transparency and reproducibility.

However, the review also has limitations. Since it does not assess the quality of included studies, it may include research with varying levels of methodological rigor, which could affect the strength of the conclusions. Additionally, the reliance on published literature may introduce publication bias, particularly if negative or inconclusive studies are underrepresented. Given the inclusion of diverse study types—both qualitative and quantitative—there may be significant heterogeneity in study designs, data collection methods, and outcome measures. To address this, we will categorize studies by common themes and conduct a narrative synthesis to identify key patterns. By using a conceptual framework to guide the analysis, we will transparently present the diversity in the evidence, allowing us to draw meaningful conclusions despite the variability in study characteristics.

Author contributions

NC is the first author of this manuscript. All authors contributed to at least some component of the scoping review protocol and/or manuscript. NC shaped all aspects of the study design with feedback from FC and CL. NC wrote the manuscript and FC, CL, SW, IE, CB and MC-B gave their feedback. All authors have read and approved the final manuscript.

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Data statement section

Not applicable

Competing interest statement

No competing interest to declare.

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Appendix 1: Search strategy (Medline-Ovid)

Ovid MEDLINE(R) ALL <1946 to November 04, 2024>

1 exp Change Management/ or exp Implementation Science/ 1809

2 ((Implement* adj2 barrier*) or (implement* adj2 factor*) or (implement* adj2 enabler*) or (implement* adj2 facilitator*) or (implement* adj2 challenge*) or (implement adj2 effectiv*) or (barrier* adj2 effectiv*) or (Resistance* adj2 change*) or "Organizational challenge*" or "organizational barrier*" or "Logistical challenge*" or "logistical barrier*" or (Policy adj2 barrier*) or "Procurement difficult*" or (Regulatory adj2 obstacle*) or (regulatory adj2 barrier*) or "Policy support*" or "Successful case stud*" or adoption or faisability or acceptability or acceptance or preference* or tolerance* or resistance* or (user* adj2 experience*) or (staff adj2 experience*) or (health* adj2 experience*) or (health* professional* adj2 experience*) or (patient* adj2 experience*) or (staff adj2 preference*) or (health* adj2 preference*) or (health* professional* adj2 preference*) or transition* or switching).ab,kf,ti. 2310261

3 1 or 2 2311541

4 exp "Cost-Benefit Analysis"/ or exp "Economics, Hospital"/ or exp "Health Care Costs"/ or exp "Cost Control"/ or exp "Efficiency, Organizational"/ or exp "Costs and cost analysis"/ 302251

5 ((Cost* adj2 analys*) or "Financial implication*" or (Cost* adj2 effectiv*) or "Economic evaluation*" or "Lifecycle* costing" or (Budget adj2 impact*) or "Purchasing expense*" or "Cost* comparison*" or "Cost-benefit* analys*" or "Financial evaluation*" or "Economic impact*" or "Investment* analys*" or "Budget assessment*" or "Expense* comparison*" or "Economic benefit*" or "Cost saving*" or "financial gain*" or "economic gain*" or "Financial advantage*" or "Financial sustainability" or "Financial viability" or "Economic efficiency" or "economic sustainability" or "economic viability" or "economic evaluation*").ab,kf,ti. 273387

6 4 or 5 491111

7 exp "Impacts, environmental "/ or exp "Carbon Footprint"/ or exp "Greenhouse Effect"/ or conservation of natural resources/ or "conservation of energy resources"/ or "conservation of water resources"/ 1616650

8 ((Environment* adj2 impact*) or (environment* adj2 consideration*) or
9 "Sustainability" or "Carbon footprint*" or (Waste adj2 reduction*) or "Resource
10 conservation*" or "Green healthcare" or "Eco-friendly practice*" or "Life cycle
11 assessment*" or "life cycle evaluation*" or "Environmental sustainability" or "Ecological
12 footprint*" or "Environmental comparison*" or (Ecological impact* adj2 assessment*) or
13 (Ecological impact* adj2 evaluation*) or "Environmental footprint*" or "Greenhouse gas
14 emission*" or "Energy consumption*" or "Water usage*" or "Material waste*" or
15 "Environmental benefit*" or "Ecological efficiency" or "waste management" or "waste
16 generation*").ab,kf,ti. 125454

17 9 7 or 8 1705648

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20 10 exp Consumer Behavior/ or exp "Infection Control"/ or exp "Infection control
21 practitioners"/ or exp "Cross Infection"/ or exp "Sterilization"/ or exp "Hygiene"/ 190159

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24 11 ((infection adj2 control*) or (infection adj2 prevention) or "hygiene standard*" or
25 (contamination adj2 risk*) or "sterilization efficacy" or "cross-contamination prevention"
26 or "safety comparison*" or (pathogen adj2 transmission*) or "protective efficacy" or
27 "protective value*" or "protective performance*" or "Sterility maintenance" or
28 (sterilization adj2 maintenance) or (laundry adj2 efficacy) or (laundry adj2 efficiency) or
29 (infection adj2 risk*) or "healthcare-associated infection*" or (staff adj2 protection*) or
30 (healthcare professional* adj2 protection) or "cross-contamination*" or "healthcare
31 associated infection*" or "nosocomial infection*").ab,kf,ti. 128081

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36 12 10 or 11 288996

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39 13 Equipment reuse/ 3267

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42 14 ((reusable adj2 mask*) or (sustainable adj2 mask*) or (eco friendly adj2 mask*) or
43 (eco-friendly adj2 mask*) or (washable adj2 mask*)).ab,kf,ti. 149

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46 15 ((reusable adj2 gown*) or (sustainable adj2 gown*) or (eco friendly adj2 gown*)
47 or (washable adj2 gown*) or (reusable adj2 scrub*) or (sustainable adj2 scrub*) or (eco
48 friendly adj2 scrub*) or (washable adj2 scrub*) or (reusable adj2 surgical garment*) or
49 (sustainable adj2 surgical garment*) or (washable adj2 surgical garment*) or (reusable
50 adj2 surgical textile*) or (washable adj2 surgical textile*) or (sustainable adj2 surgical
51 textile*) or (eco friendly adj2 surgical textile*)).ab,kf,ti. 50

16 ((reusable adj2 glove*) or (sustainable adj2 glove*) or (eco friendly adj2 glove*) or (eco-friendly adj2 glove*) or (washable adj2 glove*)).ab,kf,ti. 17

17 ((reusable adj2 head cover*) or (sustainable adj2 head cover*) or (eco friendly adj2 head cover*) or (eco-friendly adj2 head cover*) or (washable adj2 head cover*) or (reusable adj2 shoe cover*) or (sustainable adj2 shoe cover*) or (eco friendly adj2 shoe cover*) or (eco-friendly adj2 shoe cover*) or (washable adj2 shoe cover*)).ab,kf,ti. 4

18 ((reusable adj2 face shield*) or (sustainable adj2 face shield*) or (eco friendly adj2 face shield*) or (eco-friendly adj2 face shield*) or (washable adj2 face shield*) or (reusable adj2 face protection*) or (sustainable adj2 face protection*) or (eco friendly adj2 face protection*) or (eco-friendly adj2 face protection*) or (washable adj2 face protection*)).ab,kf,ti. 3

19 ((reusable adj2 goggle*) or (sustainable adj2 goggle*) or (eco friendly adj2 goggle*) or (eco-friendly adj2 goggle*) or (washable adj2 goggle*) or (reusable adj2 eye protection*) or (sustainable adj2 eye protection*) or (eco friendly adj2 eye protection*) or (eco-friendly adj2 eye protection*) or (washable adj2 eye protection*)).ab,kf,ti. 1

20 ((reusable adj2 respirator*) or (sustainable adj2 respirator*) or (eco friendly adj2 respirator*) or (eco-friendly adj2 respirator*) or (washable adj2 respirator*)).ab,kf,ti. 50

21 ((reusable adj2 protective equipment*) or (sustainable adj2 protective equipment*) or (eco friendly adj2 protective equipment*) or (eco-friendly adj2 protective equipment*) or (washable adj2 protective equipment*) or (reusable adj2 PPE) or (sustainable adj2 PPE) or (eco friendly adj2 PPE) or (eco-friendly adj2 PPE) or (washable adj2 PPE) or (protective equipment* adj2 recycling) or (protective equipment* adj2 reusability) or (protective equipment* adj2 reuse)).ab,kf,ti. 37

22 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 3515

23 ((supply chain* adj2 impact*) or (supply chain* adj2 effect*) or (supply network* adj2 impact*) or (supply network* adj2 effect*) or (retail chain* adj2 impact*) or (retail chain* adj2 effect*) or (distribution chain* adj2 impact*) or (distribution chain* adj2 effect*) or (supply channel* adj2 impact*) or (supply channel* adj2 effect*)).ab,kf,ti. 259

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Appendix 2: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	4-6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	6-7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	3
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-9
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	9-10
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix 1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8-11
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	11-12
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Not applicable
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	12
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	n/a
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	n/a
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	n/a
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	n/a
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	n/a
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	n/a
Limitations	20	Discuss the limitations of the scoping review process.	n/a
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	n/a
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	n/a

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
 * Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
 † A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
 ‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
 § The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA ScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850).

For peer review only

BMJ Open

A Scoping Review Protocol of Reusable Personal Protective Equipment in Hospitals: Barriers, Facilitators, and Impacts on Environment, Care Safety, Costs, and Supply Chain Resilience.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2024-096504.R1
Article Type:	Protocol
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Primary Subject Heading:	Health services research
Secondary Subject Heading:	Health economics, Health policy
Keywords:	Safety, Infection control < INFECTIOUS DISEASES, Health Care Costs, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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Manuscripts

Title: A Scoping Review Protocol of Reusable Personal Protective Equipment in Hospitals: Barriers, Facilitators, and Impacts on Environment, Care Safety, Costs, and Supply Chain Resilience.

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Wordcount: 2511

Abstract

Introduction: Climate degradation poses a significant global health challenge, with healthcare systems paradoxically contributing to this issue while adhering to the principle of "do no harm." Notably, the healthcare sector accounts for a considerable share of greenhouse gas emissions in many industrialized countries, primarily due to the supply chain, including pharmaceuticals, disposable medical devices and personal protective equipment. The COVID-19 pandemic exacerbated this issue, with millions of tons of CO₂ emissions attributed to single-use personal protective equipment. In response to the pandemic, some hospitals have begun adopting and implementing reusable personal protective equipment as a sustainable alternative to reduce emissions, enhance resilience to supply chain disruptions, and achieve cost savings. This scoping review aims to synthesize the available evidence on the adoption, implementation barriers and facilitators, as well as the impacts of reusable personal protective equipment in hospital settings.

Methods and analysis: This protocol is based on the York's five-stage framework outlined by Arksey and O'Malley. We will map evidence on the environmental and economic impacts of reusable versus disposable personal protective equipment, and the associated infection risks. Using an adapted Consolidated Framework for Implementation Research, our scoping review will identify enablers and barriers to implementation across different clinical settings. The methodology will adhere to PRISMA-ScR guidelines and will include a comprehensive search of peer-reviewed articles in 5 databases (Medline, Embase, CINAHL, Web of Science and Global Health) and gray literature. Two reviewers will independently evaluate the eligibility of all identified titles and abstracts for inclusion in

the full-text review, as well as for data extraction. Descriptive data will provide insights into the enablers and facilitators of reusable personal protective equipment adoption and implementation, along with its impacts on patient and staff safety, costs, the environment, and supply chain resilience to disruptions will be reported.

Ethics and dissemination: We expect the results to both identify research gaps and generate novel ideas for future studies on transitioning to reusable PPE in healthcare settings. This review will offer healthcare decision-makers valuable insights into the factors influencing the shift from disposable to reusable PPE and its associated impacts. By refining PPE management strategies, the findings will enable managers to clearly understand the challenges and anticipated outcomes, thereby guiding effective decision-making and facilitating a smooth transition that minimizes operational disruptions while upholding patient and staff safety.

Keywords: reusable personal protective equipment, adoption and implementation factors, impacts, carbon footprint, patient safety, cost control, supply chain resilience.

Registration details: <https://doi.org/10.17605/OSF.IO/DESVU>

Strengths and limitations of this study (max 5 bullet points)

- This will be the first scoping review to map the barriers, facilitators, and impacts of implementing reusable personal protective equipment (PPE) in hospital settings.
- The review employs an adapted Consolidated Framework for Implementation Research, providing a structured approach to understanding the enablers and barriers to implementing reusable PPE.

- The review will include a formal quality assessment or grading of the evidence using the mixed methods appraisal tool
- The inclusion of diverse study types—both qualitative and quantitative—may result in significant heterogeneity in study designs, data collection methods, and outcome measures. This variability may complicate synthesis, but we will use careful categorization and a narrative synthesis to identify key trends while acknowledging differences between studies.

Introduction

Climate degradation represents a global health challenge with significant implications for both the environment and public health. Paradoxically, healthcare systems contribute to this degradation, contradicting their fundamental principle of "do no harm". The health sector contributes significantly to national emissions in many countries, with hospitals being major emitters. In industrialized countries, healthcare systems are indeed responsible for a significant share of greenhouse gas (GHG) emissions. For instance, in the United States, the healthcare sector accounts for approximately 8.5% of the nation's GHG emissions.¹ In Canada, healthcare contributes around 5% of total emissions, surpassing even the aviation industry.¹ The United Kingdom's National Health Service (NHS) is responsible for about 5.4% of the country's GHG emissions.¹ France also has similar figures, with the healthcare sector contributing between 5% and 7% of the national total¹. A large part of emissions comes from Scope 3 (indirect) emissions, which are largely due to the supply chain, including pharmaceuticals, medical devices, and personal protective equipment (PPE) such as gloves, masks, and gowns.² Most PPE items are available in both

reusable and single-use forms. Although single-use PPE was originally designed to minimize infection transmission, research indicates that reusable PPE does not necessarily carry an increased risk of infections and still provides safe protection for staff and patients³⁻⁵. Life cycle assessments have shown that reusable PPE, including gowns, masks, and gloves, consumes less energy, generates less waste, and produces fewer GHG emissions over its entire lifespan compared to single-use alternatives.^{3,6-8} However, environmental impact may differ depending on the local context—particularly the local energy³—and one study demonstrates that reusable PPE is linked to increased water consumption, largely due to the water-intensive cotton production required for reusable gowns.⁸ Additionally, several studies highlight significant cost savings, with some estimates suggesting up to 75% reduction in costs per usage of reusable PPE compared to disposable counterparts.⁹⁻¹¹ During the COVID-19 pandemic, it was estimated that PPE was responsible for millions of tons of CO₂ equivalent emissions globally, with single-use masks and gloves contributing significantly to these emissions. For example, a study found that the global healthcare sector generated approximately 1.6 million tons of plastic waste per day during the pandemic, a considerable portion of which was attributed to disposable PPE.¹² Moreover, supply chain disruptions during the pandemic posed significant challenges for healthcare facilities in procuring single-use PPE.¹³

In response to these challenges—not only environmental but also logistical and cost-related, some hospitals worldwide that previously relied on single-use PPE have transitioned to reusable alternatives, driven by the need to reduce GHG emissions, mitigate supply chain disruptions, and achieve cost savings, all while maintaining high standards of safety and performance.

Despite these promising developments, some concerns remain. These include the potential for increased infection risk, the high initial investment costs, and the logistical demands of washing and storing reusable PPE. Although some studies show that the utilization of reusable PPE does not increase the risk of infections, these issues merit balanced consideration as healthcare facilities weigh the benefits and challenges associated with adopting reusable PPE.¹³

While there is growing recognition of the advantages of reusable PPE¹⁴, there is currently no clear synthesis of the literature on the implementation of reusable PPE in hospital settings and its comprehensive impact on the environment, patient and staff safety, and cost-effectiveness. Therefore, in this scoping review, we aim to synthesize the available evidence on the adoption, implementation barriers and facilitators and impacts of reusable PPE in hospital settings, addressing both its benefits and the challenges it presents.

Methods and Analysis

Protocol design

The review started in September 2024 and is expected to be completed by March 2025. The protocol for this scoping review was registered in the Open Science Framework.¹⁵ To ensure reproducibility, our review will follow the reporting standards outlined in the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (see Appendix 2).¹⁶ This protocol is based on the York's five-stage framework outlined by Arksey and O'Malley.¹⁷

Stage 1: identifying research questions and hypotheses

Through consultation with our team of researchers with diverse expertises (health management, health economics, biostatistics and medicine), the research questions are the following:

- What are the barriers and facilitators towards adopting and implementing reusable PPE in hospital settings? Are these adoption and implementation factors different across various clinical units or sectors (e.g., low risk vs. high-risk surgical units, surgical units vs. other units)?
- What is the environmental impact of reusable PPE vs. disposable PPE in hospital settings?
- What are the differences in patient and staff safety between reusable PPE and disposable PPE in hospital settings? Specifically, how do they compare in terms of infection risk levels and protective performance?
- What is the impact of reusable PPE vs. disposable PPE on the resilience to supply chain disruption?
- What are the economic costs and benefits of reusable PPE vs disposable PPE in hospital settings?

We hypothesize that implementing reusable PPE in hospital settings will result in reduced GHG emissions and plastic waste, maintain comparable infection risk levels, increase resilience to supply chain disruptions, and lead to substantial cost savings, making it a cost-effective solution.

Stage 2: identifying relevant studies

Review conceptual model

The review will be conducted using an adapted version of the updated Consolidated Framework for Implementation Research by Laura J. Damschroder et al.¹⁸. This framework will facilitate an exploration of various domains related to the implementation of innovations and their outcomes. In this context, "innovations" refer to interventions such as reusable PPE used in hospital settings.

The review will investigate both enablers and barriers to the implementation of reusable PPE through several domains:

1. **Implementation Process:** Examining the activities and strategies employed to adopt and integrate reusable PPE.
2. **Roles of Individuals/Stakeholders:** Assessing factors such as preferences, acceptability, resistance to change, and the influence of individual leadership on the implementation process.
3. **Inner Setting:** Analyzing characteristics of hospital settings, including types of clinical units, institutional culture, and infrastructure.
4. **Outer Setting:** Evaluating the impact of regulatory and policy contexts on the adoption and implementation of reusable PPE. It will be particularly examined whether safety standards and guidelines for reusable PPE exist, and how the presence or absence of these standards might influence the adoption and implementation of these innovations by healthcare facilities.

Additionally, the framework will explore the outcomes of reusable PPE through four domains of impact: financial costs, environmental impact, patient and staff safety, and resilience to supply chain disruptions.

Eligibility criteria

The Population, Concept and Context framework was applied as a guide to construct the eligibility criteria of our scoping review¹⁹. Eligibility criteria are available in Table 1.

Table 1: Inclusion and exclusion criteria

	Inclusion criteria	Exclusion criteria
Study focus	Any type of publication based on primary or secondary research findings focusing on the adoption and implementation of reusable PPE, and/or their impact(s) on the environment, costs, and infection risks	Studies neither focusing on reusable PPE implementation nor impact of PPE on infection risk, environment or costs
Population	Hospital settings, any types of clinical sectors or units	N/A
Study context	Hospital settings	Other settings than hospitals (e.g. nursing homes, primary care).
Intervention	Adoption and implementation of reusable PPE (gowns, gloves, masks, respirators, head covers, shoe covers, eye protection, goggles)	Adoption and implementation of reusable medical equipment or devices, excluding reusable PPE
Outcomes	Environmental impact (greenhouse gas emissions, waste generation, energy and water consumption) Patient and staff safety (PPE protective performance, transmission of pathogens, healthcare-associated infections) Resilience to supply chain disruption Cost reduction	
Study characteristics	Original research articles Reviews of any types Reports	Expert opinions or reviews Theoretical frameworks

	Book chapters Conference proceedings Dissertations/theses	
Timeframe	No constraints	
Publication language	No constraints	Unable to obtain translation

Search Strategy

We will conduct a comprehensive search of several electronic databases, including MEDLINE-Ovid, EMBASE-Ovid, Global Health, Web of Science, and CINAHL (EBSCO), to gather relevant evidence. All searches will be conducted in English and will encompass both qualitative and quantitative study designs. Additionally, we will perform a thorough search of gray literature through platforms such as Google Scholar, OpenGrey, Scopus, Faculty Opinions, Publons, and governmental websites, including the World Health Organization, Agency for Healthcare Research and Quality, Institute for Healthcare Improvement, and Sustainable Healthcare Coalition. Additionally, we will search the gray literature for market research and related documents from reusable PPE manufacturers. We received support from a librarian in developing and validating our research strategies for the databases.

To refine our search strategy, we initially developed it in MEDLINE, utilizing Medical Subject Headings (MeSH) and relevant keywords specific to the implementation and impacts of reusable PPE. We employed the search terms listed in Table 2, which presents a non-exhaustive list of these terms. Following a pilot search on PubMed, we reviewed the titles and abstracts of potential sources to identify additional relevant terms and index terms for incorporation into our MEDLINE search strategy (see Appendix 1).

To ensure the accuracy and comprehensiveness of the search strategy, a health sciences librarian meticulously reviewed it in accordance with the Peer Review of Electronic Search Strategies (PRESS) guidelines²⁰ before adapting it for other databases. Additionally, we will contact authors of ongoing or upcoming studies to request full-text articles or any supplementary information as needed. We will also search for relevant studies based on the reference lists of the included articles.

Table 2: Search terms

Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Reusable PPE	Implementation barriers, implementation facilitators	Environmental impact, sustainability	Care safety	Economic impact, financial impact	Supply chain resilience /vulnerability
Reusable gowns	Organizational challenges, logistic challenges, procurement challenges	GHG emissions	Pathogen transmission, Cross-contamination prevention	Cost-benefit analysis, life-cycle costing	Supply chain vulnerability
Reusable masks	Adoption, Transition, Switching	Carbon footprint	Laundry process efficacy	Cost saving, financial gain, economic gain	Supply chain resilience
Reusable gloves	Feasibility	Life cycle assessment	Protective performance, protective value	Financial sustainability, economic viability	
Reusable face covers, shoe covers	Acceptability, resistance, preference	Material waste, waste management	Healthcare associated infections, nosocomial infections	Economic evaluation, economic assessment	
Reusable face shields					
Reusable respirators					
Reusable eye protection					

Stage 3: Selecting Eligible Studies

Based on the search strategies developed for each database, all identified studies will be imported into EndNote referencing software to remove duplicates. Two reviewers (NC and CB) will independently assess the relevance of all titles and abstracts using the inclusion and exclusion criteria, facilitated by Covidence. A pilot round involving a randomly selected sample of 10% of the articles will be conducted to evaluate inter-reviewer agreement on the inclusion and exclusion criteria prior to the full screening of all articles.^{21,22} Two additional reviewers (FC and CL) will serve as referees to resolve disagreements between the primary reviewers.

Non-relevant studies will be excluded, and the full texts of selected articles will be assessed to ascertain eligibility for inclusion by the two reviewers. Any disagreements that arise during this process will be resolved through discussion with the third and fourth reviewers. Screening for eligible study will be performed with the systematic review management platform RYYAN (<https://www.rayyan.ai/>).

Stage 4: Extracting Data

At this stage, the two reviewers will extract data from the included articles and conduct the evidence synthesis. We will use a data extraction form adapted from the Joanna Briggs Institute's template. The following key information will be collected from the relevant studies: authors, publication year, country, study design, clinical settings, conceptual framework (if applicable), objectives, methods, findings, and reported limitations. Additionally, the form will capture key findings related to the scoping review questions and outcomes of interest: 1) enablers and barriers to the implementation of reusable PPE,

- 2) environmental impact of reusable PPE utilization, 2) impact on patient and staff safety, 3) effects on cost, and 4) effect on the supply chain resilience/vulnerability.

Simultaneously with data extraction, we will assess the quality of the evidence using the Mixed Methods Appraisal Tool (MMAT). Given the anticipated heterogeneity in study designs and methods among the articles included in the scoping review, the MMAT is particularly well-suited for evaluating their quality.²³

Stage 5: Structuring the Data Synthesis

The primary aim of this scoping review is to compile findings and provide an overview of the research rather than evaluate the quality of the studies. We will utilize the PRISMA-ScR checklist to guide the data synthesis process.¹⁶ The synthesis criteria will be based on the number of studies reporting outcomes of interest related to the research questions. A narrative synthesis will be employed to present these findings. For quantitative data concerning impacts on one or more dimensions (environment, patient and staff safety, cost, and resilience of the supply chain), descriptive statistics will be reported. Qualitative data will be analyzed using a conceptual model that addresses multiple dimensions of implementation: 1) the process of implementation, 2) roles of stakeholders, 3) inner setting, and 4) outer setting.

Patient and public involvement

Patients and the public were not involved in any way in the development of the scoping review protocol.

Ethics and Dissemination

Since the scoping review methodology involves reviewing and collecting data from publicly available materials, this study does not require ethics approval. We anticipate that the results will highlight research gaps and generate novel ideas for future studies on transitioning to reusable PPE in healthcare settings. The findings will be submitted for publication to relevant peer-reviewed journals and conferences focused on healthcare management and implementation science.

Beyond academic contributions, this scoping review will provide healthcare decision-makers and staff with insights into the implementation factors and potential impacts associated with transitioning from disposable to reusable PPE. The review will objectively assess the differences in patient and staff safety between reusable and disposable PPE, as well as other factors such as cost, environmental impact, and logistical requirements. This evidence will inform protocols and practices, enabling healthcare facilities to consider the implementation of reusable PPE based on a comprehensive evaluation of the available data. Ultimately, the results will not only enhance the effectiveness of reusable PPE implementation within individual hospitals but also contribute to the broader development of best practices that can be shared across the healthcare sector.

Strengths and limitations of this scoping review

The scoping review has several strengths, including its comprehensive approach to synthesizing evidence from diverse healthcare settings and its use of a robust conceptual framework to explore multiple aspects of reusable PPE implementation. By examining key impacts—such as environmental footprint, cost-effectiveness, patient and staff safety, and supply chain resilience—the review will provide a broad overview of the topic,

highlighting both enablers and barriers to adoption. Its rigorous methodology, which includes thorough database searches, multiple stages of data extraction, and adherence to PRISMA-ScR guidelines, enhances transparency and reproducibility.

However, the review also has limitations. The reliance on published literature may introduce publication bias, particularly if negative or inconclusive studies are underrepresented. Given the inclusion of diverse study types—both qualitative and quantitative—there may be significant heterogeneity in study designs, data collection methods, and outcome measures. To address this, we will categorize studies by common themes and conduct a narrative synthesis to identify key patterns. By using a conceptual framework to guide the analysis, we will transparently present the diversity in the evidence, allowing us to draw meaningful conclusions despite the variability in study characteristics.

Author contributions

Clavel N is the guarantor of this work. NC is the first author of this manuscript. All authors contributed to at least some component of the scoping review protocol and/or manuscript. NC shaped all aspects of the study design with feedback from FC and CL. NC wrote the manuscript and FC, CL, SW, IE, CB and MC-B gave their feedback. All authors have read and approved the final manuscript.

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Data statement section

Not applicable

Competing interest statement

No competing interest to declare.

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Appendix 1: Search strategy (Medline-Ovid)

Ovid MEDLINE(R) ALL <1946 to November 04, 2024>

1 exp Change Management/ or exp Implementation Science/ 1809

2 ((Implement* adj2 barrier*) or (implement* adj2 factor*) or (implement* adj2 enabler*) or (implement* adj2 facilitator*) or (implement* adj2 challenge*) or (implement adj2 effectiv*) or (barrier* adj2 effectiv*) or (Resistance* adj2 change*) or "Organizational challenge*" or "organizational barrier*" or "Logistical challenge*" or "logistical barrier*" or (Policy adj2 barrier*) or "Procurement difficult*" or (Regulatory adj2 obstacle*) or (regulatory adj2 barrier*) or "Policy support*" or "Successful case stud*" or adoption or faisability or acceptability or acceptance or preference* or tolerance* or resistance* or (user* adj2 experience*) or (staff adj2 experience*) or (health* adj2 experience*) or (health* professional* adj2 experience*) or (patient* adj2 experience*) or (staff adj2 preference*) or (health* adj2 preference*) or (health* professional* adj2 preference*) or transition* or switching).ab,kf,ti. 2310261

3 1 or 2 2311541

4 exp "Cost-Benefit Analysis"/ or exp "Economics, Hospital"/ or exp "Health Care Costs"/ or exp "Cost Control"/ or exp "Efficiency, Organizational"/ or exp "Costs and cost analysis"/ 302251

5 ((Cost* adj2 analys*) or "Financial implication*" or (Cost* adj2 effectiv*) or "Economic evaluation*" or "Lifecycle* costing" or (Budget adj2 impact*) or "Purchasing expense*" or "Cost* comparison*" or "Cost-benefit* analys*" or "Financial evaluation*" or "Economic impact*" or "Investment* analys*" or "Budget assessment*" or "Expense* comparison*" or "Economic benefit*" or "Cost saving*" or "financial gain*" or "economic gain*" or "Financial advantage*" or "Financial sustainability" or "Financial viability" or "Economic efficiency" or "economic sustainability" or "economic viability" or "economic evaluation*").ab,kf,ti. 273387

6 4 or 5 491111

7 exp "Impacts, environmental "/ or exp "Carbon Footprint"/ or exp "Greenhouse Effect"/ or conservation of natural resources/ or "conservation of energy resources"/ or "conservation of water resources"/ 1616650

8 ((Environment* adj2 impact*) or (environment* adj2 consideration*) or
9 "Sustainability" or "Carbon footprint*" or (Waste adj2 reduction*) or "Resource
10 conservation*" or "Green healthcare" or "Eco-friendly practice*" or "Life cycle
11 assessment*" or "life cycle evaluation*" or "Environmental sustainability" or "Ecological
12 footprint*" or "Environmental comparison*" or (Ecological impact* adj2 assessment*) or
13 (Ecological impact* adj2 evaluation*) or "Environmental footprint*" or "Greenhouse gas
14 emission*" or "Energy consumption*" or "Water usage*" or "Material waste*" or
15 "Environmental benefit*" or "Ecological efficiency" or "waste management" or "waste
16 generation*").ab,kf,ti. 125454

17 9 7 or 8 1705648

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20 10 exp Consumer Behavior/ or exp "Infection Control"/ or exp "Infection control
21 practitioners"/ or exp "Cross Infection"/ or exp "Sterilization"/ or exp "Hygiene"/ 190159

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24 11 ((infection adj2 control*) or (infection adj2 prevention) or "hygiene standard*" or
25 (contamination adj2 risk*) or "sterilization efficacy" or "cross-contamination prevention"
26 or "safety comparison*" or (pathogen adj2 transmission*) or "protective efficacy" or
27 "protective value*" or "protective performance*" or "Sterility maintenance" or
28 (sterilization adj2 maintenance) or (laundry adj2 efficacy) or (laundry adj2 efficiency) or
29 (infection adj2 risk*) or "healthcare-associated infection*" or (staff adj2 protection*) or
30 (healthcare professional* adj2 protection) or "cross-contamination*" or "healthcare
31 associated infection*" or "nosocomial infection*").ab,kf,ti. 128081

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36 12 10 or 11 288996

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39 13 Equipment reuse/ 3267

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42 14 ((reusable adj2 mask*) or (sustainable adj2 mask*) or (eco friendly adj2 mask*) or
43 (eco-friendly adj2 mask*) or (washable adj2 mask*)).ab,kf,ti. 149

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46 15 ((reusable adj2 gown*) or (sustainable adj2 gown*) or (eco friendly adj2 gown*)
47 or (washable adj2 gown*) or (reusable adj2 scrub*) or (sustainable adj2 scrub*) or (eco
48 friendly adj2 scrub*) or (washable adj2 scrub*) or (reusable adj2 surgical garment*) or
49 (sustainable adj2 surgical garment*) or (washable adj2 surgical garment*) or (reusable
50 adj2 surgical textile*) or (washable adj2 surgical textile*) or (sustainable adj2 surgical
51 textile*) or (eco friendly adj2 surgical textile*)).ab,kf,ti. 50

16 ((reusable adj2 glove*) or (sustainable adj2 glove*) or (eco friendly adj2 glove*) or (eco-friendly adj2 glove*) or (washable adj2 glove*)).ab,kf,ti. 17

17 ((reusable adj2 head cover*) or (sustainable adj2 head cover*) or (eco friendly adj2 head cover*) or (eco-friendly adj2 head cover*) or (washable adj2 head cover*) or (reusable adj2 shoe cover*) or (sustainable adj2 shoe cover*) or (eco friendly adj2 shoe cover*) or (eco-friendly adj2 shoe cover*) or (washable adj2 shoe cover*)).ab,kf,ti. 4

18 ((reusable adj2 face shield*) or (sustainable adj2 face shield*) or (eco friendly adj2 face shield*) or (eco-friendly adj2 face shield*) or (washable adj2 face shield*) or (reusable adj2 face protection*) or (sustainable adj2 face protection*) or (eco friendly adj2 face protection*) or (eco-friendly adj2 face protection*) or (washable adj2 face protection*)).ab,kf,ti. 3

19 ((reusable adj2 goggle*) or (sustainable adj2 goggle*) or (eco friendly adj2 goggle*) or (eco-friendly adj2 goggle*) or (washable adj2 goggle*) or (reusable adj2 eye protection*) or (sustainable adj2 eye protection*) or (eco friendly adj2 eye protection*) or (eco-friendly adj2 eye protection*) or (washable adj2 eye protection*)).ab,kf,ti. 1

20 ((reusable adj2 respirator*) or (sustainable adj2 respirator*) or (eco friendly adj2 respirator*) or (eco-friendly adj2 respirator*) or (washable adj2 respirator*)).ab,kf,ti. 50

21 ((reusable adj2 protective equipment*) or (sustainable adj2 protective equipment*) or (eco friendly adj2 protective equipment*) or (eco-friendly adj2 protective equipment*) or (washable adj2 protective equipment*) or (reusable adj2 PPE) or (sustainable adj2 PPE) or (eco friendly adj2 PPE) or (eco-friendly adj2 PPE) or (washable adj2 PPE) or (protective equipment* adj2 recycling) or (protective equipment* adj2 reusability) or (protective equipment* adj2 reuse)).ab,kf,ti. 37

22 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 3515

23 ((supply chain* adj2 impact*) or (supply chain* adj2 effect*) or (supply network* adj2 impact*) or (supply network* adj2 effect*) or (retail chain* adj2 impact*) or (retail chain* adj2 effect*) or (distribution chain* adj2 impact*) or (distribution chain* adj2 effect*) or (supply channel* adj2 impact*) or (supply channel* adj2 effect*)).ab,kf,ti. 259

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Appendix 2: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	4-6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	6-7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	3
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-9
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	9-10
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix 1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8-11
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	11-12
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Not applicable
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	12
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	n/a
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	n/a
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	n/a
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	n/a
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	n/a
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	n/a
Limitations	20	Discuss the limitations of the scoping review process.	n/a
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	n/a
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	n/a

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
 * Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
 † A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
 ‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
 § The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA ScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850).

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BMJ Open

A Scoping Review Protocol of Reusable Personal Protective Equipment in Hospitals: Barriers, Facilitators, and Impacts on Environment, Care Safety, Costs, and Supply Chain Resilience.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2024-096504.R2
Article Type:	Protocol
Date Submitted by the Author:	23-Apr-2025
Complete List of Authors:	Clavel, Nathalie; Université de Montréal, École de santé publique Castonguay, François M.; University of Montreal, Laprise, Claudie; Université de Montréal, École de santé publique Williams, Stephan; Université de Montréal Faculté de Médecine Ethier, Isabelle; Université de Montréal Faculté de Médecine Bernier, Marie-Claude; Centre Hospitalier de l'Université de Montreal Beauharnais, Christine; Université de Montréal, École de santé publique
Primary Subject Heading:	Health services research
Secondary Subject Heading:	Health economics, Health policy
Keywords:	Safety, Infection control < INFECTIOUS DISEASES, Health Care Costs, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

SCHOLARONE™
Manuscripts

Title: A Scoping Review Protocol of Reusable Personal Protective Equipment in Hospitals: Barriers, Facilitators, and Impacts on Environment, Care Safety, Costs, and Supply Chain Resilience.

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Wordcount: 2520

Abstract

Introduction: Climate degradation poses a significant global health challenge, with healthcare systems paradoxically contributing to this issue while adhering to the principle of "do no harm." Notably, the healthcare sector accounts for a considerable share of greenhouse gas emissions in many industrialized countries, primarily due to the supply chain, including pharmaceuticals, disposable medical devices and personal protective equipment. The COVID-19 pandemic exacerbated this issue, with millions of tons of CO₂ emissions attributed to single-use personal protective equipment. In response to the pandemic, some hospitals have begun adopting and implementing reusable personal protective equipment as a sustainable alternative to reduce emissions, enhance resilience to supply chain disruptions, and achieve cost savings. This scoping review aims to synthesize the available evidence on the adoption, implementation barriers and facilitators, as well as the impacts of reusable personal protective equipment in hospital settings.

Methods and analysis: This protocol is based on the York's five-stage framework outlined by Arksey and O'Malley. We will map evidence on the environmental and economic impacts of reusable versus disposable personal protective equipment, and the associated infection risks. Using an adapted Consolidated Framework for Implementation Research, our scoping review will identify enablers and barriers to implementation across different clinical settings. The methodology will adhere to PRISMA-ScR guidelines and will include a comprehensive search of peer-reviewed articles in 5 databases (Medline, Embase, CINAHL, Web of Science and Global Health) and gray literature. Databases will be searched from inception to December 2024. Two reviewers will independently evaluate

the eligibility of all identified titles and abstracts for inclusion in the full-text review, as well as for data extraction. Descriptive data will provide insights into the enablers and facilitators of reusable personal protective equipment adoption and implementation, along with its impacts on patient and staff safety, costs, the environment, and supply chain resilience to disruptions will be reported.

Ethics and dissemination: We expect the results to both identify research gaps and generate novel ideas for future studies on transitioning to reusable PPE in healthcare settings. This review will offer healthcare decision-makers valuable insights into the factors influencing the shift from disposable to reusable PPE and its associated impacts. By refining PPE management strategies, the findings will enable managers to clearly understand the challenges and anticipated outcomes, thereby guiding effective decision-making and facilitating a smooth transition that minimizes operational disruptions while upholding patient and staff safety. Ethics approval was not required for this review. The findings will be shared through conferences on healthcare management and sustainability, and submitted to peer-reviewed journals in healthcare management and implementation science.

Keywords: reusable personal protective equipment, adoption and implementation factors, impacts, carbon footprint, patient safety, cost control, supply chain resilience.

Registration details: <https://doi.org/10.17605/OSF.IO/DESVU>

Strengths and limitations of this study

- The review employs an adapted Consolidated Framework for Implementation Research, providing a structured approach to understanding the enablers and barriers to implementing reusable PPE.
- The review will include a formal quality assessment or grading of the evidence using the mixed methods appraisal tool
- The inclusion of diverse study types—both qualitative and quantitative—may result in significant heterogeneity in study designs, data collection methods, and outcome measures.

Introduction

Climate degradation represents a global health challenge with significant implications for both the environment and public health. Paradoxically, healthcare systems contribute to this degradation, contradicting their fundamental principle of "do no harm". The health sector contributes significantly to national emissions in many countries, with hospitals being major emitters. In industrialized countries, healthcare systems are indeed responsible for a significant share of greenhouse gas (GHG) emissions. For instance, in the United States, the healthcare sector accounts for approximately 8.5% of the nation's GHG emissions.¹ In Canada, healthcare contributes around 5% of total emissions, surpassing even the aviation industry.¹ The United Kingdom's National Health Service (NHS) is responsible for about 5.4% of the country's GHG emissions.¹ France also has similar figures, with the healthcare sector contributing between 5% and 7% of the national total¹. A large part of emissions comes from Scope 3 (indirect) emissions, which are largely due

to the supply chain, including pharmaceuticals, medical devices, and personal protective equipment (PPE) such as gloves, masks, and gowns.² Most PPE items are available in both reusable and single-use forms. Although single-use PPE was originally designed to minimize infection transmission, research indicates that reusable PPE does not necessarily carry an increased risk of infections and still provides safe protection for staff and patients³⁻⁵. Life cycle assessments have shown that reusable PPE, including gowns, masks, and gloves, consumes less energy, generates less waste, and produces fewer GHG emissions over its entire lifespan compared to single-use alternatives.^{3,6-8} However, environmental impact may differ depending on the local context—particularly the local energy³—and one study demonstrates that reusable PPE is linked to increased water consumption, largely due to the water-intensive cotton production required for reusable gowns.⁸ Additionally, several studies highlight significant cost savings, with some estimates suggesting up to 75% reduction in costs per usage of reusable PPE compared to disposable counterparts.⁹⁻¹¹ During the COVID-19 pandemic, it was estimated that PPE was responsible for millions of tons of CO₂ equivalent emissions globally, with single-use masks and gloves contributing significantly to these emissions. For example, a study found that the global healthcare sector generated approximately 1.6 million tons of plastic waste per day during the pandemic, a considerable portion of which was attributed to disposable PPE.¹² Moreover, supply chain disruptions during the pandemic posed significant challenges for healthcare facilities in procuring single-use PPE.¹³

In response to these challenges—not only environmental but also logistical and cost-related, some hospitals worldwide that previously relied on single-use PPE have transitioned to reusable alternatives, driven by the need to reduce GHG emissions,

mitigate supply chain disruptions, and achieve cost savings, all while maintaining high standards of safety and performance.

Despite these promising developments, some concerns remain. These include the potential for increased infection risk, the high initial investment costs, and the logistical demands of washing and storing reusable PPE. Although some studies show that the utilization of reusable PPE does not increase the risk of infections, these issues merit balanced consideration as healthcare facilities weigh the benefits and challenges associated with adopting reusable PPE.¹³

While there is growing recognition of the advantages of reusable PPE¹⁴, there is currently no clear synthesis of the literature on the implementation of reusable PPE in hospital settings and its comprehensive impact on the environment, patient and staff safety, and cost-effectiveness. Therefore, in this scoping review, we aim to synthesize the available evidence on the adoption, implementation barriers and facilitators and impacts of reusable PPE in hospital settings, addressing both its benefits and the challenges it presents.

Methods and Analysis

Protocol design

The review started in September 2024 and is expected to be completed by August 2025. The protocol for this scoping review was registered in the Open Science Framework.¹⁵ To ensure reproducibility, our review will follow the reporting standards outlined in the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (see Appendix 2).¹⁶

This protocol is based on the York’s five-stage framework outlined by Arksey and O’Malley.¹⁷

Stage 1: identifying research questions and hypotheses

Through consultation with our team of researchers with diverse expertises (health management, health economics, biostatistics and medicine), the research questions are the following:

- What are the barriers and facilitators towards adopting and implementing reusable PPE in hospital settings? Are these adoption and implementation factors different across various clinical units or sectors (e.g., low risk vs. high-risk surgical units, surgical units vs. other units)?
- What is the environmental impact of reusable PPE vs. disposable PPE in hospital settings?
- What are the differences in patient and staff safety between reusable PPE and disposable PPE in hospital settings? Specifically, how do they compare in terms of infection risk levels and protective performance?
- What is the impact of reusable PPE vs. disposable PPE on the resilience to supply chain disruption?
- What are the economic costs and benefits of reusable PPE vs disposable PPE in hospital settings?

We hypothesize that implementing reusable PPE in hospital settings will result in reduced GHG emissions and plastic waste, maintain comparable infection risk levels, increase

resilience to supply chain disruptions, and lead to substantial cost savings, making it a cost-effective solution.

Stage 2: identifying relevant studies

Review conceptual model

The review will be conducted using an adapted version of the updated Consolidated Framework for Implementation Research by Laura J. Damschroder et al.¹⁸. This framework will facilitate an exploration of various domains related to the implementation of innovations and their outcomes. In this context, "innovations" refer to interventions such as reusable PPE used in hospital settings.

The review will investigate both enablers and barriers to the implementation of reusable PPE through several domains:

1. **Implementation Process:** Examining the activities and strategies employed to adopt and integrate reusable PPE.
2. **Roles of Individuals/Stakeholders:** Assessing factors such as preferences, acceptability, resistance to change, and the influence of individual leadership on the implementation process.
3. **Inner Setting:** Analyzing characteristics of hospital settings, including types of clinical units, institutional culture, and infrastructure.
4. **Outer Setting:** Evaluating the impact of regulatory and policy contexts on the adoption and implementation of reusable PPE. It will be particularly examined whether safety standards and guidelines for reusable PPE exist, and how the presence or absence of these standards might influence the adoption and implementation of these innovations by healthcare facilities.

Additionally, the framework will explore the outcomes of reusable PPE through four domains of impact: financial costs, environmental impact, patient and staff safety, and resilience to supply chain disruptions.

Eligibility criteria

The Population, Concept and Context framework was applied as a guide to construct the eligibility criteria of our scoping review¹⁹. Eligibility criteria are available in Table 1.

Table 1: Inclusion and exclusion criteria

	Inclusion criteria	Exclusion criteria
Study focus	Any type of publication based on primary or secondary research findings focusing on the adoption and implementation of reusable PPE, and/or their impact(s) on the environment, costs, and infection risks	Studies neither focusing on reusable PPE implementation nor impact of PPE on infection risk, environment or costs
Population	Hospital settings, any types of clinical sectors or units	N/A
Study context	Hospital settings	Other settings than hospitals (e.g. nursing homes, primary care).
Intervention	Adoption and implementation of reusable PPE (gowns, gloves, masks, respirators, head covers, shoe covers, eye protection, goggles)	Adoption and implementation of reusable medical equipment or devices, excluding reusable PPE
Outcomes	Environmental impact (greenhouse gas emissions, waste generation, energy and water consumption) Patient and staff safety (PPE protective performance, transmission of pathogens,	

	healthcare-associated infections)	
	Resilience to supply chain disruption	
	Cost reduction	
Study characteristics	Original research articles Reviews of any types Reports Book chapters Conference proceedings Dissertations/theses	Expert opinions or reviews Theoretical frameworks
Timeframe	No constraints	
Publication language	No constraints	Unable to obtain translation

Search Strategy

We will conduct a comprehensive search of several electronic databases, including MEDLINE-Ovid, EMBASE-Ovid, Global Health, Web of Science, and CINAHL (EBSCO), to gather relevant evidence. Databases will be searched from inception to December 2024. All searches will be conducted in English and will encompass both qualitative and quantitative study designs. Additionally, we will perform a thorough search of gray literature through platforms such as Google Scholar, OpenGrey, Scopus, Faculty Opinions, Publons, and governmental websites, including the World Health Organization, Agency for Healthcare Research and Quality, Institute for Healthcare Improvement, and Sustainable Healthcare Coalition. Additionally, we will search the gray literature for market research and related documents from reusable PPE manufacturers. We received support from a librarian in developing and validating our research strategies for the databases.

To refine our search strategy, we initially developed it in MEDLINE, utilizing Medical Subject Headings (MeSH) and relevant keywords specific to the implementation and impacts of reusable PPE. We employed the search terms listed in Table 2, which presents a non-exhaustive list of these terms. Following a pilot search on PubMed, we reviewed the titles and abstracts of potential sources to identify additional relevant terms and index terms for incorporation into our MEDLINE search strategy (see Appendix 1).

To ensure the accuracy and comprehensiveness of the search strategy, a health sciences librarian meticulously reviewed it in accordance with the Peer Review of Electronic Search Strategies (PRESS) guidelines²⁰ before adapting it for other databases. Additionally, we will contact authors of ongoing or upcoming studies to request full-text articles or any supplementary information as needed. We will also search for relevant studies based on the reference lists of the included articles.

Table 2: Search terms

Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Reusable PPE	Implementation barriers, implementation facilitators	Environmental impact, sustainability	Care safety	Economic impact, financial impact	Supply chain resilience /vulnerability
Reusable gowns	Organizational challenges, logistic challenges, procurement challenges	GHG emissions	Pathogen transmission, Cross-contamination prevention	Cost-benefit analysis, life-cycle costing	Supply chain vulnerability
Reusable masks	Adoption, Transition, Switching	Carbon footprint	Laundry process efficacy	Cost saving, financial gain, economic gain	Supply chain resilience
Reusable gloves	Feasibility	Life cycle assessment	Protective performance, protective value	Financial sustainability, economic viability	

Reusable face covers, shoe covers	Acceptability, resistance, preference	Material waste, waste management	Healthcare associated infections, nosocomial infections	Economic evaluation, economic assessment	
Reusable face shields					
Reusable respirators					
Reusable eye protection					

Stage 3: Selecting Eligible Studies

Based on the search strategies developed for each database, all identified studies will be imported into EndNote referencing software to remove duplicates. Two reviewers (NC and CB) will independently assess the relevance of all titles and abstracts using the inclusion and exclusion criteria, facilitated by Covidence. A pilot round involving a randomly selected sample of 10% of the articles will be conducted to evaluate inter-reviewer agreement on the inclusion and exclusion criteria prior to the full screening of all articles.^{21,22} Two additional reviewers (FC and CL) will serve as referees to resolve disagreements between the primary reviewers.

Non-relevant studies will be excluded, and the full texts of selected articles will be assessed to ascertain eligibility for inclusion by the two reviewers. Any disagreements that arise during this process will be resolved through discussion with the third and fourth reviewers. Screening for eligible study will be performed with the systematic review management platform RYYAN (<https://www.rayyan.ai/>).

Stage 4: Extracting Data

At this stage, the two reviewers will extract data from the included articles and conduct the evidence synthesis. We will use a data extraction form adapted from the Joanna Briggs

Institute’s template. The following key information will be collected from the relevant studies: authors, publication year, country, study design, clinical settings, conceptual framework (if applicable), objectives, methods, findings, and reported limitations. Additionally, the form will capture key findings related to the scoping review questions and outcomes of interest: 1) enablers and barriers to the implementation of reusable PPE, 2) environmental impact of reusable PPE utilization, 2) impact on patient and staff safety, 3) effects on cost, and 4) effect on the supply chain resilience/vulnerability.

Simultaneously with data extraction, we will assess the quality of the evidence using the Mixed Methods Appraisal Tool (MMAT). Given the anticipated heterogeneity in study designs and methods among the articles included in the scoping review, the MMAT is particularly well-suited for evaluating their quality.²³

Stage 5: Structuring the Data Synthesis

The primary aim of this scoping review is to compile findings and provide an overview of the research rather than evaluate the quality of the studies. We will utilize the PRISMA-ScR checklist to guide the data synthesis process.¹⁶ The synthesis criteria will be based on the number of studies reporting outcomes of interest related to the research questions. A narrative synthesis will be employed to present these findings. For quantitative data concerning impacts on one or more dimensions (environment, patient and staff safety, cost, and resilience of the supply chain), descriptive statistics will be reported. Qualitative data will be analyzed using a conceptual model that addresses multiple dimensions of implementation: 1) the process of implementation, 2) roles of stakeholders, 3) inner setting, and 4) outer setting.

Patient and public involvement

Patients and the public were not involved in any way in the development of the scoping review protocol.

Ethics and Dissemination

Since the scoping review methodology involves reviewing and collecting data from publicly available materials, this study does not require ethics approval. We anticipate that the results will highlight research gaps and generate novel ideas for future studies on transitioning to reusable PPE in healthcare settings. The findings will be submitted for publication to relevant peer-reviewed journals and conferences focused on healthcare management and implementation science.

Beyond academic contributions, this scoping review will provide healthcare decision-makers and staff with insights into the implementation factors and potential impacts associated with transitioning from disposable to reusable PPE. The review will objectively assess the differences in patient and staff safety between reusable and disposable PPE, as well as other factors such as cost, environmental impact, and logistical requirements. This evidence will inform protocols and practices, enabling healthcare facilities to consider the implementation of reusable PPE based on a comprehensive evaluation of the available data. Ultimately, the results will not only enhance the effectiveness of reusable PPE implementation within individual hospitals but also contribute to the broader development of best practices that can be shared across the healthcare sector.

Strengths and limitations of this scoping review

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The scoping review has several strengths, including its comprehensive approach to synthesizing evidence from diverse healthcare settings and its use of a robust conceptual framework to explore multiple aspects of reusable PPE implementation. By examining key impacts—such as environmental footprint, cost-effectiveness, patient and staff safety, and supply chain resilience—the review will provide a broad overview of the topic, highlighting both enablers and barriers to adoption. Its rigorous methodology, which includes thorough database searches, multiple stages of data extraction, and adherence to PRISMA-ScR guidelines, enhances transparency and reproducibility.

However, the review also has limitations. The reliance on published literature may introduce publication bias, particularly if negative or inconclusive studies are underrepresented. Given the inclusion of diverse study types—both qualitative and quantitative—there may be significant heterogeneity in study designs, data collection methods, and outcome measures. To address this, we will categorize studies by common themes and conduct a narrative synthesis to identify key patterns. By using a conceptual framework to guide the analysis, we will transparently present the diversity in the evidence, allowing us to draw meaningful conclusions despite the variability in study characteristics.

Author contributions

NC is the first author of this manuscript and is responsible for the overall content as guarantor. All authors contributed to at least some component of the scoping review protocol and/or manuscript. NC shaped all aspects of the study design with feedback from FM-C and CL. NC wrote the manuscript and FM-C, CL, SW, IE, MC-B and CB gave their feedback. All authors have read and approved the final manuscript.

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Data statement section

Not applicable

Competing interest statement

No competing interest to declare.

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Appendix 1: Search strategy (Medline-Ovid)

Ovid MEDLINE(R) ALL <1946 to November 04, 2024>

1 exp Change Management/ or exp Implementation Science/ 1809

2 ((Implement* adj2 barrier*) or (implement* adj2 factor*) or (implement* adj2 enabler*) or (implement* adj2 facilitator*) or (implement* adj2 challenge*) or (implement adj2 effectiv*) or (barrier* adj2 effectiv*) or (Resistance* adj2 change*) or "Organizational challenge*" or "organizational barrier*" or "Logistical challenge*" or "logistical barrier*" or (Policy adj2 barrier*) or "Procurement difficult*" or (Regulatory adj2 obstacle*) or (regulatory adj2 barrier*) or "Policy support*" or "Successful case stud*" or adoption or faisability or acceptability or acceptance or preference* or tolerance* or resistance* or (user* adj2 experience*) or (staff adj2 experience*) or (health* adj2 experience*) or (health* professional* adj2 experience*) or (patient* adj2 experience*) or (staff adj2 preference*) or (health* adj2 preference*) or (health* professional* adj2 preference*) or transition* or switching).ab,kf,ti. 2310261

3 1 or 2 2311541

4 exp "Cost-Benefit Analysis"/ or exp "Economics, Hospital"/ or exp "Health Care Costs"/ or exp "Cost Control"/ or exp "Efficiency, Organizational"/ or exp "Costs and cost analysis"/ 302251

5 ((Cost* adj2 analys*) or "Financial implication*" or (Cost* adj2 effectiv*) or "Economic evaluation*" or "Lifecycle* costing" or (Budget adj2 impact*) or "Purchasing expense*" or "Cost* comparison*" or "Cost-benefit* analys*" or "Financial evaluation*" or "Economic impact*" or "Investment* analys*" or "Budget assessment*" or "Expense* comparison*" or "Economic benefit*" or "Cost saving*" or "financial gain*" or "economic gain*" or "Financial advantage*" or "Financial sustainability" or "Financial viability" or "Economic efficiency" or "economic sustainability" or "economic viability" or "economic evaluation*").ab,kf,ti. 273387

6 4 or 5 491111

7 exp "Impacts, environmental "/ or exp "Carbon Footprint"/ or exp "Greenhouse Effect"/ or conservation of natural resources/ or "conservation of energy resources"/ or "conservation of water resources"/ 1616650

8 ((Environment* adj2 impact*) or (environment* adj2 consideration*) or
"Sustainability" or "Carbon footprint*" or (Waste adj2 reduction*) or "Resource
conservation*" or "Green healthcare" or "Eco-friendly practice*" or "Life cycle
assessment*" or "life cycle evaluation*" or "Environmental sustainability" or "Ecological
footprint*" or "Environmental comparison*" or (Ecological impact* adj2 assessment*) or
(Ecological impact* adj2 evaluation*) or "Environmental footprint*" or "Greenhouse gas
emission*" or "Energy consumption*" or "Water usage*" or "Material waste*" or
"Environmental benefit*" or "Ecological efficiency" or "waste management" or "waste
generation*").ab,kf,ti. 125454

9 7 or 8 1705648

10 exp Consumer Behavior/ or exp "Infection Control"/ or exp "Infection control
practitioners"/ or exp "Cross Infection"/ or exp "Sterilization"/ or exp "Hygiene"/ 190159

11 ((infection adj2 control*) or (infection adj2 prevention) or "hygiene standard*" or
(contamination adj2 risk*) or "sterilization efficacy" or "cross-contamination prevention"
or "safety comparison*" or (pathogen adj2 transmission*) or "protective efficacy" or
"protective value*" or "protective performance*" or "Sterility maintenance" or
(sterilization adj2 maintenance) or (laundry adj2 efficacy) or (laundry adj2 efficiency) or
(infection adj2 risk*) or "healthcare-associated infection*" or (staff adj2 protection*) or
(healthcare professional* adj2 protection) or "cross-contamination*" or "healthcare
associated infection*" or "nosocomial infection*").ab,kf,ti. 128081

12 10 or 11 288996

13 Equipment reuse/ 3267

14 ((reusable adj2 mask*) or (sustainable adj2 mask*) or (eco friendly adj2 mask*) or
(eco-friendly adj2 mask*) or (washable adj2 mask*)).ab,kf,ti. 149

15 ((reusable adj2 gown*) or (sustainable adj2 gown*) or (eco friendly adj2 gown*)
or (washable adj2 gown*) or (reusable adj2 scrub*) or (sustainable adj2 scrub*) or (eco
friendly adj2 scrub*) or (washable adj2 scrub*) or (reusable adj2 surgical garment*) or
(sustainable adj2 surgical garment*) or (washable adj2 surgical garment*) or (reusable
adj2 surgical textile*) or (washable adj2 surgical textile*) or (sustainable adj2 surgical
textile*) or (eco friendly adj2 surgical textile*)).ab,kf,ti. 50

16 ((reusable adj2 glove*) or (sustainable adj2 glove*) or (eco friendly adj2 glove*) or (eco-friendly adj2 glove*) or (washable adj2 glove*)).ab,kf,ti. 17

17 ((reusable adj2 head cover*) or (sustainable adj2 head cover*) or (eco friendly adj2 head cover*) or (eco-friendly adj2 head cover*) or (washable adj2 head cover*) or (reusable adj2 shoe cover*) or (sustainable adj2 shoe cover*) or (eco friendly adj2 shoe cover*) or (eco-friendly adj2 shoe cover*) or (washable adj2 shoe cover*)).ab,kf,ti. 4

18 ((reusable adj2 face shield*) or (sustainable adj2 face shield*) or (eco friendly adj2 face shield*) or (eco-friendly adj2 face shield*) or (washable adj2 face shield*) or (reusable adj2 face protection*) or (sustainable adj2 face protection*) or (eco friendly adj2 face protection*) or (eco-friendly adj2 face protection*) or (washable adj2 face protection*)).ab,kf,ti. 3

19 ((reusable adj2 goggle*) or (sustainable adj2 goggle*) or (eco friendly adj2 goggle*) or (eco-friendly adj2 goggle*) or (washable adj2 goggle*) or (reusable adj2 eye protection*) or (sustainable adj2 eye protection*) or (eco friendly adj2 eye protection*) or (eco-friendly adj2 eye protection*) or (washable adj2 eye protection*)).ab,kf,ti. 1

20 ((reusable adj2 respirator*) or (sustainable adj2 respirator*) or (eco friendly adj2 respirator*) or (eco-friendly adj2 respirator*) or (washable adj2 respirator*)).ab,kf,ti. 50

21 ((reusable adj2 protective equipment*) or (sustainable adj2 protective equipment*) or (eco friendly adj2 protective equipment*) or (eco-friendly adj2 protective equipment*) or (washable adj2 protective equipment*) or (reusable adj2 PPE) or (sustainable adj2 PPE) or (eco friendly adj2 PPE) or (eco-friendly adj2 PPE) or (washable adj2 PPE) or (protective equipment* adj2 recycling) or (protective equipment* adj2 reusability) or (protective equipment* adj2 reuse)).ab,kf,ti. 37

22 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 3515

23 ((supply chain* adj2 impact*) or (supply chain* adj2 effect*) or (supply network* adj2 impact*) or (supply network* adj2 effect*) or (retail chain* adj2 impact*) or (retail chain* adj2 effect*) or (distribution chain* adj2 impact*) or (distribution chain* adj2 effect*) or (supply channel* adj2 impact*) or (supply channel* adj2 effect*)).ab,kf,ti. 259

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Appendix 2: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	4-6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	6-7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	3
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	8-9
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	9-10
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix 1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	8-11
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	11-12
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Not applicable
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	12
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	n/a
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	n/a
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	n/a
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	n/a
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	n/a
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	n/a
Limitations	20	Discuss the limitations of the scoping review process.	n/a
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	n/a
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	n/a

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
 * Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
 † A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
 ‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
 § The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA ScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850).

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