

# A STUDY ON FACTORS CONTRIBUTING TO RESTERILIZATION AND ITS COST ANALYSIS IN A TERTIARY CARE HOSPITAL IN GANGTOK

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## ABSTRACT

### Background

The Central Sterile Supply Department (CSSD) plays a vital role in hospitals by ensuring that surgical instruments and equipment are properly sterilized before use. Improper sterilization can cause infections, longer hospital stays, increased costs, and even threaten patient safety. Despite this, many hospitals struggle to consistently follow sterilization protocols. The CSSD works closely with the Infection Control Committee to monitor quality using various indicators. Since sterilization is a significant expense, understanding the costs especially those related to re-sterilization can help reduce waste, save money, and improve hospital efficiency. This helps hospital leaders make better decisions to protect patients and optimize resources.

### Objective

This study aims to identify the reasons behind re-sterilization of medical items and assess its cost impact at a tertiary care hospital in Sikkim. It focuses on the types of items sterilized, frequency of sterilization and re-sterilization, causes of sterilization failures, and the financial burden of repeated sterilization.

### Methods

An observational study was conducted at Central Referral Hospital, Gangtok, over four months, with data collected from March 17 to May 17, 2025. It included all medical and surgical items processed in the CSSD, excluding single-use and damaged instruments. Data collection used a checklist and cost sheet after necessary approvals. Analysis involved organizing data in Excel and using descriptive statistics, mainly mean costs.

### Results

Over two months, most re-sterilized items came from Operation Theatres, followed by Emergency, ICU, Labour Rooms, and wards. Specialized departments contributed fewer but specific instruments. Daily re-sterilization averages were highest in mid-March (21 items/day), dropped in April (11/day), and slightly rose in May (12/day), likely due to expired sterility and improved inventory management. The main cause of re-sterilization (98.7%) was items returned after sterility expiry, indicating inventory and scheduling issues. Smaller causes included items opened for academic use (0.1%) and staff verification (1.2%). This shows re-sterilization is mostly due to user practices rather than sterilization process failures, highlighting the need for better coordination and training. The total re-sterilization cost was ₹2,84,344 over two months. Fixed costs (infrastructure and equipment depreciation) accounted for 55.87%, while variable costs (manpower, consumables, utilities) were 44.13%. Equipment depreciation was the largest cost (49.39%), followed by manpower (34.07%). The study stresses the importance of staff training, adherence to protocols, and regular audits to reduce re-sterilization and control costs.

## Keywords

Central Sterile Supply Department (CSSD), Sterilization, Re-sterilization, Inventory management, Sterility expiry, Cost analysis, Equipment depreciation, Manpower cost.

## Introduction

The Central Sterile Supply Department (CSSD) is responsible for delivering sterile tools and equipment to critical areas like operating rooms (CDC, 1998). Failures in sterilization can lead to hospital-acquired infections (HAIs), prolonged hospital stays, antibiotic overuse, higher costs, and increased morbidity and mortality (Tabish et al., 1994; Babcock et al., 2003). Despite the importance of proper sterilization, many facilities struggle with consistent adherence to standards, leading to infection outbreaks (Basu et al., 2017).

Working with the Infection Control Committee, the CSSD enforces sterilization standards vital for infection prevention and patient safety (Babcock et al., 2003; WHO, 2016). Its effectiveness is evaluated using key quality indicators, including equipment condition, structural compliance, and procedural adherence (Donabedian, 1983). Verification of microbial inactivation relies on mechanical, chemical, and biological indicators (Kumar et al., 2018).

Understanding and managing CSSD costs allow hospitals to optimize spending, improve efficiency, and maintain high-quality sterilization services within financial constraints (Shepard et al., 2000). Strengthening cost control also supports sustainability by reducing waste and conserving resources, enabling evidence-based decisions that balance infection control, resource use, and financial stability (Basu et al., 2018).

## Methodology

This observational study, conducted at a tertiary care hospital in Gangtok, examined factors influencing the re-sterilization of medical equipment and assessed related costs. Data collection spanned two months (March 17–May 17, 2025) within a four-month study period. The study focused on all medical and surgical supplies processed by the Central Sterile Supply Department (CSSD) of the Central Referral Hospital, Gangtok, Sikkim. Only equipment that underwent re-sterilization during the study was included, while single-use, disposable, or irreparably damaged items were excluded.

Ethical approval was obtained from the SMIMS Departmental Research Committee, the Medical Superintendent of the Central Referral Hospital, and the SMIMS Chief Operating Officer. Data were gathered using a validated cost sheet and a self-structured checklist reviewed during departmental assessment. Descriptive statistics were applied for analysis, with cost data organized and tabulated in Excel. Mean values were calculated to summarize financial impacts and key trends associated with equipment re-sterilization in the hospital setting.

## Results and Findings

### Findings on Items Received from Different Hospital Departments

Data from the Central Sterile Supply Department (CSSD) over two months were analyzed to identify departments most frequently contributing to re-sterilization and to assess workload distribution across hospital units. The CSSD handled diverse instruments from operation theatres, ICUs, labour rooms, and wards. Operation Theatres were the main contributors, particularly OT Level 4 (187 items) and General OT (57 items), reflecting high surgical activity. Emergency and intensive care units submitted numerous critical sets such as Dressing, Central Line, and ICD Sets.

Labour Rooms and Obstetrics HDU provided delivery kits and trays, while wards mainly sent routine care instruments like Dressing and Catheter Sets. Specialized units like Orthopaedics, ENT, and Dialysis submitted fewer but specific tools, including Bone, ENT, and Dialysis sets. Occasionally, specialty items such as Craniotomy, Neurosurgical, and Urology kits were processed, indicating specialized procedures. The study also compared consumables used for steam (autoclaving) and ethylene oxide (ETO) sterilization, detailed in a comparative table.



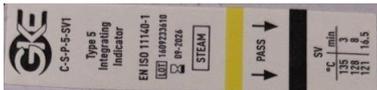
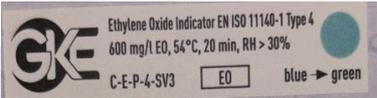
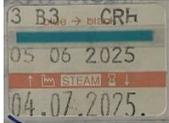
Steam Sterilization Consumables	ETO Sterilization Consumables
<p>1. Class 5 integrator indicator:</p> <p>This indicator is used for OT items and sets to ensure sterilization parameters (time, temperature, and steam penetration) have been met.</p> 	<p>Class 4 integrator indicator:</p> <p>This indicator is used for every item and set to ensure sterilization parameters</p> 
<p>2. 3 Line for Steam:</p> <p>This indicator is for every single/set instrument</p> 	<p>3 Line for ETO:</p> <p>This indicator is used for every single/set instrument</p> 
<p>3. Batch Monitoring Steam indicator for Steam:</p> <p>This is used for each batch</p> 	<p>Batch Monitoring Steam Indicator for ETO:</p> 
<p>4. Bowie-Dick test</p> 	<p>No Bowie-Dick test</p>
<p>5. Biological Indicator for Steam</p> 	<p>Biological Indicator for ETO</p> 
<p>6. Masking Tape for Steam</p> 	<p>Masking Tape for ETO</p> 
<p>7. No Gas used</p>	<p>Cartridge Gas</p> 

Table : Per-Sterile Cycle Consumables Used for Steam and ETO Sterilization

## Findings on the Frequency of Sterilization and Re-Sterilization

Given the limitations of the available data, this study concentrated exclusively on items subjected to re-sterilization between mid-March and mid-May 2025. Consequently, the research objective was refined to focus on analyzing the frequency of re-sterilization within this defined period. Monthly data on the number of reprocessed items were systematically collected and analyzed to identify temporal trends and to assess the workload associated with re-sterilization in the Central Sterile Supply Department (CSSD) during the study timeframe.

### ➤ Monthly Distribution of Re-Sterilization

Period	Days Covered	Total Items	Average Re-sterilizations/Day
Mid-March 2025	15 days	316	21/day
April 2025	30 days	322	11/day
Mid-May 2025	17 days	203	12/day

Table : Monthly Distribution of Re-sterilization in CSSD

### Trend Analysis of Re-Sterilization Frequency

To assess re-sterilization trends, data were normalized by calculating average daily re-sterilization rates to account for unequal collection periods. In mid-March 2025 (15 days), the rate averaged 21 items per day; in April (30 days), it decreased to 11; and in mid-May (17 days), it rose slightly to 12 per day. The peak in March likely reflected more items returned due to expired sterility, while lower, steadier rates in April and May suggested better inventory control and stock rotation. Normalization enabled accurate comparison across periods, revealing temporal variations in the CSSD's re-sterilization workload.

### Findings on Factors Contributing to Re-Sterilization

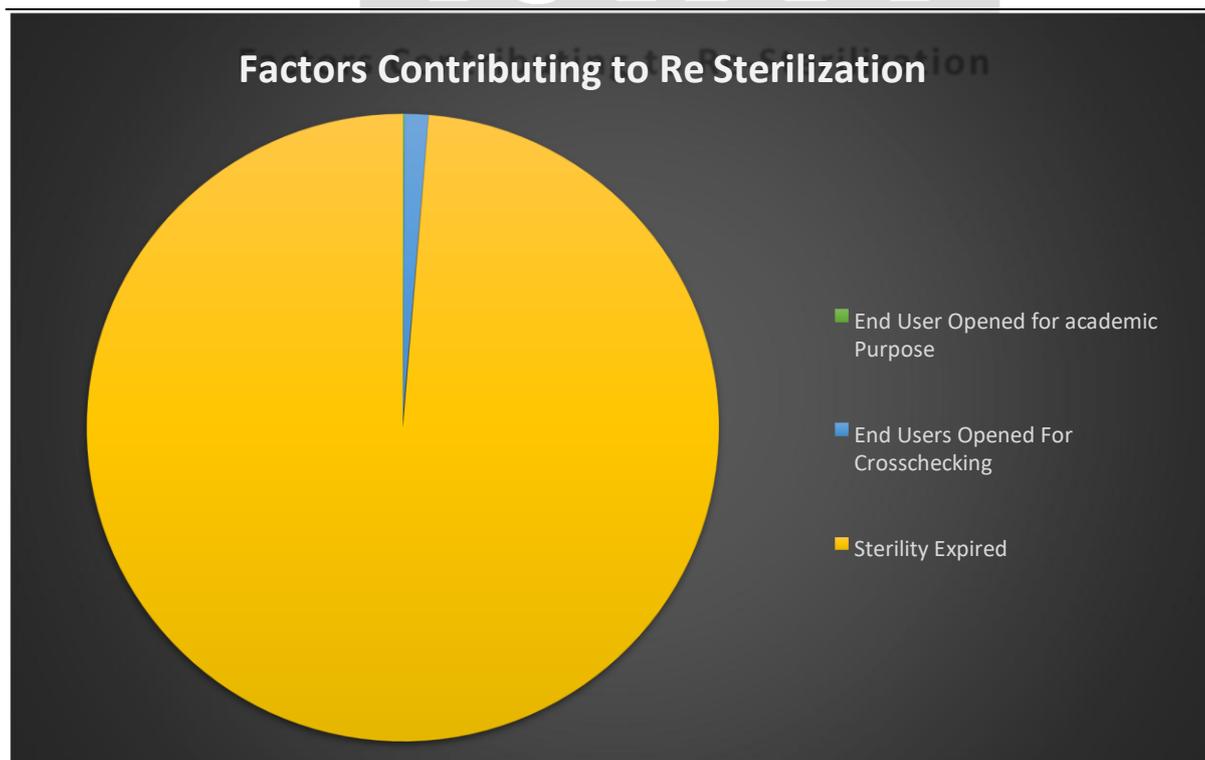


Figure : Distribution of Contributing Factors Leading to Re-Sterilization

The study found that most re-sterilization cases were due to expired sterility, items opened for academic use, and items reopened for verification. Nearly all cases (98.7%) resulted from expired sterility, indicating lapses in inventory control, scheduling, or demand forecasting. A smaller portion (1.2%) involved items reopened

to check sterility, suggesting labelling or assurance concerns, while 0.1% were opened for teaching purposes. Overall, re-sterilization primarily stemmed from post-sterilization handling rather than process failures, emphasizing the need for better staff awareness, inventory management, and stronger coordination between CSSD and user departments to minimize waste and unnecessary reprocessing.

## Findings related to the cost incurred due to the Re-Sterilization

Once the frequency and causes of re-sterilization were established, it became essential to assess the financial impact of these occurrences. Evaluating the associated costs not only reveals the considerable strain placed on hospital resources but also emphasizes the critical need for intervention. The following section provides a detailed examination of both the direct and indirect costs linked to re-sterilization, highlighting the pressing need for effective corrective measures.

Cost Heads	Total Resterile Cost (₹)	Mean of each Cost Head	% Share of Total	Cost Type
Manpower Cost	96,878	8,807	34.07%	Variable Cost
Consumable Cost	22,022	469	7.74%	Variable Cost
Utility Cost	6,575	664	2.31%	Variable Cost
Building Cost	5,694	5,694	2.00%	Fixed Cost
Depreciation	1,40,425	3,79,274	49.39%	Fixed Cost
Repair & Maintenance	12,749	1,778	4.48%	Fixed Cost
<b>Total</b>	<b>2,84,344</b>		<b>100%</b>	

### Cost Estimation Methodology

To assess the financial impact of re-sterilization, costs were estimated using hospital data and staff inputs. Total costs were divided into **variable** (workload-dependent) and **fixed** (constant) components.

#### 1. Manpower Cost (Variable)

Included salaries of CSSD staff involved in re-sterilization, calculated based on time spent during the study. Total manpower cost: ₹96,878, varying with workload.

#### 2. Consumable Cost (Variable)

Based on store records and invoices, consumables were grouped as per-cycle (e.g., indicators, pouches) and general (e.g., PPE, cleaning agents). Steam and ETO sterilization required specific materials. Total consumable cost: ₹22,022 (₹3,680 per-cycle; ₹18,342 general).

### 3. Utility Cost (Variable)

Covered electricity and water use. Autoclave No. 3 had the highest energy consumption (~₹3,000). Total utility cost: ₹6,575 (electricity ₹6,556; water ₹19).

### 4. Building Depreciation Cost (Fixed)

Depreciation of 4,876 sq. ft. CSSD area valued at ₹30.77 lakh was calculated over 25 years. For two months, re-sterilization share (0.28) equaled ₹5,694.

### 5. Equipment Depreciation Cost (Fixed)

Depreciation of key equipment (autoclaves, ETO sterilizer, cleaner, etc.) was estimated using the straight-line method over 10 years. Older units were fully depreciated; newer ones retained value.

### 6. Repair & Maintenance Cost (Fixed)

Maintenance expenses were proportionally calculated for two months and adjusted for re-sterilization share. Total: ₹12,447.

### Summary of Costs

Total re-sterilization cost (two months): ₹2,84,344

- **Fixed costs:** ₹1,58,868 (55.87%)
- **Variable costs:** ₹1,25,475 (44.13%)

Fixed (infrastructure) costs formed the largest share, emphasizing the need for efficient cost control and workload management.

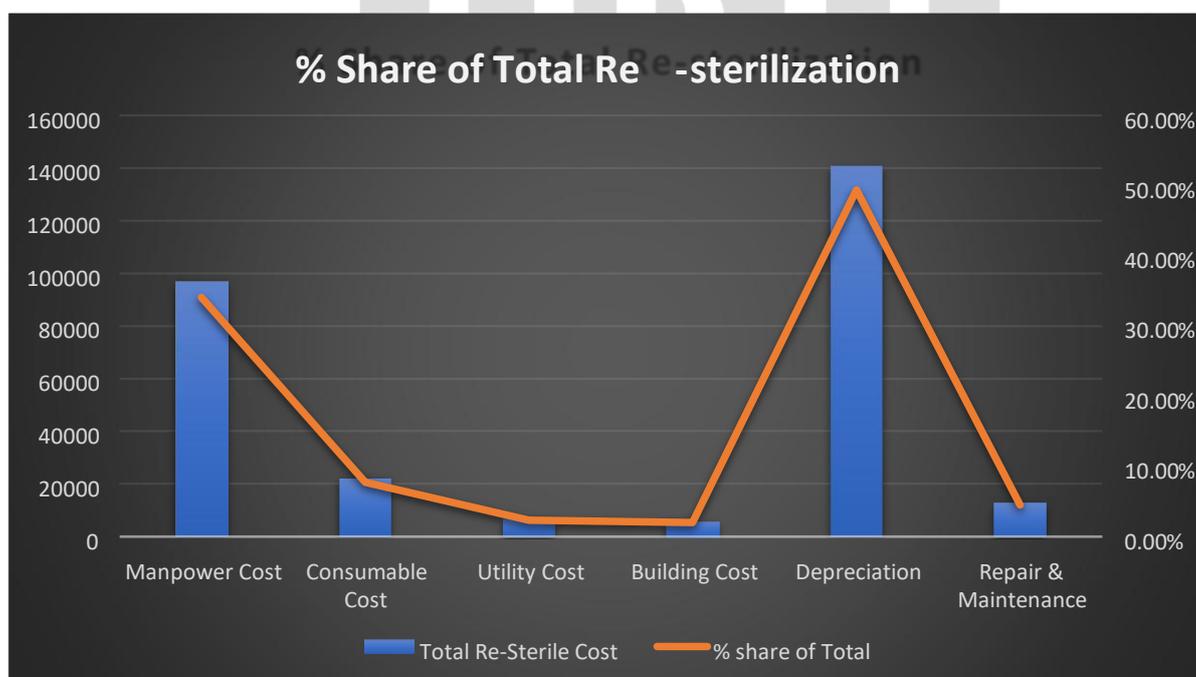


Figure: Percentage Share of Each Cost Component in Total Re-Sterilization Cost

As shown in the figure, **equipment depreciation** was the largest cost component (49.39%), followed by **manpower expenses** (34.07%), indicating significant machinery wear and additional staff effort during reprocessing. **Consumables** contributed 7.74%, while **utilities** (2.31%), **building depreciation** (2.00%), and **maintenance** (4.48%) made up smaller portions. These findings underscore the importance of minimizing re-sterilization through enhanced staff training, strict adherence to protocols, and regular performance audits.

## Description of descriptive statistics through mean value of each cost head

### Descriptive Cost Analysis of Re-Sterilization

Descriptive statistics, mainly **mean values**, were used to summarize re-sterilization costs. Microsoft Excel was employed to analyze manpower, consumables, utilities, depreciation, and maintenance. Mean values indicated average expenditures per cost category, while ranges highlighted variability, identifying areas for potential cost control.

The **average cost per re-sterilization event** was:

- **Manpower:** ₹8,807, representing a major labor-related expense.
- **Consumables:** ₹469 per cycle
- **Utilities (electricity and water):** ₹664 per cycle.
- **Fixed costs:** Building depreciation averaged ₹5,694, and equipment depreciation contributed ₹3,79,274 over the study period.

These results emphasize the financial impact of each cost component and provide insights for budgeting, operational planning, and targeted cost-control strategies.

### DISCUSSION

The data revealed that the highest frequency of re-sterilization occurred in departments such as the General Operation Theatre (OT), Surgical Intensive Care Unit (SICU), Medical Intensive Care Unit (MICU), and the Labour Room. These units manage a high volume of emergency and critical cases, leading to increased use of sterile supplies. Consequently, there is a greater likelihood of items becoming contaminated, damaged, or remaining unused beyond their sterile period. (Alfred et al. 2021) similarly observed that busy departments tend to experience higher rates of re-sterilization due to rapid activity and frequent use of complex instruments.

The study further identified the primary causes of re-sterilization as damage to packaging, contamination during handling, and expiry of sterility validity. These issues largely resulted from lapses in packaging practices and inconsistent adherence to standard operating procedures. (Panta et al. 2020) also reported significant deficiencies in sterilization protocol compliance, especially regarding wrapping and handling techniques. Additionally, challenges such as inadequate staff training, poor interdepartmental coordination, and insufficient supervision were found to contribute to increased CSSD workload, potentially compromising patient safety if left unaddressed.

Re-sterilization was shown to impose a substantial financial burden on the hospital's operating costs. Key expense areas included labor (₹96,878.28), utilities (electricity and water), equipment depreciation, space utilization, and maintenance contracts. Labor costs were the most significant, reflecting the extensive time CSSD staff devote to repeated handling and documentation processes. This finding aligns with (Jain et al. 2023), who highlighted labor as the largest component of reprocessing expenses due to the time-intensive nature of sterilization and quality assurance tasks.

Moreover, although older equipment such as autoclaves and ethylene oxide (ETO) sterilizers were fully depreciated, their maintenance costs continued to contribute to overall expenses. Conversely, newly acquired equipment incurred fresh depreciation charges despite offering improved efficiency. These results illustrate how re-sterilization affects both immediate operational costs and long-term financial planning.

Ensuring effective communication between the CSSD and user departments is critical to facilitate the timely use of sterilized items before their sterility expires. Regular staff training, combined with surprise inspections and routine audits, can significantly reduce errors such as contamination or improper handling. According to (da Cruz et al. 2021), the implementation of standardized protocols including checklists and regular performance evaluations substantially decreased re-sterilization incidents, thereby enhancing resource management and patient safety.

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