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Abstract

The document presents the first version of "Green Lean Six Sigma Methodology" (GLSS-HC) for hospitals and an example of its application on the *Cholecystectomy patient journey* at FPG.

The methodology integrates the principles of Lean Six Sigma (LSS) structure with an environmental perspective, addressing the specificities of the healthcare (HC) context.

The GLSS-HC methodology is based on six key pillars which are: focus on the Clinical Pathway, focus on the Clinical Work Areas (CWAs) and the resources that they use, adoption of the LSS five stages (Define Measure, Analyse, Improve, Control), adoption of a sub-set of the LSS tools acceptable in the HC context, contextualization of the tools to the healthcare and green distinctive elements, performance assessed against the Quadruple Aims indicators and the Environmental impacts.

18 CWAs (e.g. Operating Room, Laboratory, Intensive Care Unit) have been identified to cover most of the typical clinical pathways of a hospital.

The methodology provides indications of how the use of each tool can be contextualized to capture the distinctive elements. This is facilitated by providing 12 artifacts (definitions, check lists, examples) to be used when using the tools. Many of these artifacts provide examples for each of the 18 CWAs (e.g. the types of waste, type of medical technology).

The methodology has been applied in Italy at Policlinico Gemelli hospital, to identify the most relevant CWAs belonging to the Cholecystectomy patient journey, the Operating Room and the Laboratory. The DMAIC stages have then been performed using the LSS tools for the Operating Room. The document provides the results obtained by applying the tools.

The methodology will be finetuned by M32 of the project, integrating information provided by other two use cases in Spain and Germany which will act as validators of the solution. In addition, further information from Gemelli hospital and other Caring Nature Stakeholders will be collected.

The operational uses of the GLSS-HC methodology include analysing clinical pathways to identify priority areas for improvement, supporting DMAIC execution at CWA level, auditing clinical pathways, evaluating investments, setting new performance targets, and comparing similar CWAs. At a strategic level, the methodology provides a knowledge-sharing framework and an analytical basis for assessing and improving the environmental impact of hospitals

Keywords

Lean Six Sigma, Green Healthcare, Quadruple aim, Clinical Pathway

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Acronyms

Acronym	Description
7HRC	7th Health Region Crete
CE	Clinical Episode
CP	Clinical Pathway or Critical Pathway
CSRD	Corporate Sustainability Reporting Directive
CWA	Clinical Work Area
DMAIC	Define Measure Analyse Improve Control
DRG	Disease Related Group
ED	Emergency Department
FHAG	Fundaciòn Privada Hospital Asil Degranollers/ Asil De Granollers Hospital Private Foundation
FPG	Fondazione Policlinico Universitario A. Gemelli IRCCS/ A. Gemelli University Hospital Foundation IRCCS
FU	Functional Unit
GDPR	General Data Protection Regulation
GLSS-HC	Green Lean Six Sigma for Healthcare
HC	Healthcare
HCO	Healthcare Organization
HVAC	Heating, Ventilation and Air Conditioning
ICU	Intensive Care Unit
IDC	International Classification of Diseases, Injuries and Causes of Death
KPI	Key Performance Indicator
LSS	Lean Six Sigma
NICU	Neonatal Intensive Care Unit
OR	Operating Room
PCD	Project Context Diagram
PDPC	Process Decision Program Chart
PREMs	Patient-Reported Experience Measures
PROMs	Patient-Reported Outcome Measures
RINA	RINA Consulting
SIPOC	Suppliers, Inputs, Process, Outputs, and Customers
SOP	Standard Operation Procedures
UKHD	Universitätsklinikum Heidelberg/Heidelberg University Hospital
WA	Work Area
WHO	World Health Organization
WPH	Päijät-Hämeen hyvinvointialue/Wellbeing services county of Päijät-Häme)



Executive summary

Scope. This document one of the two milestones of Task 4.3 and presents the first version of the "Green Lean Six Sigma Methodology" (GLSS-HC) for hospitals, with an example of application on the *Cholecystectomy patient journey* at FPG. This document present all the work conducted up to M18 of the project (i.e.: June 2025). The methodology integrates Lean Six Sigma (LSS) principles with an environmental perspective, addressing the specificities of the healthcare context.

Methodology to develop GLSS-HC. The methodology has been developed setting up a core team of experts from RINA and FPG, including LSS experts, process design and management experts, and on-call specialists like waste managers and clinical managers. The methodology was developed through four key steps: framework definition, framework implementation, validation and finetuning. It integrates requirements from stakeholders and standards, such as ISO 14044: 2006 and ISO 7101:2023.

GLSS-HC methodology. The methodology is focused on the clinical activities performed by a hospital, considering that for other types of activities (e.g. administrative, technical) the standard LSS methodology can be applied.

The analysis of the literature has shown that,

- Even if examples of application of the standard LSS methodology to the HC context have been conducted, no systematic methodology that combines HC context and environmental ("green") perspective has been done.
- Similarly, examples of green LSS are present in literature, but never plied to hospitals.
- The methodology proves to be particularly valuable as it incorporates specific features and terminology of the healthcare sector, includes performance indicators tailored to HC, and integrates knowledge from both the HC and green domains—thus reducing the initial exploration effort typically required when starting a process improvement project and helping to overcome the common barrier of limited time.

Interviews with the FPG clinical process expert allowed to identify some key HC-specific elements to be considered when describing and evaluating the clinical processes

The methodology is based on six key pillars:

- 1) **Clinical Pathway (CP) focus:** the analysis is centred on Clinical Pathway and Clinical Work Areas (CWAs)
- 2) **Clinical Work Area (CWA) and Resources:** suitable CWAs, such as Operating Room, Laboratory and Intensive Care Unit have been identified, with specific profiles in terms of resources (people, equipment, materials, energy). CWAs have been the basis for developing a GLSS approach that can be used across different hospitals and different CPs considering the typical resources consumed by each type of CWA
- 3) **DMAIC Stages:** Adoption of the LLS stages, i.e. Define, Measure, Analyse, Improve, and Control (DMAIC), for analysing and improving the processes
- 4) **Selected LSS Tool:** For each DMAIC stage, a subset of the LSS tools is proposed. One tool is added to allow the environmental impact calculations.
- 5) **Distinctive HC and Green elements:** Some tools are pre-contextualized to the healthcare and green distinctive elements
- 6) **Quadruple Aim+1:** The process performance evaluation is based on well-established HC metrics from the quadruple aim perspective: enhancing patient experience, improving population health, reducing costs, improving work life of healthcare providers, enriched with the assessment of the environmental impact, along 14 dimensions.

At the core of the methodology there are:



- **24 tools (23 from LSS + 1) to be used in the DMAIC stages**
- **Specificity**, since the methodology is both:
 - **Healthcare-Specific:** Clinical Pathways, International Classification of Diseases (ICD) codes, Clinical Work Areas, Disease Related Groups (DRG), natural variations, hospital reporting systems, health roles, patient involvement, medical technologies, Quadruple Aim KPIs, healthcare innovation trends.
 - **Green-Specific:** Waste and environmental impact factors, energy and waste management information systems, Corporate Sustainability Reporting Directive (CSRD) reporting, green roles, environmental KPIs, green solutions.
- **A matrix that shows which distinctive elements** are taken into account to contextualize the tools to the HC context and the Green improvement
- **A list of 18 CWAs** that capture the variety of work areas in a generic hospital
- **A set of 12 artifacts (drafted so far):** The contextualization of the LSS methodology is implemented associating the healthcare and green distinctive elements to the LSS tools through a set of artifacts. The artifacts are checklists, definitions, and examples to be used with the tools. When the tool is used, the distinctive elements is taken into consideration. For instance, when performing the root causes analysis, the GLSS-HC offers cause-effect diagrams including hints for each type of cause (man, machine, method, material, work context) for each of the 4+1 aims; and for each CWA. This can speed the search of the root causes, diminish the risk of overlooking important aspects, trigger meaningful conversation with the involved staff. The majority of the artifacts provide examples for each of the 18 CWAs (e.g. the types of waste, type of medical technology).

Possible use of the GLSS-HC. The primary operational uses of the GLSS-HC methodology include analysing clinical pathways to identify priority areas for improvement, supporting DMAIC execution at CWA level, auditing clinical pathways, evaluating investments, setting new performance targets, and comparing similar CWAs.

At a strategic level, the methodology provides a knowledge-sharing framework and an analytical basis for assessing and improving the environmental impact of hospitals.

GLSS-HC Application: The methodology has first been applied to identify the most relevant clinical working areas belonging to the *Cholecystectomy patient journey*, the Operating Room and the Laboratory.

The DMAIC stages have been performed using the LSS tools for the Operating Room. The document provides the results obtained applying the tools.

Final considerations: The GLSS-HC methodology complies with the requirements and the key standards indicated in *D2.1- Report on requirement definition*.

The methodology will be finetuned by M32 of the project, based on the completion of the FPG use case and on the application in other two use cases in other two Healthcare organizations (FHAG and UKHD).

The finetuning will also leverage the healthcare expertise of all the 5 HCOs partnering CARING NATURE (FPG, FHAG, UKHAD, WPH, 7HRC). A survey involving the Reference Stakeholder Group will also be launched to get their feedback.

The GLSS-HC can contribute to the CARING NATURE Knowledge Sharing System, under development in Task 3.1, providing a framework to capture knowledge about methods and for reducing the environmental impact of the HCOs.



1 Introduction

The document is the intermediate output (at M18) of the *Task 4.3-Green Lean Six Sigma methodology for health and care*, that has the purpose to develop and test GLSS-HC, i.e. an integrated methodology for performing process reengineering in health care domain integrating in the Lean Six Sigma (LSS) the greening perspective and the specificities of the healthcare organizational context (GLSS-HC).

The document is structured in three main parts:

- The methodology for developing the GLSS-HC methodology (Section 2)
- The justification and ambition of the GLSS-HC methodology, its components and its possible uses (Section 3)
- The presentation of the initial application of the GLSS-HC to the *Cholecystectomy patient journey* at FPG, with a focus on the waste management process in the Operating room (Section 4).

2 Methodology

2.1 Development steps

The GLSS-HC methodology has been developed following these steps:

- Setting up a core team including LSS experts from RINA and process design/management experts from FPG (Quality Assurance, Clinical Pathways designers and auditors) and involving call experts (Waste Manager, Data Manager, Clinical Managers)
- Going through four steps, described in Table 1 in terms of sources, methods and results.

Table 1 - Development steps of the GLSS-HC methodology

Step	Key sources	Methods	Results
Framework definition	<ul style="list-style-type: none"> • Deliverable D2.1 • Literature • PMI LSS body of knowledge 	<ul style="list-style-type: none"> • Analysis of the requirements collected from the Reference Stakeholder Group • Literature review • Analysis of LSS methodology • FPG-RINA brainstorming to define the framework 	<ul style="list-style-type: none"> • Limitations of the available approaches • GLSS-HC framework (Pillars, Distinctive elements, Tools short list)
Framework implementation	<ul style="list-style-type: none"> • Literature • FPG instructions on Clinical Pathway drafting and auditing • FPG performance control reports • <i>Deliverables D2.1, D3.1</i> 	<ul style="list-style-type: none"> • Analysis of the LSS tools, FPG practice, and literature to identify relevant categories of process analysis • Use of Generative AI (ChatGPT) to find HC-relevant content (examples, definitions) to be inserted in the artifacts • Extraction from D2.1 and D3.1 of content usable in the GLSS-HC 	<ul style="list-style-type: none"> • List of Clinical Work Areas • Artifacts (check lists, definitions) • Indications on how to contextualize the LSS tools
Validation and finetuning	<ul style="list-style-type: none"> • FPG use case 	<ul style="list-style-type: none"> • Validation of the ChatGPT product through interviews with FPG 	<ul style="list-style-type: none"> • Finetuned framework and artifacts



		clinical experts + core team experts evaluation <ul style="list-style-type: none"> • First results/lessons learned from the application of GLSS-HC to the FPG use case 	
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2.2 References

1) Requirements from *D2.1- Report on requirement definition*

- Make sure that GLSS-HC methodology is well integrated with the methodologies developed in WP3 and described in D3.1- *Model of the knowledge sharing and decision support system-v1*
- Include the Patient-Reported Experience Measures (PREMs) and Patient-Reported Outcome Measures (PROMs) in the set of KPIs to assess the process performance.
- Define HC-specific methods to engage operators in the business process reengineering activities
- Leverage the already available information not only from administrative systems but also from healthcare-specific and energy/facility management systems

2) Standards from *D2.1- Report on requirement definition*

- ISO 14044: 2006 - Environmental management – Life Cycle Assessment – Requirements and guidelines (as part of ISO 14001)
- ISO 7101:2023 - Healthcare organization management — Management systems for quality in healthcare organizations — Requirements

3) Literature

A literature review have been conducted through sources like Scopus, PubMed, Web of Science, Google Scholar, Consensus, SCISPACE, using as keyword a combination AND/OR “Lean Six Sigma”, “Green”, “Healthcare”, “Clinical Pathway”

4) Use of ChatGPT

The list of the Clinical Work Areas in Table 6 and portions of the content of Annex B were generated with the assistance of *ChatGPT 4o* and were subsequently reviewed and revised by the authors with the support of domain experts to ensure accuracy and appropriateness.

3 The GLSS-HC methodology

3.1 Purpose and scope

The GLSS-HC is a methodology for performing process reengineering in health care domain, integrating the green perspective (environmental impact reduction) and the specificities of the healthcare organizational context in the Lean Six Sigma (thus the acronym: GLSS-HC).

The methodology is focused on the clinical activities performed by a hospital, considering that for the other types of activities (e.g. administrative, technical) the standard LSS methodology can be applied.

3.2 LSS methodology

Lean Six Sigma (LSS) is a process (*Delleci Y., 2023*) improvement methodology that:



- Is focused on eliminating waste, reducing variation and improving quality of the process.
- Combines two improvement programs: Lean management and Six Sigma.
 - Lean is about increasing the customer value through reducing the non-value-adding activities (waste) that are generated along the process. Lean is focused on efficiency by improving process flow and reducing waste
 - Six Sigma is a structured and systematic approach to process improvement, aiming for a reduced defect rate (quality of the output). Six Sigma is focused on effectiveness by reducing defects and errors
- Is applicable to any business process—manufacturing, IT development, customer service, administrative, and so on, because every business suffers from the three profit/performance demons: delay (the idle time between steps in a business process—the waiting time), defects (mistakes that render a product or service unacceptable to the customers), and deviations (differences from piece to piece, day to day, month to month of your products and services).

The LSS improvement concepts (reduce delay, defects and deviations) are put in practice through an improvement process articulated in the five stages of the DMAIC cycle (*Alkinaidri A et al., 2018*):

- **Define:** “What is most vital to the business?” This includes defining what the problems are, including customers’ needs and demands, that are mandatory to explore to determine requirements for the improvement
- **Measure:** “How are we progressing with the present process?” This involves assessing the process to be applied—data needs to be collected and then compared to the predicted state
- **Analyse:** “Identify what could be wrong with the present process” This includes analysing data in order to determine what the major causes of the issues could be
- **Improve:** “What could be possibly applied to improve the process?” Here, the team initiates brainstorming to develop ideas to solve the problems and identify different variations in that process. The results at this point are then analysed to determine whether the problems have been resolved or not. Further alterations are required if problems still persist
- **Control:** “How could performance be guaranteed in order to sustain improvements over time?” This means that the progress should be sustained so that no unanticipated or unwanted changes could occur. The process then should operate at the desired level of performance to make sure that the problem never re-exist.

Each stage is executed using tools. A list of tools¹ is shown in Table 2 (the tools with * are included in the GLSS-HC methodology)

Table 2 - LSS DMAIC process phases and tools

	Stages				
	Define	Measure	Analyse	Improve	Control

¹ The list shown in the table is the one proposed by the Process Management International (PMI) in its LSS training and used by RINA Consulting in its advisory services. No official list of LSS tools exist. In the literature, when the tools are listed, their number is variable. For instance, (*George M. L., 2003*) at page 274 lists 69 tools, while (*Ferreira D. et al., 2022*) list 37 tools, with some of them not included in the (*George M. L., 2003*) list. (*Uluskan, M., 2017*) analysed 68 tools and, based on survey with 106 respondents who are Six Sigma team leaders and practitioners, found that the most frequently used LSS tools are Pareto histograms, brainstorming, process flow maps, supplier–input–process–output–customer (SIPOC), control charts, plan-do-check-act and Ishikawa diagram.



Tools					
	<ul style="list-style-type: none"> • Project Context Diagram (PCD)* • Charter • Team Contract* • SIPOC* • Linear* Chart • Integrated* flowchart 	<ul style="list-style-type: none"> • 8 Waste* • Kanon Model* • T- Matrix* • Data Collection* • Individual and moving Control Chart* • Capability Analysis* • Histogram • VSM 	<ul style="list-style-type: none"> • Cause-Effect Diagram* • Scatter Diagram* • Pareto Diagram* • MUDA • MURI • Takt 	<ul style="list-style-type: none"> • Idea* Generation • T-Matrix • *Control Chart • Poka-yoke • *Integrated flowchart • *PDPC • Gantt Chart 	<ul style="list-style-type: none"> • 5S* • Visual Management* • Standardize* • Review*

The LSS methodology is industry-independent. In particular, it can be applied to the core processes that are specific of the different industries (see for instance *SSGI, 2025*).

However, some level of sectoral contextualization to the HC sector is desirable, because it can contribute to align the LSS projects to the critical success factors (CSFs) of the LSS projects. (*Sohal A. et al., 2022*) have identified 8 CSFs, driven by three key factors: i) active and visible leadership, ii) recognition of the complexity of health services projects (reflected in projects with involvement of the process owner, usually a clinicians), iii) clinicians view the project as relevant and valuable.

The second and third factors suggest the relevance of a methodology that incorporates specific HC features and “language” and performance indicators tailored on the HC sector.

Sijm-Eeken et al (2024) report the experience of 24 Dutch healthcare professionals in the first six to eight months after completing GLSS training. Even though 76% (N = 16) of trained healthcare professionals applied GLSS at their workplace and 43% of them (N = 9) completed a project within the first six to eight months after training, they all experienced one or more barriers. The most frequently reported barriers were lack of time, difficulties with project selection and a lack of management support.

The first two barriers suggest the relevance of a methodology that incorporates some knowledge of the HC and Green domain, thus reducing the “exploration” effort needed when starting a new DMAIC stage or start using a tool and facilitating the selection and scoping of the project to be implemented.

In the Healthcare the LSS important application areas include (*SSGI, 2025*):

- Patient care processes, such as medical diagnoses and treatment
- Supply chain management processes such as procurement and inventory management, e.g. of pharmaceutical products
- Revenue cycle management processes, such as billing and payment processing.

If we focus our attention to Hospitals and their “core business”, i.e. the patient care processes, for each one of the International Classification of Diseases (ICD) codes² the delivery model is quite standard across the different hospitals: it is regulated by clinical protocols, involves the same specialties, the potential wastes are the same, the applicable improvement interventions may refer to a similar catalogue.

² The International Classification of Diseases, Injuries and Causes of Death (ICD) is a standard for classifying diseases and related conditions, developed by the World Health Organization (WHO). The ICD has reached its tenth edition (ICD-10), after being approved by the 43rd World Health Assembly in May 1990 and having entered into force and into use in the WHO Member States in 1994.



This further suggests that the users of the LSS methodology would be highly facilitated if they could count on a methodology based on tools contextualized to the hospital context, including, e.g. ready to use checklists and/or variables to be assessed.

Some efforts have been done in that direction. For instance, Ali (2023) describes how LSS may be applied in the hospital setting to improve processes in patient-care services, providing examples of:

- Mapping tools: Value stream map, Value-added and non-value-added activities in a hypothetical healthcare facility, per type of work area (Emergency room, Laboratory, etc.) and per type of non-value-added activity (defects, overproduction, overprocessing, etc.)
- Analysis/Diagnostic tools: Root-Cause Analysis, A3 Process of Problem Solving, Total Productive Maintenance (TPM), Failure Modes and Effects Analysis (FMEA)
- Improvement tools: 5S (sort, store, shine, standardize, and sustain), Kanban, Just-in-time, Jidoka (autonomation), Poka-Yoke (fool proof mechanisms), Visual Management.

Also Ashmore and Ruthven (2015) offer examples of the different tools that can be used to perform Root-Cause Analysis in clinical audit.

An important contextualization feature would be a list of goals/motivations and key performance indicators specific to the clinical activities, that set the improvement direction along all the DMAIC stages.

According to McDermott (2022), in the healthcare organizations the motivations for applying LSS are related to the strategic goals of sustainability and competitiveness, improving operational performance and profitability.

While many of the motivations for deploying LSS are common to private and public healthcare organisations, there are differences between public and private healthcare providers. For example, motivations for private organisations are to increase their competitiveness by acting on cost and profitability elements. On the other hand, public providers are more motivated by the need to respond to the challenges related to the treatment at hand and reduce national expenditure on healthcare. Safety of patients, ensuring safe treatments, and preventing harm or illnesses is an overarching motivator.

Key expected benefits regard improvement of overall operational and financial performance, customer satisfaction and quality of service, reduction of waiting time of patients, cycle time, medical errors, turnaround time.

However, even if examples of application of the standard LSS methodology, no systematic methodology to be used in the HC context has been found and no systematic methodology to be used in the HC context AND aiming at “green” improvement has been found.

3.3 GLSS-HC components

3.3.1 Pillars of the GLSS-HC methodology

The GLSS-HC methodology aims to go beyond the limitations of the current available approaches by:

- Identifying a set of healthcare and/or green distinctive elements and embedding them into some of the standard LSS tools used in the DMAIC phases, e.g. check lists, KPIs, enrichment of the structure of the tools
- “Speaking” as much as possible the same language of those that in the healthcare organizations design, audit and improve the clinical processes
- Exploiting as much as possible the sources of data and management/technical reports that are typically already used in the hospitals



The **GLSS-HC methodology** is based on **six pillars** (Figure 1)

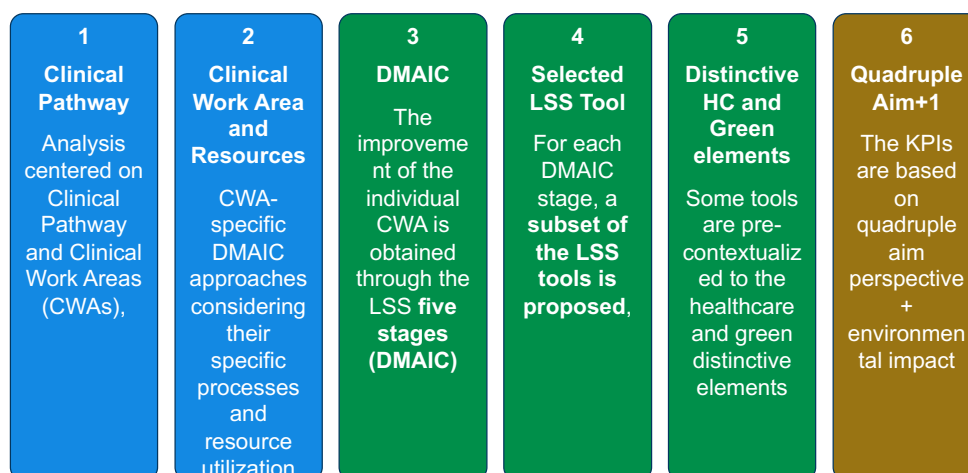


Figure 1 - The 6 Pillars of the GLSS-HC methodology

1) The GLSS-HC is a methodology for improving the performances of clinical processes

A clinical process is described as a **Clinical Pathway (CP)**, i.e. the journey of the patients³ affected by a disease through a series of **Clinical Work Areas (CWAs)**. A CWA may be involved in more than one CP (see Figure 2). Examples of CWAs⁴ are the Operating room, the Intensive Care Unit, the Laboratory.

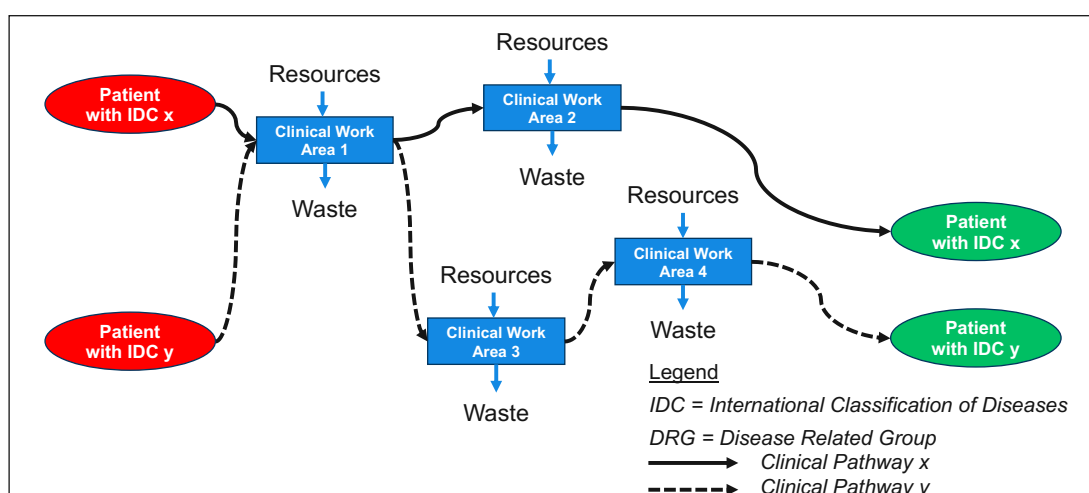


Figure 2 - Conceptual representation of the relationship between Clinical Pathways (CPs) and Clinical Work Areas (CWAs)

2) Each Clinical Work Area uses resources (people, equipment, materials, energy) and produces waste and environmental impact. The improvement of the CP is obtained improving the performances of the CWAs belonging to the CP. Given the limited number of different CWAs, the methodology aims to provide **CWA-specific GLSS approaches** that can be used across different hospitals and different CPs considering the typical resources consumed by each type of CWA.

It must be noted that the overall improvement of a CP must consider the relationships between CWAs. For instance, errors in tagging a vial in the general ward, implies the need to repeat the analysis in Laboratory; or a long waiting list in the Operating Room, may

³ Or of elements regarding the patient, e.g. the blood samples that go to the laboratory

⁴ So far (at M18 of the project) have been identified 17 types of CWAs, that cover the most part of the clinical activities of a hospital



require the repetition of blood/urine analysis done when preparing the patient for the surgical intervention.

- 3) The improvement of the individual CWA is obtained through the LSS **five stages (DMAIC)**
- 4) For each DMAIC stage, a **subset of the LSS tools is proposed**, considering the need of minimizing the use of the time by the staff to perform the analysis and the sources of data already available in the HCOs. A non-LSS tool is added to evaluate the environmental impact
- 5) Some tools are pre-contextualized to the healthcare context and to the green perspective.
- 6) The performances are assessed along **five dimensions**. Four of them are taken from the **quadruple aim approach (Bodenhimer T. et al., 2014)**: enhancing patient experience, improving population health, reducing costs and improving the work life of health care providers. The fifth one is about reducing the **environmental impact**

In Table 3 the **LSS tools** of the GLSS-HC methodology are listed for each of the five **DMAIC stages**, with the indication of which **distinctive elements** can be taken into account to contextualize the tool to the HC context and the Green improvement.

Table 3 - Distinctive elements and tools of the GLSS-HC methodology

DMAIC Stage	LSS tools	Distinctive elements																
		HC-specific elements											Green-specific elements					
		Clinical Pathway (CPE) Clinical Episode s (Ces)	International Classification of Disease s (ICD) codes	Clinical Work Area (CWA)	Disease Related Groups (DRG)	Natural variations	Hospital Reporting System	Health roles	Patient	Medical technologies	4-ple aim KPIs	HC innovation trends	Waste & other environmental impact factors	Energy & Waste Mgmt information systems	CSRD Reporting	Green roles	Environmental KPIs	Green solutions
Define	PCD	x	x	x						x			x					
	Charter	x	x	x							x						x	
	Team Contract									x							x	
	SIPOC	x		x				x	x	x	x		x				x	x
Measure	Integrated/Linear flowchart	x		x				x	x		x		x					
	8Waste			x														
	Kano Model																	
	T- Matrix																	
	Data Collection							x						x	x			
	Control Chart						x											
	Capability Analysis																	
Analyse	LCA calculator												x					
	Cause-Effect Diagram			x					x	x	x		x					
	Scatter Diagram																	
Improve	Pareto Diagram											x					x	
	Idea Generation			x									x					x
	T- Matrix																	
	Control Chart						x											
	PDP								x								x	
Control	LCA calculator												x					
	5S			x														x
	Standardize																	
	Visual Management																	
	Review								x	x		x					x	x

Following three sections it provide a short description of the tools, the description of the distinctive elements and how the distinctive elements contribute to contextualize the tools to the HC context and to the Green perspective.

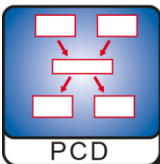



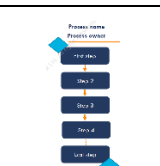
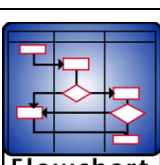
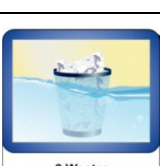
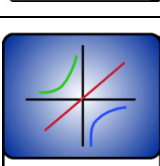
To be noted, a non-LSS tool (LCA calculator), in red in Table 3) is added to support the environmental impacts calculations in the Measure and Improve stages.






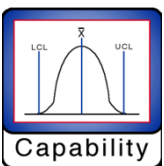

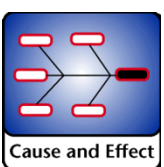
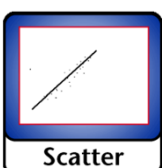
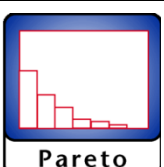

3.3.2 GLSS-HC tools

A short description of the tools is provided in Table 4



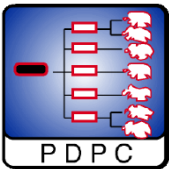



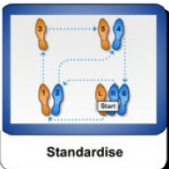

Table 4 - Short description of the GLSS-HC tools

Stage	Tool Name	Icon	Description
Define	Problem Context Diagram (PCD)		to highlight the potential causal processes of a problem within a system
	Charter		a document to initially define the focus for the improvement activity
	Team Contract		a document that outlines the rules, expectations, and agreements of a team working on a project
	SIPOC		a single page summary containing a high level view of the process, customers and suppliers, measures, current performance and initial theories on sources of waste & variation
	Linear Flowchart		a tool that describes the sequence of steps in a process. Helps to view the work steps and decisions needed to complete a process
	Integrated flowchart		a comprehensive visual representation of a process (Identifies process roles/functions, draws out the purpose of the process, Shows the major activities & their interactions, shows customer and supplier relationships, Identifies inputs and outputs, Leads to discussion of ownership.)
Measure	8 Waste		activities that consume resources without adding value to the final product or service (D efects, O ver-Production, W aiting, N on-utilized talent, T ransport, I nventory, M otion, E xcessive Processing)
	Kano Model		a model to help customer requirements and classify into three categories (expected, wanted, delight factors)



	T- Matrix	 Matrix	to prioritize the voice of the customer requirements
	Data Collection	 Data Collect	database that involves systematically gathering and measuring information on process variables to answer specific research questions, test hypotheses, or evaluate outcomes
	Control Chart	 Control chart	to detect signals of an assignable cause variation. Consistently learning from and then removing assignable causes leads to continual improvement
	Capability Analysis	 Capability	a method of assessing the level of confidence in the ability of the process to meet customer requirements as expressed by specifications.
	LCA Calculator	 LCA Calculator	a modelling tool for LCA-based environmental impact analysis, that performs impact calculations accessing external databases providing, e.g., emissions per functional unit, KPI list according to model
Analyse	Cause-Effect Diagram	 Cause and Effect	a diagram to generate ideas for several potential causes of variation within a process
	Scatter Diagram	 Scatter	a diagram that provides a picture of the relationship between two variables. It may help to demonstrate the strength of a relationship between two variables or between the effect and potential cause but cannot, however, serve as proof that a causal relationship exists
	Pareto Diagram	 Pareto	a diagram that indicates priorities for problem investigation or the main sources of variation
Improve	Idea Generation	 Idea Generation	prioritise direct causes - root cause analysis - identify potential solution



	Prioritization Matrix		a matrix for select solution to test
	Control Chart		to plot new data live (baseline) and to eviue the data from the small-scale tests to see how the actual results compare with the expected
	PDPC		A visual tool used for contingency planning and risks analysis
	LCA Software		See in Measure
Control	5S		a tool for creating an organised workspace and is one of the foundations of good process management
	Visual Management		a view of process steps, measures, team activities, and any abnormal conditions that may impact the capability of a process
	Standardise		a detailed description of how a well-defined process should be operated.
	Review		review the process regularly to continually learn and develop theories on how work can be improved by identifying opportunities to remove waste and opportunities to reduce variation

The list of Tools is a selection, among the many LSS tools, based on the experience gained in applying the methodology in the first use case at FPG. It will be finalized during the rest of the project, taking into account the other two planned uses cases to be run in other two different HCOs (FHAG and UKHD).

A description of each tool is provided in Annex A-TOOLS, with an indication of how they are configured to take into account the distinctive elements.



3.3.3 Healthcare and Green distinctive elements

A list of distinctive elements is provided in Table 5

Table 5 - Healthcare and Green distinctive elements

Type	Element	Description
HC-specific elements	Clinical Pathway (CP) e Clinical Episodes (CEs)	The Clinical Pathway for a given type of disease is the sequence of the clinical activities along the end-to-end patient's journey through phases (Clinical Episodes) executed in CWAs. They are used to standardize and monitor the delivery and run audits. In general, hospitals have documents describing the Clinical Pathways.
	International Classification of Diseases (ICD) codes	The International Classification of Diseases, Injuries and Causes of Death (ICD) is a standard coding for classifying diseases and related conditions
	Clinical Work Area (CWA)	The clinical activities are performed in a limited set of work contexts (e.g. Operating Room, Laboratory). The CWAs are important units of analysis, because the CWAs differ according to many aspects relevant for the LSS application
	Disease Related Groups (DRG)	Diagnosis-related group (DRG) is a classification of hospital case types into groups that are clinically similar and are expected to have similar hospital resource use. To each DRG the hospitals associate their actual full cost, to be compared with the revenues
	Natural variations	One aim of the LSS is to eliminate the variations. However, in the HC many variations are "natural" due the differences among the patients for the same type of disease.
	Hospital Reporting System	All the hospitals have reporting systems, to monitor the service delivery and the costs; the GLSS-HC should leverage these reports, at least in the initial stages, to grasp at least a high level understanding of the magnitude of the process performance
	Health roles	When describing the processes and composing the project team it is important to know which are the key professions and the managerial roles in a hospital
	Patient	The patient is a type of "client" that is also an active actor of the clinical processes; clinical outcome, quality of service and privacy are key aspects to be considered when analysing and improving a process
	Medical technologies	The clinical processes performance depend on the medical technologies: diagnostic tools, monitoring tools, therapeutic devices, health information systems, and wearable technologies
	4-ple aim KPIs	In the HC sector the performances at organization and process level are measured along four dimensions: enhancing patient experience, improving population health, reducing costs and improving the work life of health care providers ⁵
	HC innovation trends	Best practices suggest types of interventions to improve along the four aims. In particular new clinical procedures and medical devices (including AI-based)
Green-specific elements	Waste & other environmental impact factors	The energy consumption and the waste generated in each CWA must be considered by the LSS intervention, also by type, because different types have different management policies, regulatory framework (e.g. the medical waste) and carbon footprint.

⁵ (Bodenheimer, T., 2014)



	Energy & Waste Mgmt information systems	These information systems in general are not part of the hospital information systems; in case they exist, can be the source of useful data regarding waste and energy
	CSRD Reporting	For some hospital it is mandatory to comply with the CSRD European Directive, which asks to draft each year a sustainability report. This report could be a source of data on the environmental performance of the hospital
	Green roles	In general hospital have an Energy and a Waste Manager. In some cases there is also a Sustainability Manager. These roles should be involved in GLSS-HC interventions and should have a role in the implementation of the green oriented solutions
	Environmental KPIs	A fifth category of KPIs must be added to the 4-ple aim KPIs, to consider the potential environmental impact of the process in scope, e.g. CO2eq emissions, water use, contaminants
	Green solutions	Are actions that can be implemented to reduce the environmental impact; the GLSS-HC in the Improvement stage can take inspiration from a list of actions clustered into 8 categories (eg. Energy, Food, Supply chain)

In the following two sections the key distinctive elements are described more in details.

3.3.3.1 Healthcare-specific distinctive elements

1) Clinical Pathway (CP), Clinical Episodes (CEs), Work Areas (WAs)

The typical Clinical Pathway is described as a flow through two dimensions (see Figure 3)

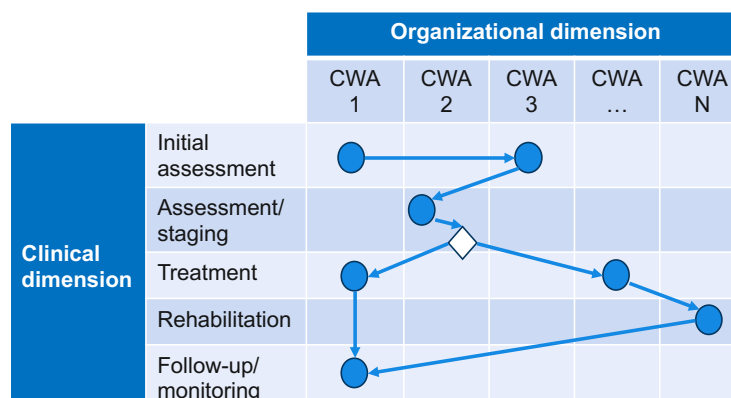


Figure 3 - Conceptual representation of a Clinical Pathway

- **Clinical dimension, described in terms of Clinical Episodes**
 - Initial assessment
 - Evaluation/Staging
 - Treatment
 - Rehabilitation
 - Follow-up/Monitoring
- **Organizational dimension, described in terms of Work Areas.**

The Work Areas can be Clinical (e.g. the Operating Room) and non-Clinical (e.g. the acceptance desk). The list of **Clinical Work Areas (CWAs)** relevant for the GLSS-HC, given their higher environmental impacts, has been built considering areas that differ along the following dimensions:



- Patient Presence
- Healthcare Staff Presence
- Equipment Presence
- Quantity of Material Consumed
- Quantity of Pharmaceutical Products Consumed
- Quantity of Waste
- Energy Used
- HVAC Need
- Duration of Patient Stay

because they point to the key factors to be analysed/modified to increase the operational efficiency, and reduce the economic, social and environmental impacts.

Table 6 provides a quite exhaustive list of such Clinical Work Areas, as defined in Annex B.2.

Table 6 - Types of Clinical Work Areas relevant for the GLSS-HC methodology

Clinical Area	Equipment Presence	Patient Presence	Staff Presence	Material Use	Pharma Use	Waste Quantity	Energy Use	HVAC Need	Patient Stay Duration
1. Operating Room (OR)	Very High	Intermittent	High	High	High	High	Very High	Very High	Short
2. Interventional Radiology	High	Intermittent	High	Moderate	High	Moderate	High	High	Short
3. Intensive Care Unit (ICU)	Very High	Continuous	Very High	High	High	High	Very High	Very High	Long (days-weeks)
4. Emergency Dept. (ED)	High	Continuous	High	High	High	High	High	High	Short/Very short
5. General Ward	Moderate	Continuous	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
6. Day Surgery Unit	High	Short-term	Moderate	Moderate-High	High	Moderate	High	High	Short
7. Outpatient Clinics	Low to Moderate	Short-term	Moderate	Low to Moderate	Moderate	Low	Low	Low to Moderate	Very Short
8. Radiology/ Imaging Dept.	High	Intermittent	Moderate	Low	Low	Low	High	Moderate	Very Short
9. Radiotherapy	Very High	Short-term	High	Moderate	Moderate	Moderate	Very High	High	Short to moderate
10. Clinical Laboratory	High	None	High	High	Low	Moderate	High	High	N/A
11. Pathology Lab	High	None	High	High	Low	Moderate	High	High	N/A
12. Pharmacy (Hospital)	Moderate to High	None	High	Moderate	Very High	Moderate	Moderate	Moderate	N/A
13. Dialysis Unit	High	Intermittent-Regular	High	High	High	High	High	Moderate	Short regular visits
14. NICU (Neonatal ICU)	Very High	Continuous	Very High	High	High	High	Very High	Very High	Long
15. Chemotherapy Unit	High	Intermittent-Regular	High	Moderate	Very High	Moderate-High	Moderate	High	Short to moderate
16. Burn Unit	Very High	Continuous	Very High	High	High	High	Very High	Very High	Long
17. Sterile Processing Dept. (SPD)	High	None	Moderate	Very High	None	High	High	High	N/A
18. Morgue/Autopsy Suite	High	None (deceased only)	Low to Moderate	Moderate	None	Moderate	Moderate	High	N/A

Legend
Presence/Use/Quantity Levels: **Low** – minimal or rarely needed, **Moderate** – average usage, **High** – frequent/essential, **Very High** – critical/heavy use
Patient Stay Duration: **Very Short:** minutes to 1 hour, **Short:** few hours, **Moderate:** days, **Long:** weeks to months, **N/A:** not applicable (no live patients)



2) Diagnosis Related Groups (DRG)

A key entity used by the hospitals to control the costs is Diagnosis-related group (DRG). According to the WHO(2020) the Diagnosis-related group (DRG) is a classification of hospital case types into groups that are clinically similar and are expected to have similar hospital resource use.

The DRGs are related to the ICDs and, therefore to the CPs.

In Italy, the National Health system pays on the basis of the DRG associated to the CP, identified via the relevant ICD codes.

The hospital's industrial accounting function measures the actual average cost of each DRG.

Therefore, If we know the instances of the CP in scope in one year we can calculate

- the actual cost for one year
- the related revenues

and assess if the actual costs are too high.

3) 4-ple aim KPIs

According to the ISO 7101:2023 standard as stated in its clause 9.1.2 Healthcare quality indicators, the organization shall identify what is to be monitored by the quality monitoring system and shall include:

- a) outcomes from clinical and non-clinical services, which examine effectiveness, efficiency and continued appropriateness of the system and its offerings;
- b) patient safety issues, risk reduction strategies, adverse events, and results of patient safety interventions;
- c) risk (clinical and non-clinical) identification, minimization and mitigation strategies and results;
- d) the capacity of the organization to deliver the appropriate and required continuum of care to the patient, including during transfer to other healthcare providers and facilities;
- e) wait times as defined by the organization

and, where applicable, health indicators shall include morbidity, mortality and quality of life and wellbeing.

This is also aligned with what is described in the **quadruple aim approach** (*Bodenhimer T. et al., 2014*), (*De Belvis A.G. et al., 2021*) i.e.: enhancing patient experience, improving population health, reducing costs and improving the work life of health care providers

3.3.3.2 Green-specific distinctive elements

1) Waste

According to (*ISO 7101, 2023*), as stated in its clause 9.1.2 Healthcare quality indicators, the organization shall identify what is to be monitored by the quality monitoring system and shall include: ... e) waste reduction efforts.

Therefore, it is important that the waste is included among the entities in the scope of analysis of the GLSS-HC methodologies and the different types of waste are identified, due to their different impacts, origin and management possibilities.

In addition to the municipal waste, hospitals produce and manage specific types of waste. A list is provided in Table 7.



Table 7 - Types of waste in a hospital: definitions and examples

Waste Type	Definition	Examples
Infectious	Waste suspected to contain pathogens capable of causing disease	Used gloves, masks, bloody dressings, contaminated sharps, lab cultures
Liquid (Non-Water)	Hazardous liquids excluding water-based fluids	Blood products, body fluids (pus, sputum), oils, solvent-based cleaners
Liquid (Water-Based)	Mostly water-based waste containing contaminants from hospital use	Wastewater from sinks/showers, dialysis discharge, laundry water from isolation wards
Chemical	Waste with harmful chemicals from diagnostics or cleaning	Lab reagents, disinfectants, chemotherapy drugs, mercury thermometers, batteries
Radioactive	Waste with radioactive substances from medical or research use	Radiotherapy liquids, isotope vials, contaminated syringes/gloves, iodine-131 waste
Biomedical (No Food)	Medical waste excluding food, potentially hazardous	Human tissues/organs, placentas, biopsy samples, discarded vaccines
Biomedical (Food)	Food waste contaminated with biomedical material or from isolation wards	Leftovers from infectious wards, trays with blood/body fluids, food from isolation patients
Food	General, uncontaminated food waste from kitchens or cafeterias	Spoiled produce, meal scraps from patients, expired packaged food
Plastic	Plastic materials used in hospital operations	IV bags, syringe barrels (clean), water bottles, packaging plastics
Glass	Glass items used in labs or medical care	Broken slides, ampoules, glass IV bottles
Paper & Cardboard	Paper/cardboard used in admin, packaging, or general operations	Patient records, packaging boxes, paper towels (clean)
Wood	Wooden items from infrastructure or supply packaging	Broken beds, wooden splints, crates
Metal	Metal items from tools or equipment	Surgical tools (damaged), aluminium seals, empty oxygen tanks
Mixed	Waste with two or more combined categories	Overflow bins with gloves, wrappers, food; mixed recyclable/contaminated materials

In general, the Hospitals collect the waste generated by their CWAs and send it out for treatment. A typical⁶ waste management map is provided in Figure 4.

More than for its content, the map is proposed to the GLSS-HC practitioners as an easy manner to represent how the waste is managed in an HCO.

⁶ The map refers to the waste management as performed at FPG, in Italy; a similar map applies to WPH, in Finland

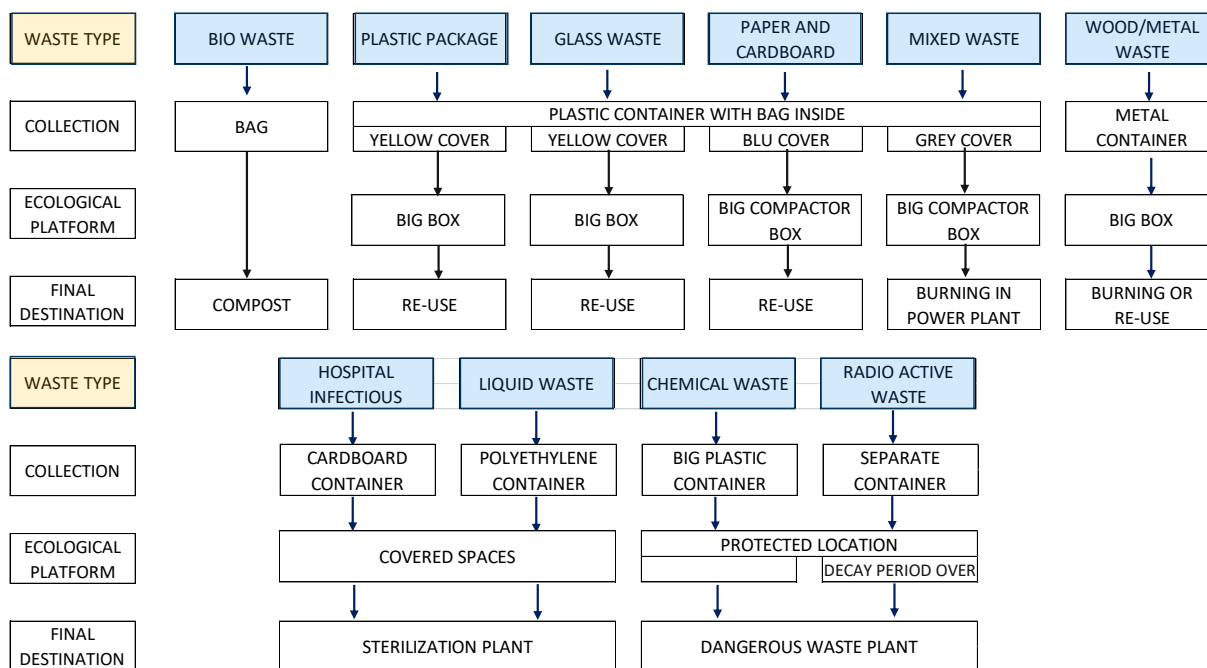


Figure 4 - Typical Hospital waste management map

Each CWA has a reference set of waste, as shown in Annex B6.

2) Categories of environmental impacts

The environmental impact of the HCO is not limited to direct or indirect emissions of CO₂e. It includes a variety of other categories of impact. According to the EU indications (see *EU Commission Green Forum*) and the impact assessment method of CML 2001 (Aug 2016 version), the impact categories to calculate through the LCA are those listed and described in following Table 1

Table 8 - Description of the environmental impact categories

Impact Category	Description
Water use	This category represents the abstraction of water from lakes, rivers or groundwater that can contribute to the 'depletion' of available water. The impact category considers the availability or scarcity of water in the regions where the activity takes place, if this information is known. The potential impact is expressed in cubic meters (m ³) of water used related to the local scarcity of water
Cumulative energy demand	This category includes all renewable and non-renewable energy sources used (expressed in MJ), during the life cycle, for: production processes, production and transport of raw materials and transport and disposal of waste. This includes in addition to the energy consumed within the site, all energy sources consumed for the extraction, processing/production and transportation of all materials and energy sources used
Abiotic Depletion (ADP elements)	This category corresponds to minerals and resources used and is, in this sense, mainly influenced by the rate of resources extracted. The effect of this consumption on their depletion is estimated according to their availability stock on a global scale
Abiotic Depletion (ADP fossil):	This factor is derived for each extraction of fossil fuels. The resources in the impact category of fossil fuels are fuels like oil, natural gas, and coal, which are all energy carriers and assumed to be mutually substitutable. Consequently, the stock of the fossil fuels is formed by the total amount of fossil fuels, expressed in Megajoules (MJ)



Acidification Potential (AP)	<p>This category estimates the potential of emissions to contribute to the development and deposit of acid rain on soil and water which can seriously affect plant and animal life and damage infrastructure. The acidification impacts are mainly primarily caused by fossil fuel combustion emissions, particularly Sulphur Dioxide (SO₂) and Nitrogen Oxides (NO_x). Emissions from burning fossil fuels to generate grid electricity are a significant contributor to acidification effects of the system. Also, emissions from the extraction and processing of natural gas impact the AP category</p>
Eutrophication Potential (EP)	<p>Eutrophication occurs when excess nutrients (nitrates, phosphates) are introduced to surface water causing the rapid growth of aquatic plants. Excess releases of these substances may provide undesired effects on the waterways. The characterization factors for eutrophication are the product of a nutrient factor and a transport factor. The nutrient factor is based on the amount of plant growth caused by each pollutant, while the transport factor accounts for the probability that the pollutant will reach a body of water. Atmospheric emissions of nitrogen oxides (NO_x) as well as waterborne emissions of nitrogen, phosphorus, ammonia, biochemical oxygen demand (BOD), and chemical oxygen demand (COD) are the main contributors to eutrophication impacts, converted into Kg Phosphate equivalent</p>
Freshwater Aquatic Ecotoxicity Potential (FAETP inf.)	<p>This category represents the toxic effects of chemicals on an ecosystem, in this case in the freshwater, causing biodiversity loss and/or species extinction. The characterization factors are expressed like ETP in kg. 1,4-dichlorobenzene equivalent</p>
Global Warming Potential (GWP 100 years)	<p>Greenhouse gases (GHGs) warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space; different GHGs can have different effects on the Earth's warming. The Global Warming Potential (GWP) indicator was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period, relative to the emissions of 1 ton of carbon dioxide (CO₂). The larger the GWP, the more that a given gas warms the Earth compared to CO₂ over that time. The period mostly used for GWPs is 100 years, with the GWP 100 factors are reported by IPCC 2021: fossil carbon dioxide 1 kgCO₂eq/kg, fossil methane 27.9 kgCO₂eq/kg, nitrous oxide 273 kgCO₂eq/kg, etc</p>
Global Warming Potential (GWP 100 years), excl. biogenic carbon	<p>The time horizon used is GWP 100 years, excl. biogenic carbon. It only includes fossil carbon dioxide and thereby excludes the uptake and emissions of biogenic carbon dioxide. Burning fossil fuels releases carbon that has been locked up in the ground for millions of years, while burning biofuel emits carbon that is part of the biogenic carbon cycle. In other words, fossil fuel use increases the total amount of carbon in the biosphere-atmosphere system while bioenergy systems operate within this system; biomass combustion simply returns to the atmosphere the carbon that was absorbed as the plants grew⁷;</p>
Human Toxicity Potential (HTP inf.)	<p>considers the toxic effects of chemicals on humans. It reflects the potential impact of a unit of chemical released into the environment that are mainly caused by electricity production from fossil sources. Human Toxicity Potential is expressed in kg. 1,4-dichlorobenzene equivalent</p>
Marine Aquatic Ecotoxicity Pot. (MAETP inf.)	<p>This category represents the toxic effects of chemicals on an ecosystem, in this case in the marine ecosystems, causing biodiversity loss and/or species</p>

⁷ IPCC distinguishes between the slow domain of the carbon cycle, where turnover times exceed 10,000 years, and the fast domain (the atmosphere, ocean, vegetation and soil), vegetation and soil carbon have turnover times in the magnitude of 1– 100 and 10– 500 years, respectively. Fossil fuel transfers carbon from the slow domain to the fast domain, while bioenergy systems operate within the fast domain. (source: National Council for Air and Stream Improvement)



	extinction. The characterization factors are expressed like in kg. 1,4-dichlorobenzene equivalent
Ozone Layer Depletion Potential (ODP, steady state)	The reduction of protective ozone in the stratosphere caused by emissions of ozone-depleting substances (e.g. CFCs and halons) is known as Ozone Layer Depletion (ODP). The ozone depletion impact category characterizes the potential to destroy ozone based on a chemical's reactivity and lifetime. Effects related to ozone depletion can include skin cancer, cataracts, material damage, immune system suppression, crop damage, and other plant and animal effects
Photochemical Ozone Creation Potential (POCP)	The Photochemical Ozone Creation Potential (POCP) impact category characterizes the potential of airborne emissions to cause photochemical smog. The creation of photochemical smog occurs when sunlight reacts with NOx and volatile organic compounds (VOCs), resulting in tropospheric (ground-level) ozone and particulate matter. Endpoints of such smog creation can include increased human mortality, asthma, and deleterious effects on plant growth. Smog formation impact is generally dominated by emissions associated with fuel combustion, so that impacts are higher for life cycle stages and components that have higher process fuel and transportation fuel requirements
Terrestrial Ecotoxicity Potential (TETP inf.)	This category represents the toxic effects of chemicals on an ecosystem, in this case in the terrestrial ecosystems, causing biodiversity loss and/or species extinction. The characterization factors are expressed like in kg. 1,4-dichlorobenzene equivalent

The impacts associated to each CWA has a reference set of waste, as shown in Annex B6 According to ISO 14044:2006, to evaluate the environmental impacts, the Lyfe Cycle Assessment (LCA) methodology should be used.

The LCA consider all stages of a product's life cycle, that includes raw material extraction, production, use, end-of-life treatment, (including recycling, and/or final disposal). In order to capture all the environmental impacts of the activities performed in a CWA, it is important to evaluate not only the impact directly generated by those activities (e.g. the anaesthetic gases, in an Operating Room) but also those related to the life of the material/equipment/information used in the CWA. This means that a “Cradle to Grave” analysis should be performed, as represented in Figure 5(adapted from EC, 2010).

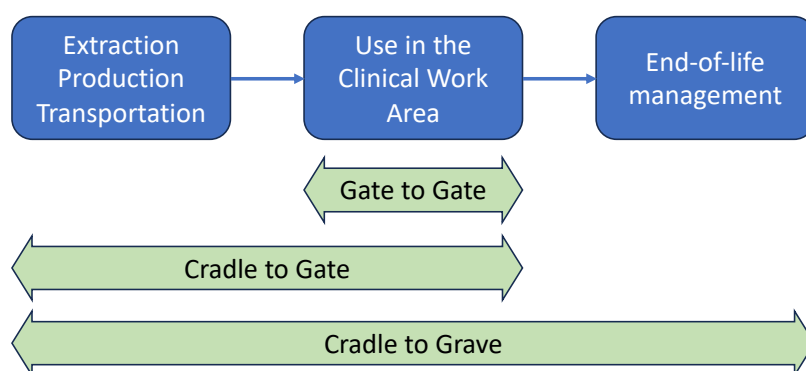


Figure 5 - Schematic representation of the “cradle to grave”, “cradle to gate” and “gate to gate” concepts.



3.3.4 Artifacts of the GLSS-HC methodology

The distinctive elements are linked to the tools, meaning that when the tool is used, it exploits the knowledge capitalized in the distinctive elements.

For instance, when performing the root causes analysis, the GLSS-HC offers Ishikawa diagrams including hints for each type of pf causes (man, machine, method, material, work context) for each of the 4+1 aims; and for each CWA.

This can speed the search of the root causes, diminish the risk of overlooking important aspects, trigger meaningful conversation with the involved staff.

The contextualization of the LSS methodology is implemented associating the HC and Green distinctive elements to the LSS tools through a set of **Artifacts**.

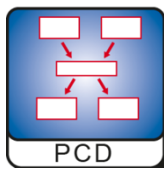


The artifacts are tables or lists that translate the distinctive element into usable knowledge.

So far, **13 Artifacts** have been drafted so far. They are provided in Annex B.

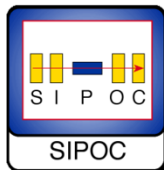
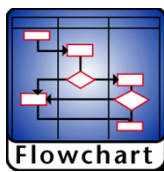

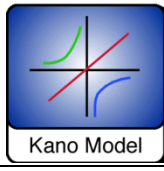

Following Table 9 shows for each tool

- how the HC and Green elements can be taken into account when using the tool
- which Artifacts can be used to capture the HC and Green specificities.


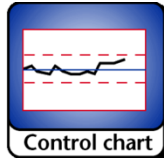
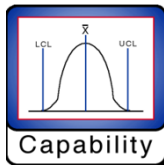

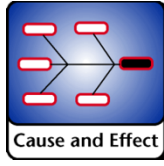
Table 9 - Relationship between Tools, HC & Green distinctive elements, artifacts

Stage	Tool Name	Icon	HC	Green	Artifacts
Define	Project Context Diagram (PCD)		The problem scope is defined indicating the relevant CE, ICD Codes, CWA.	The diagram includes a section to be used, if applicable, to capture elements related to waste of material and other environmental impacts and to energy	B.1 Reference List of Clinical Episodes B.2 Reference List of CWAs
	Charter		The project scope is defined also indicating the relevant CEs, ICD Codes, CWA. The sections specifying sponsor, process owner and team members should take into account the specificities of the health roles	The sections specifying sponsor, process owner and team members should take into account the existence of the "green" roles in the hospital	B.1 Reference List of Clinical Episodes B.2 Reference List of CWAs
	Team Contract		Rules, expectations, and agreements should take into account the responsibilities of the different Green roles	Rules, expectations, and agreements should take into account the responsibilities of the different Green roles	B.2 Reference List of CWAs



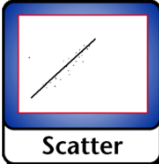


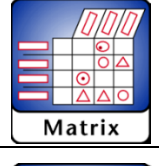
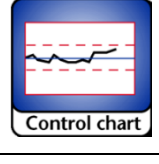
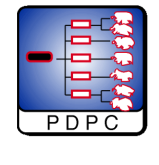


	SIPOC		<p>The process should consider the Clinical Path documents applicable to the process in scope, if they exist. In any case, it is important to explicitly refer to the CEs and to the CWAs for describing the high level description of the process</p> <p>The "Process measures" section should include 4-ple aim indicators</p> <p>The "Customer" column should contain the indication of the involvement of the patient (if applicable)</p>	<p>In the Supplier and Input columns, sections should be put to indicate the types of suppliers of materials and equipment used in the process. In the Output column should include a sections should be put to indicate the types of waste and other elements impacting the environment produced by the process.</p> <p>The Process measures section should include environmental indicators</p>	<p>B.5 4-ple aim + environmental KPIs</p> <p>B.6 Types of Waste by CWA</p> <p>B.7 Types environmental impacts by CWA</p>
	Integrated flowchart		<p>The process should consider the flow diagrams included in the Clinical Path documents applicable to the process in scope, if they exist. In any case, it is important to explicitly refer to the CEs and to the CWAs.</p> <p>Among the actors, a column for the patient should in be included.</p> <p>A column (or an indication) for the used technology should be added</p> <p>The actors should include the typical health roles</p>	<p>A column for the waste and other environmental impact produced by the activities should be added</p>	<p>B.3 Medical technologies by CWA</p> <p>B.5 4-ple aim + environmental KPIs</p> <p>B.6 Types of Waste by CWA</p> <p>B.7 Types environmental impacts by CWA</p>
Measure	8 Waste		<p>Clinical activities that consume resources without adding value to the final product or service (Defects, Over-Production, Waiting, Non-utilized talent, Transport, Inventory, Motion, Excessive Processing)</p>	<p>8 wastes are categories of activities or resources that do not add value to the customer but consume resources and time.</p> <p>Wastes that generate environmental impact should be identified</p>	<p>B.8 Examples of the 8 LSS wastes by CWA</p>
	Kano Model		<p>a framework used for understanding and prioritizing product features based on their impact on patient sand or healthcare operators satisfaction.</p>	<p>The exploration of the needs should include the environmental impact needs</p>	<p>B.4 Typical reports available in a Hospital</p>
	T- Matrix		<p>a type of matrix diagram used to analyze the relationships between three sets of elements. The KPIs should include refer to the Quadruple Aim perspectives</p>	<p>supports eco-efficient process design by integrating quality, operational performance, and environmental responsibility.</p>	<p>B.9 Examples of causes by CW and by aim - Examples of relationship between</p>






					different types of KPIs
	Data Collection		The Data collection can leverage - the reports already used in the hospitals - the cost analysis by IC and DRG	The data base should include a section to collect data about - waste & other environmental impact factors - energy consumption	B.4 Typical reports available in a Hospital
	Control Chart		The natural variations must be taken into account when setting the thresholds. It is important to note that in the HC some variations are natural, due to the variability of the patients and of their clinical profile	ensures quality control, and supports environmental and sustainability metrics—tracking variables like waste volume, emissions, energy use, or compliance with eco-protocols.	B.4 Typical reports available in a Hospital
	Capability Analysis		a statistical measure of how well a process can consistently produce outputs within specified limits, meaning it's the process's ability to meet desired quality standards. It is important to note that in the HC the range between the limits can be high, due to the variability of the patients and of their clinical profile	expanded to include environmental and sustainability performance , in addition to traditional quality metrics	B.4 Typical reports available in a Hospital
	LCA Calculator		The calculator calculates the environmental impacts, considering the specific components of the Lifecycle of the HC sector (e.g. the presence of pharma and medical device industries in the up-stream phases)	Once data collection is complete, an LCA software (e.g. openLCA ⁸) can be used to calculate the impacts, using parameters provided by open -access databases or licensed datasets	B.7 Types environmental impacts by CWA
Analysis	Cause-Effect Diagram		The final effects should consider the 4-ple aim KPIs The types of causes should consider among - the "machine" the HC technologies - the "man" the HC roles - the "methods" the clinical methods/procedures - the "materials" those that are typically HC (e.g. drugs, OR instruments)	The final effects should consider the types of causes should consider among - the "machine" the Green technologies' - the "man" the Green roles and the staff motivation for green - the "methods" the waste management procedures	B.9 Examples of causes by CW and by aim - Examples of relationship between different types of KPIs

⁸ <https://www.openlca.org/about/>



	Scatter Diagram	 Scatter	a diagram that provides a picture of the relationship between two variables. This analysis should consider variables that are HC-specific, e.g. patient age, type of disease, surgical procedure.	are powerful for exploring how process variables influence environmental metrics—such as waste, energy use, emissions, or resource consumption.	B.7 Types environmental impacts by CWA
	Pareto Diagram	 Pareto	The vertical axis of the Pareto Diagram could be the final (or intermediate) along the 4-ple aim KPIs	The vertical axis of the Pareto Diagram could be the final (or intermediate) along the environmental aim KPIs	B.7 Types environmental impacts by CWA
Improve	Idea Generation	 Idea Generation	The ideas for improvement may be supported by exploring the novelties/innovations in the domain of the HC solutions	The ideas for improvement may be supported by exploring the novelties/innovations in the domain of the Green solutions	B.11 Technological innovation trends by CWAs B.12 Actions for green transitions in HC
	T- Matrix	 Matrix	see in Measure	see in Measure	see in Measure
	Control Chart	 Control chart	see in Measure	see in Measure	see in Measure
	PDPC	 P D P C	It helps identify potential problems and develop countermeasures to mitigate risks during process implementation. HC-specific risks should be considered regarding resistance to change, such as lack of time or low priority to non-medical aspects	Is especially valuable for integrating sustainability measures into processes—where environmental, clinical, and operational goals must align under strict regulations and time pressures.	B.5 4-ple aim +environmental KPIs
	LCA Software	 LCA Calculator	see in Measure	see in Measure	see in Measure
Control	5S	 22	provides a basis for eliminating waste and establishing continue improvement; the peculiarities of the different CWAs and of the clinical procedures (e.g. in surgery) must be taken into account	Integrates sustainability principles by optimizing resource use, reducing waste, and enhancing environmental awareness at the point of care.	B.10 Examples of 5S by CWA



	Standardize		a detailed description of how a well defined process should be operated. To express and enforce the desired standard behaviours, the Clinical Pathways and the Clinical Episodes can be considered to localize and contextualize the standards	the step where best practices become the norm, and eco-efficiency is embedded into routine operations through procedures, training, and visual tools	B.1 Reference list of Clinical Episodes
	Visual Management		a view of process steps, measures, team activities and any abnormal conditions that may impact the capability of a process. Information/data/performance taken from the existing reports can provide the content/messages to be visualized	adapted to promote environmental awareness, sustainable process execution, and compliance with eco-protocols in real-time—without needing verbal instruction or memory.	B.4 Typical reports available in a Hospital
	Review		Review by 4-ple aim KPIs	Review by environmental KPIs	B.5 4-ple aim +environmental KPIs

3.4 Possible uses of the GLSS-HC methodology

At the **operational level**, the GLSS-HC methodology primary operational uses include:

- Analysis of a Clinical Pathway to identify the CWA that require priority analysis for improvement
- Support in the execution of the DMAIC at CWA level.

Other occasions for operational uses of the GLSS-HC methodology include:

- Design of a Clinical Pathway, applying the GLSS-HC to get the CP performant-by-design, e.g. in terms of length of stay and environmental impact, as shown, e.g. in (*Niemeijer G. C. et al, 2012*)
- Execution of an audit of the Clinical Pathway in case performance indicators routinely monitored take abnormal values
- Evaluation of an investment, to evaluate its impact on the performance of the affected clinical pathways
- Need to improve the performance of a process, e.g. to align the cost to a DRG with low value
- Need to set new performance targets after the change of a medical technology
- Comparison between similar CWAs (e.g. Operating Rooms, General Wards)

At a **strategic level**, the GLSS-HC methodology provides:

- A **knowledge sharing framework**, to systematically collect lessons from process improvement projects. It can be used for this purpose by the individual HCO, by the consulting company that adopts it. It can also become **part of the CARING NATURE Knowledge Sharing System (KSS)**.
- The **analytical basis** for the assessment and continuous improvement of the environmental impact of a hospital. The total environmental impact can be calculated summing-up the impacts at a meaningful and manageable level (CWA, or CWA per



medical field, or per medical field), with standardized metrics, that allow benchmarks in the HCO and across HCOs, and to monitor progress over time.

The conceptual scheme for the strategic level is shown in Table 10, where the FU stands for Functional Unit. The FU is the volume driver to calculate the total consumption of a resource or the total impact. It depends on the type of factor and can be, e.g., patient, surgical procedure, square meter, laboratory exam, bed.

Table 10 - A scheme for using the GLSS-HC as a framework for knowledge sharing

Medical field (eg. identified with ICD codes)	CWA 1	CWA 2	...	CWAn
Cardiology				
Urology				
...				

For each pair (Medical field, CWA), the KSS could store information regarding

- Contextualized GLSS-HC Artifacts
- Best Practices of application of the GLSS-HC methodology
- Relevant literature on the application of the GLSS-HC methodology
- Benchmark data per Functional Unit (e.g. patient, bed, exam, m², m³) regarding Energy consumed, Waste produced, Environmental impact categories
- Applicable improvement actions
- ...

4 FPG Use Case

4.1 Introduction

The purpose of the use case is to show how the GLSS-HC methodology described in previous chapter 3 section 3 can be applied to a real patient journey. In particular we wanted to show it can support in finding solutions for **reducing the environmental impact** in the healthcare sector.

The Use Case regards the **Cholecystectomy patient journey** (see Figure 6). The scope spans across all the clinical stages of the journey (green work areas in the Figure), including the surgical stage in the ORs.

The choice of this journey derives from two considerations.

First, the Fondazione Policlinico Universitario Agostino Gemelli IRCCS (FPG), as one of the leading medical institutions in Italy, hosts a state-of-the-art surgical platform encompassing numerous operating rooms (ORs) equipped for various surgical specialties. Among these procedures, laparoscopic cholecystectomy is frequently performed due to its minimally invasive nature and high success rate in treating gallbladder pathologies.

Second, the ORs offer a good opportunity to test the “green” aspect of the GLSS-HC. For instance, at FPG each operating room within the surgical platform is outfitted with three primary bins intended for waste segregation: one for general waste (non-contaminated, non-recyclable), one for hazardous medical waste (including biological and infectious materials), and one for recyclable materials (such as paper, certain plastics, and sterile packaging).



Theoretically, this system supports the hospital’s sustainability goals. However, observational studies, internal audits, and qualitative feedback from surgical and support staff have shown that bin usage often falls short of optimal: bins are incorrectly labeled, materials are miscategorized, bins overflow due to irregular collection intervals, and excess single-use packaging contributes to unnecessary volume.

In the first steps of the Define stage, it has emerged that the most relevant Clinical Work Areas (CWAs) are the Operating Room (OR) and the Laboratory. Therefore, apart from an overall exploratory step, in the Define stage, the actual application of the methodology regards OR and Laboratory.

Until M18 the use case has been focused on the OR. The results of the application of GLSS-HC to the Laboratory will be included in the deliverable *D4.7-Green Lean Six Sigma methodology for health and care-v2*.

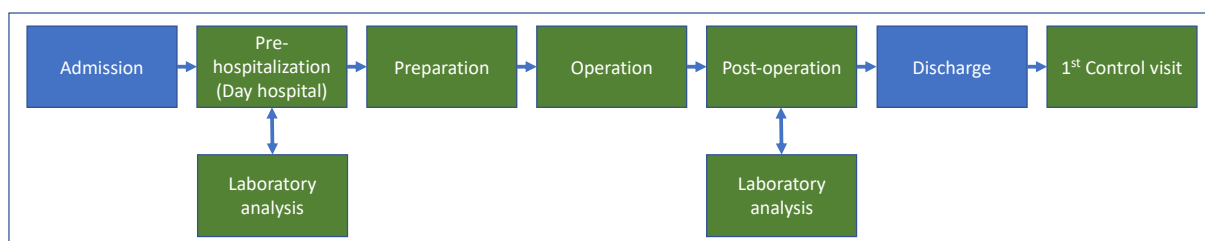


Figure 6 - Cholecystectomy patient journey

4.2 High level profiling of the patient journey

The Define stage has included a **high level description of the patient journey**, applying the indications of the GLSS-HC.

- 1) The **Cholecystectomy patient journey** is a Clinical Path that includes four ICD-9-CM codes (Table 11);

Table 11 - ICD-9-CM codes for the Cholecystostomy

ICD-9-CM	Description
51.21	Cholecystostomy (gallbladder drainage)
51.22	Laparoscopic cholecystectomy
51.23	Open cholecystectomy
51.24	Cholecystectomy with exploration of the bile duct

- 2) The Cholecystectomy patient journey can be represented (Figure 7) in terms Clinical Work Areas CWAs and Clinical Episodes (CEs)

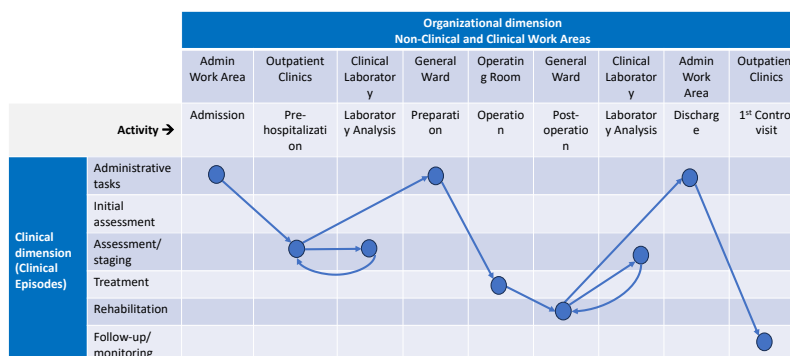


Figure 7 - Representation of Cholecystostomy patient journey with the GLSS-HC language

- 3) Existing FPG reports provide useful indicators (Figure 12) that can support analysis regarding **clinical performance (production and outcome)** and, indirectly, the



environmental impact per patient (in general due to the need to repeat the activity) and social impact (in terms of patient satisfaction/wellbeing and staff wellbeing).

Table 12 - Some indicators provided by the FPG reports

Activity	Indicators
Admission	<ul style="list-style-type: none"> Time interval between admission to the list and surgery
Pre-hospitalization	<ul style="list-style-type: none"> % of Repetition due to too long Time interval between pre-hospitalization and surgery (if the patient is not operated on 3 months after pre-hospitalization, she/he must repeat the preparatory analysis)
Preparation (in the general ward)	<ul style="list-style-type: none"> Average pre-operative hospital stay (by DRG, elective)
Operating Room	<ul style="list-style-type: none"> % of operations performed with a fully completed computerized checklist (by operating block) % of operations with a computerized checklist not completed and not in emergencies % signatures not completed before the start of the anaesthetic procedure – computerized checklist Time in the room (exceeding the assigned time) Time in the recovery room % of planned and not executed operations
Post-operation (in the general ward)	<ul style="list-style-type: none"> Average post-operative hospital stay (or hospital stay exceeding a certain number of days) % patients with post-operative infection % of patients with in-hospital sepsis % of patients with complications Total in-hospital mortality by access method to the facility, by age group and by type of DRG
Laboratory	<ul style="list-style-type: none"> Volumes Turnaround time (TAT) per patient hospitalized (for routine and emergency)
Discharge	<ul style="list-style-type: none"> Readmission within 30 days for DRG (detail of elective hospitalizations for UO) Re-operation 30 days after discharge % of patients for whom the AAC (Augmentative and Alternative Communication) is activated

- 4) From the economic/cost point of view, for each code, there are three levels of complexity and, therefore, unit cost. This leads to 12 types of patient journeys (e.g. ICD-9-CM 51.21, DRG 420 is one of them). (see Table 13)

Table 13 - DRGs applicable to a Critical Path, the Cholecystostomy

ICD-9-CM codes for the Cholecystostomy		DRG associated to the Cholecystostomy		
		419	420	421
ICD-9-CM	Description	Gallbladder and bile duct interventions with MCC (major complications or comorbidities)	Gallbladder and bile duct interventions with CC (complications or comorbidities)	Gallbladder and bile duct interventions without CC/MCC
51.21	Cholecystostomy (gallbladder drainage)	X €	Y €	Z €
51.22	Laparoscopic cholecystectomy	X €	Y €	Z €
51.23	Open cholecystectomy	X €	Y €	Z €
51.24	Cholecystectomy with exploration of the bile duct	X €	Y €	Z €



In Italy the National Health system pays on the basis of the DRG associated to the CP, identified via the relevant ICD codes.

The hospital's industrial accounting function measures the actual average cost of each DRG.

Therefore, given the number of Cholecystomies in one year and the mix of types, it is possible to calculate

- the actual cost for one year
- the related revenues

and assess if the actual costs are too high.

5) With regard general features, from Table 6 in section 3 we get Table 14, where the red indicates features that are relevant for selecting the CWA in view of the reduction of the environmental impact

Table 14 - Features of the CWAs of the Cholecystectomy patient journey

Clinical Area	Equipment Presence	Patient Presence	Staff Presence	Material Use	Pharma Use	Waste Quantity	Energy Use	HVAC Need	Patient Stay Duration
Operating Room (OR)	Very High	Intermittent	High	High	High	High	Very High	Very High	Short
General Ward	Moderate	Continuous	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Outpatient Clinics	Low to Moderate	Short-term	Moderate	Low to Moderate	Moderate	Low	Low	Low to Moderate	Very Short
Clinical Laboratory	High	None	High	High	Low	Moderate	High	High	N/A

Legend
Presence/Use/Quantity Levels: **Low** – minimal or rarely needed, **Moderate** – average usage, **High** – frequent/essential, **Very High** – critical/heavy use
Patient Stay Duration: **Very Short:** minutes to 1 hour, **Short:** few hours, **Moderate:** days, **Long:** weeks to months, **N/A:** not applicable (no live patients)

6) With regard to environmental features, from Artifact B.7 we get a first understanding of the key⁹ environmental impacts associated to each of the CWAs involved in the patient journey (Table 15).

Table 15 - Key type of environmental impacts associated to each of the CWAs involved in the Cholecystectomy patient journey

Environmental Impact Category	Clinical Work Area			
	Operating Room (OR)	General Ward	Outpatient Clinics	Clinical Laboratory
Water Use	✓			
Cumulative Energy Demand	✓			
Abiotic Depletion (ADP elements)				✓

⁹ The absence of the ✓ means no or negligible presence in comparison across the four CWAs



Abiotic Depletion (ADP fossil)	✓			
Acidification Potential (AP)	✓			
Eutrophication Potential (EP)				✓
Freshwater Aquatic Ecotoxicity Potential (FAETP inf.)				
Global Warming Potential (GWP 100 years)	✓			
Global Warming Potential (GWP 100 years), excl. biogenic carbon	✓			
Human Toxicity Potential (HTP inf.)				
Marine Aquatic Ecotoxicity Pot. (MAETP inf.)				✓
Ozone Layer Depletion Potential (ODP, steady state)				
Photochemical Ozone Creation Potential (POCP)	✓			
Terrestrial Ecotoxicity Potential (TETP inf.)				✓

Based on all above elements, the Operating Room and the Laboratory are the most promising work areas from the point of view of the reduction of the environmental impacts. So far, the the Use Case has regarded the Operating Room.

4.3 FPG Operating Room Use Case

4.3.1 General Description and Used Tools

In the increasingly complex and sustainability-driven environment of modern healthcare, optimizing waste management practices within operating rooms (ORs) has become a critical priority.

Surgical procedures demand strict protocols, sterile materials, and time-sensitive workflows, all of which contribute to the production of significant volumes of medical waste.

Within this high-pressure setting, the correct classification and segregation of waste often become secondary to surgical priorities, resulting in the frequent misplacement of recyclable or non-contaminated materials into bins designated for infectious or hazardous waste.

This leads to increased contamination rates, higher treatment costs, and significant environmental burdens, particularly through the excessive use of incineration, which contributes to elevated CO₂ emissions.

This chapter introduces the application of the Green Lean Six Sigma (GLSS) methodology to address these challenges by systematically improving waste management processes within operating rooms. GLSS is an integrated framework that merges:

- Lean principles (to eliminate waste and improve process flow),
- Six Sigma tools (to reduce process variability and ensure data-driven decisions), and
- Green strategies (to minimize environmental impact and promote sustainability).

The primary focus of this application is to enhance the accuracy of waste segregation during and after surgical procedures.

By ensuring that clean packaging, non-infectious disposables, and recyclable items are correctly sorted and excluded from hazardous waste streams, the methodology aims to:

- Reduce the volume of contaminated waste,
- Lower CO₂ emissions associated with incineration,
- Improve sustainability indicators in surgical practice, and



- Reinforce staff awareness and behavioral consistency through visual and procedural standardization.

This structured methodological approach is developed around the traditional DMAIC cycle—Define, Measure, Analyze, Improve, and Control—with a focus on surgical workflow integration and environmental performance. Each phase incorporates tools that facilitate the identification of inefficiencies, root causes of misclassification, and opportunities for sustainable improvement.

The tools, summarized in the chapter 3.3.2, applied in each phase and described in the following chapters are listed below:

Table 16 - GLSS – Used Tool in Use Case (Operating Room)

DMAIC Phase	Selected Tool	Purpose and Context in OR Waste Management
Define	Problem Context, Contract Agreement, SIPOC Diagram, Linear and Integrated Flowcharts, Waste Audit	To map the surgical waste process, from material input to final disposal
Measure	Data Collection Grid, Voice of the Customer, KANO Model, True Quality Characteristics, T Matrix, Control and Individual charts	To quantify the amount of waste produced per procedure and bin fill times
Analyse	Root Cause Analysis (Ishikawa diagram)	To identify key drivers of misclassification and overfilling in contaminated bins
Improve	PDPC (Process Decision Program Chart)	To proactively design countermeasures and reduce waste variability
Control	5S, Visual Management, Standardize, Review	To sustain correct waste segregation through visual cues, SOPs, and staff training

4.3.2 Current state and ongoing activities

As part of the **Green Lean Six Sigma** methodology implementation for optimizing waste management in the operating rooms of the **Fondazione Policlinico Universitario A. Gemelli IRCCS**, the project is currently in the **development phase of operational results**.

The **Analyze phase** has been completed, during which key data on the generation, segregation, and disposal of medical waste were collected, validated¹⁰, and analyzed¹¹, with a specific focus on the volume of contaminated waste, collection practices, and inefficiencies observed in the bin usage process.

Based on the findings from this step, the **Improve phase** has now begun, aiming to identify and test corrective and enhancement strategies. The **tools planned for the Improve and Control phases**—including prioritization matrices, Process Decision Program Charts (PDPC), control charts, operational checklists, visual management systems, and audit protocols—are

¹⁰ Data collection and validation are described in the MEASURE phase in chapter §4.3.4

¹¹ Depicted in ANALYSE phase in chapter §4.3.5



under development on the foundation of previous analyses and field observations, incorporating feedback from healthcare staff and sustainability benchmarks.

These instruments, designed to support **continuous improvement, standardization, and environmental impact reduction**, will undergo internal validation and will be formally delivered by **Month 23**.

The overarching goal is to ensure the systemic and sustainable implementation of the proposed improvements, promote best practices among staff, and enable effective long-term monitoring of key performance indicators

4.3.3 DEFINE Phase

4.3.3.1 Problem Context and Contract Agreement

The first phase of the project involved defining the problem through a comprehensive Problem Context Diagram.

This diagram allowed stakeholders to visualize the various layers of influence within the surgical waste management system. It revealed how decisions made during the procurement of surgical kits, the behavior of staff during waste disposal, the configuration of waste bins, and the policies of third-party waste contractors all converge to impact the final outcomes.

The surgical staff—comprising surgeons, scrub nurses, anesthetists, and OR aides—are key actors, but their actions are governed by operational constraints, such as procedure duration, urgency, and the physical layout of the operating theater.

Additionally, support units such as infection control, hospital engineering, and external waste contractors are essential to the process. The Problem Context Diagram thus served to delineate these relationships and surface latent risks and opportunities.

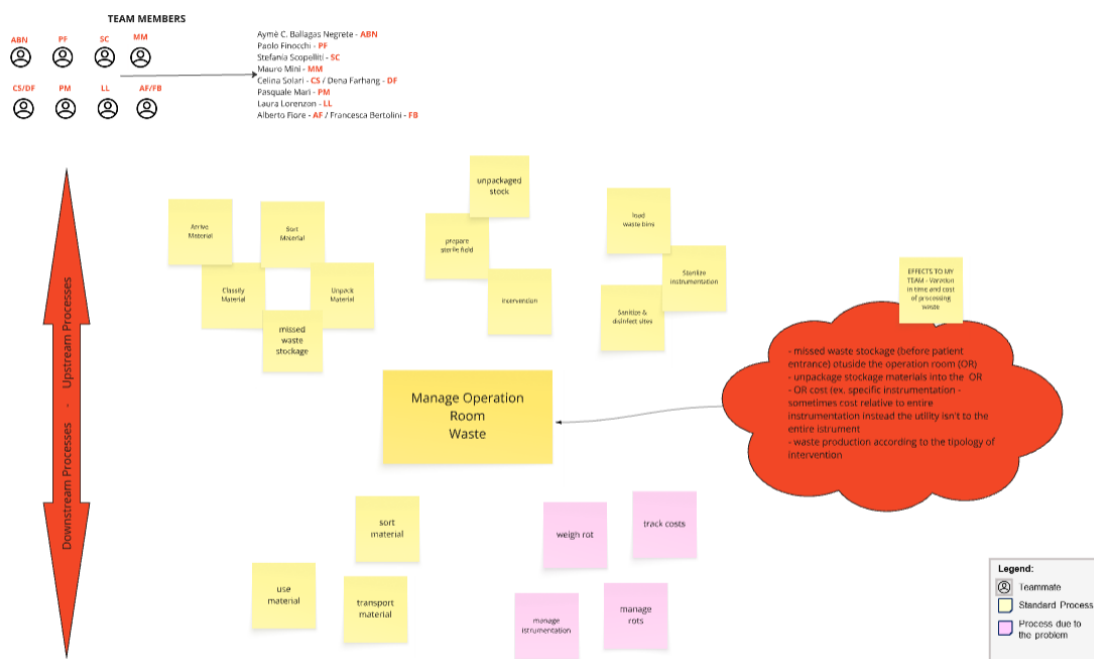


Figure 8 - Problem Context Diagram (PCD)



Following this, a formal Contract Agreement was shared with all stakeholders to establish the project’s framework. This document outlined the project’s scope, goals, expected deliverables, constraints, and timelines. Key targets included improving waste segregation accuracy, reducing total waste volume, enhancing compliance with regulatory standards, and improving operational efficiency without burdening the clinical staff.

This agreement defined the project boundaries (focusing solely on cholecystectomy waste), established the roles of each team member (clinical leads, quality engineers, data analysts), and set quantitative objectives.

These objectives included: reducing the waste volume per procedure, achieving segregation accuracy, and eliminating waste-related procedural delays by redesigning workflow and waste logistics.

4.3.3.2 SIPOC Analysis and Process Mapping

A SIPOC (Suppliers, Inputs, Process, Outputs, Customers) diagram was utilized to map the end-to-end process for waste handling during cholecystectomy procedures.

Suppliers include surgical equipment vendors, hospital supply chains, and environmental service providers. Inputs encompass surgical materials, bin liners, and sterilization supplies. The process begins with the setup of the operating room, continues through the surgical procedure, and concludes with post-operative cleanup and waste disposal.

Outputs are categorized waste streams, while customers range from internal departments to external waste regulators.

Key Business Process Name: Manage Waste in Operation Room							Results Measures	Customer Needs
Suppliers	Input	Process	Process Purpose:	Process Owner:	Output	Process Steps (High Level)	Results Measures	Customer Needs
<ul style="list-style-type: none"> disposal company surgeon company anesthesia company nursing disposal company termostatic company internal family hospital manufacturer of supplies healthcare company on-waste provider company facility manager supply and handling 	<ul style="list-style-type: none"> Dressing equipments (the drapes - into various material - various drugs - anaesthetics) equipment for staff in the operating room (gown - hairphones - shoe covers - surgical clothing) Equipment for minimally invasive surgery (optical instruments - video lumen) standard equipment for surgeons (scissors and grasper - retractor) equipment for hemostasis - surgical drainages - special cutters - endoscopic material - need cases) waste bins 	<p>to manage waste after surgeon</p> <p>Healthcare Provider (PPG-Surgical Unit)</p>	sorted waste	quantity of waste bin leaving the operation room	<ul style="list-style-type: none"> nurses surgeons anaesthetists health management Subcontracted waste management company 	<p>supply material</p> <p>distribute material</p> <p>provide material</p> <p>use material</p> <p>sort waste</p> <p>recycling waste</p>	kg of waste properly classified	<ul style="list-style-type: none"> a clear standard for waste classification uncontaminated and contained bins quantity of bins assessed for the technician quantity of bins for standard recycling
<p>time to fill request forms</p> <p>number of material request forms</p>	<p>quantity of materials according to average capacity</p>	<p>List of required quantities of materials according to the type of intervention and additional material request</p>	<p>quantity of the processed material used during the intervention</p>	<p>amount of waste generated in the operating room</p>	<p>amount of waste generated in the operating room</p>	<p>time to fill request forms</p> <p>number of material request forms</p>	<p>kg of waste properly classified</p>	<p>time to fill request forms</p> <p>number of material request forms</p>
<p>24 hours</p>	<p>none</p>	<p>18 hours</p>	<p>none</p>	<p>none</p>	<p>none</p>	<p>✓</p> <p>✗</p> <p>✓</p> <p>✗</p> <p>✓</p> <p>✗</p>	<p>kg of waste properly classified</p>	<p>time factor minimized</p> <p>difficulty in understanding the type of waste to be sorted</p> <p>lack of time of operators in sorting waste</p>
<p>lack of material</p>	<p>risk of failure to check the stock</p>	<p>lack of failure to control the supply in the use of a stock</p>	<p>absence events during the intervention, inappropriate cutters/forceps</p>	<p>Lack of possibility for correct waste separation</p>	<p>none</p>	<p>lack of material</p>	<p>kg of waste properly classified</p>	<p>time factor minimized</p> <p>difficulty in understanding the type of waste to be sorted</p> <p>lack of time of operators in sorting waste</p>
<p>delay</p> <p>mismanagement of the needs of the intermediate or contact</p>	<p>delay</p> <p>mismanagement of the needs of the intermediate or contact</p> <p>mismanagement of the information</p>	<p>delay</p> <p>mismanagement of the needs of the intermediate or contact</p> <p>risk for the patient</p>	<p>delay</p> <p>mismanagement of the needs of the intermediate or contact</p> <p>risk for the patient</p>	<p>delay</p> <p>mismanagement of the needs of the intermediate or contact</p> <p>risk for the patient</p>	<p>increased disposal of waste</p>	<p>delay</p> <p>mismanagement of the needs of the intermediate or contact</p>	<p>kg of waste properly classified</p>	<p>time factor minimized</p> <p>difficulty in understanding the type of waste to be sorted</p> <p>lack of time of operators in sorting waste</p>

Figure 9 - SIPOC

This model served as a cornerstone analytical tool to understand the waste management process from beginning to end. Suppliers include surgical product vendors, hospital logistics services, and sterilization units. Inputs involve disposable materials such as sterile gloves, surgical drapes, PPE, and single-use instruments.



The process consists of three main stages: the surgical setup (preparation and packaging unwrapping), the surgical act itself (generation of contaminated and general waste), and postoperative dismantling (removal and classification of remaining materials).

Outputs are the various waste streams categorized under general, hazardous, and recyclable types. Customers of this process include hospital administrators, environmental compliance officers, and waste disposal firms. Mapping this system highlighted areas where waste was generated but not monitored—especially in instrument over-preparation and discarded unused supplies.

Two detailed flowcharts were created to model the existing and future workflows. The linear flowchart depicted the current procedure, highlighting redundancy and delays.

The integrated flowchart represented the improved process, with Lean interventions such as point-of-use segregation, visual bin management tools, and automated bin sensors introduced to reduce waste and time losses.

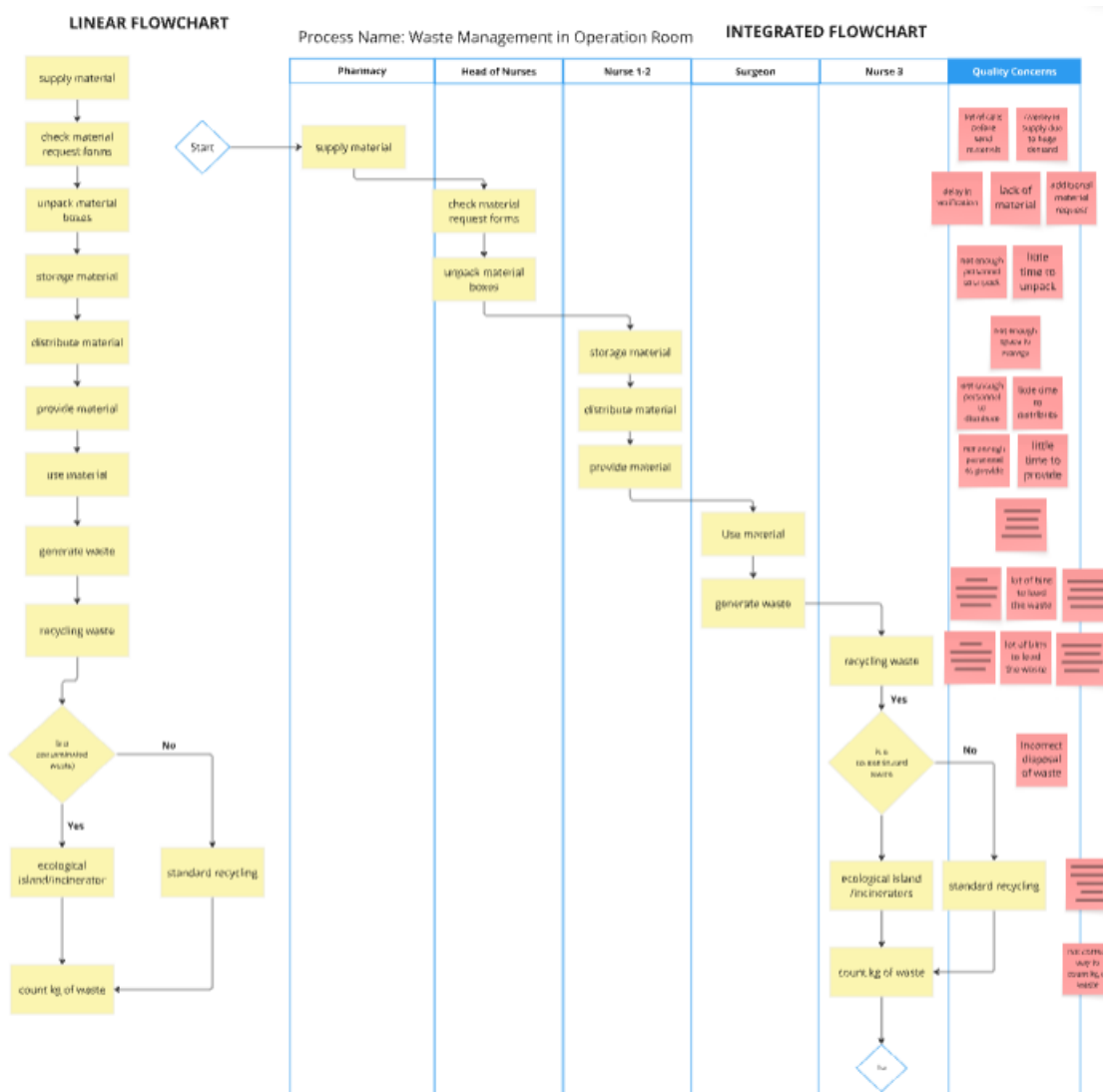


Figure 10 - Linear (left) and integrated (right) flowchart

The existing process was then visualized through a linear flowchart, illustrating how waste moved from the surgical table to bins, and then to internal collection points.



In this current-state map, multiple non-value-adding steps were found, including double-handling of waste, unclear labeling that led to staff confusion, and procedural pauses due to full or misplaced bins.

An integrated future-state flowchart was developed that introduced Lean interventions such as point-of-use disposal carts, color-coded and RFID-tagged bins, and standardization of material kits. These tools aimed to eliminate overproduction, motion waste, and waiting—three of the eight lean wastes.

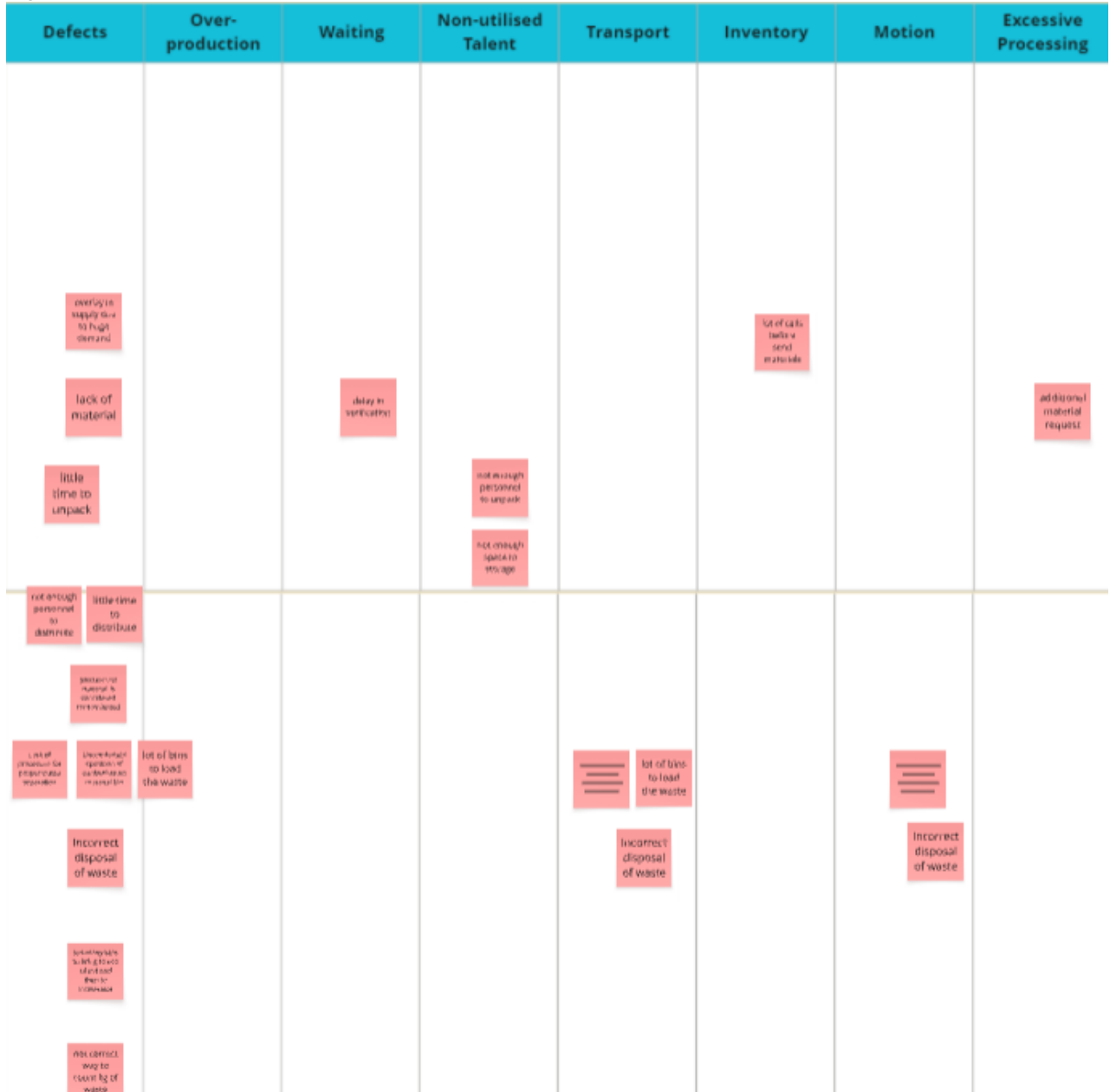


Figure 11 - 8 Waste

4.3.4 MEASURE Phase

4.3.4.1 Voice of the Customer and Kano Analysis

In the early stages of the project, feedback was collected from all relevant personnel through interviews, questionnaires, and observations.



The Voice of the Customer (VoC) exercise revealed dissatisfaction with the ergonomics of current bin placement, the ambiguity of segregation rules, and lack of feedback mechanisms regarding proper waste handling.

VOICE OF THE CUSTOMER COLLECTION



Figure 12 - The Voice of the Customer (VoC)

A detailed Voice of the Customer (VoC) analysis was undertaken using structured interviews, online surveys, and shadowing sessions with staff from various disciplines.

Surgeons emphasized the importance of uninterrupted workflow and ease of access to waste containers. Nurses highlighted the inconsistency of bin labeling and physical strain caused by bin positioning. Cleaning personnel reported difficulties in identifying correctly segregated waste and noted that waste from different procedures was often mixed.

The data collected through the VoC were analyzed using the Kano Model. This approach categorized needs into basic requirements (e.g., hygiene and infection control compliance), performance expectations (e.g., consistent waste collection timing, ergonomic bin location), and delighters (e.g., digital bin status alerts, mobile waste-sorting apps). Understanding these needs allowed the project team to prioritize improvements based on their potential impact on satisfaction and compliance.

A Kano Model analysis was then applied to categorize these needs. Basic needs included hygiene and regulatory compliance, which are mandatory but not necessarily noticed unless absent. Performance needs, such as accessibility and timely collection, directly influenced staff efficiency.

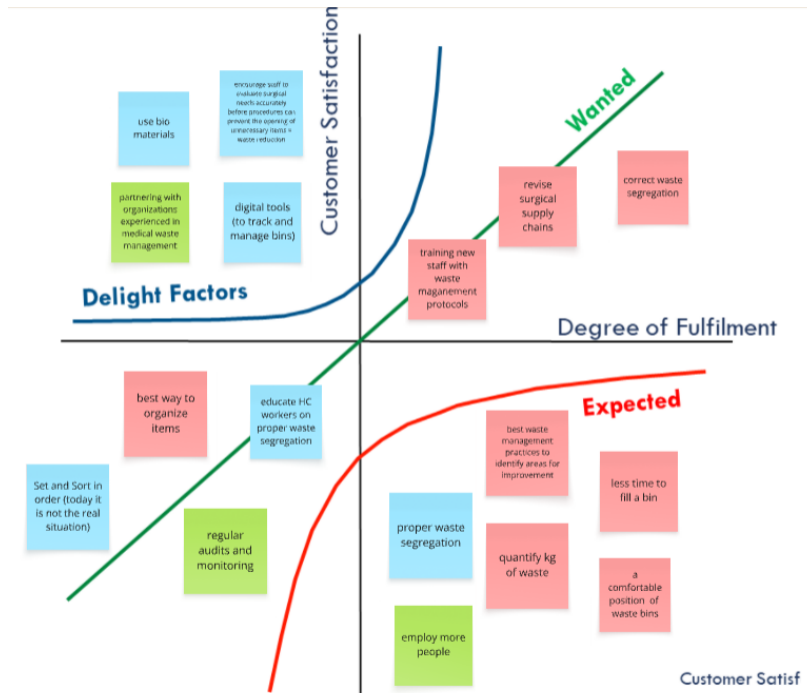


Figure 13 - KANO Model

Excitement needs, such as digital feedback displays and AI-based fill-level alerts, offered the potential for innovation and engagement beyond expectations.

4.3.4.2 Quality Concerns and True Quality Characteristics (TQCs)

Key concerns identified through observational audits and failure mode analyses included: frequent bin overflow, incorrect waste disposal practices, and excessive use of disposable materials. These challenges were directly linked to patient safety risks and higher environmental costs.

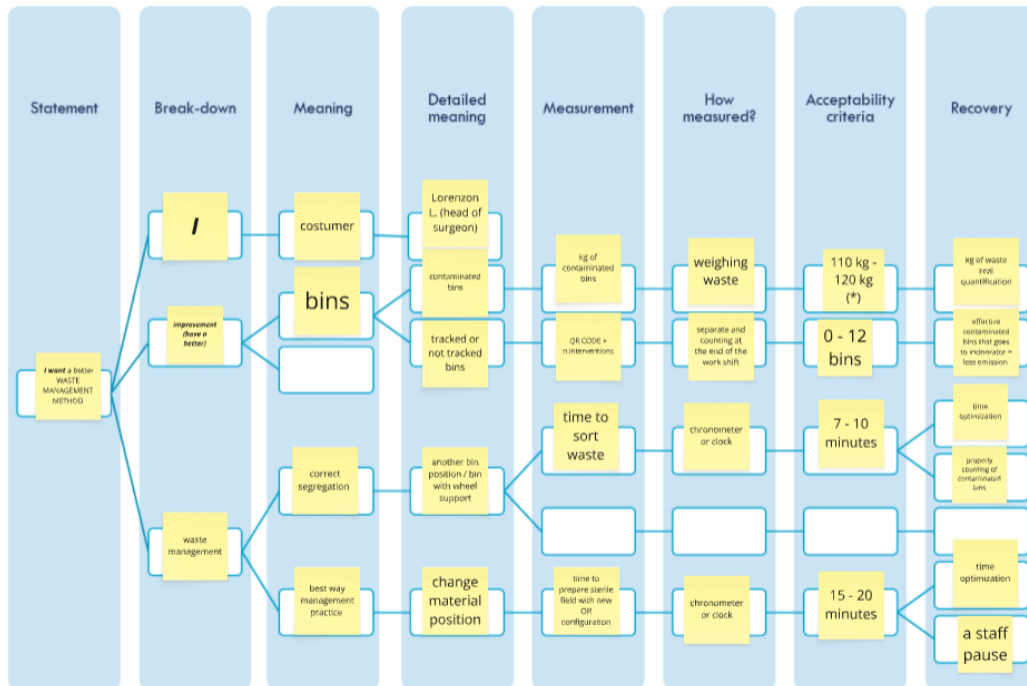


Figure 14 - True Quality Characteristics



To ensure robust process monitoring, the project defined a set of True Quality Characteristics (TQCs), each associated with a measurable indicator. These included:

- Correct waste segregation rate
- Time between surgery end and bin replacement
- Non-compliance events with hygiene protocols
- Waste volume per procedure
- Staff compliance audit score

These metrics will be tracked using control charts and integrated into hospital dashboards for continuous quality monitoring.

4.3.4.3 Implementation Strategy: T - Matrix

Application in managing surgical waste during cholecystectomy procedures has proven to be a powerful tool for operational excellence. By identifying waste in both the literal and process sense, the project has laid the foundation for a more sustainable, efficient, and compliant waste management system

The next steps include piloting the improved workflow in select operating rooms, training OR personnel on the revised process, and conducting follow-up audits to assess impact. A phased rollout is expected, followed by the inclusion of additional procedures and operating areas in the hospital.

This methodology has the potential to be a replicable model not only within Policlinico Gemelli but also in other major surgical centers focused on sustainability and Lean transformation.

By aligning the Voice of the Customer (VOC) with Critical to Quality (CTQ) characteristics, process measures, and result measures, the T-Matrix becomes not merely a descriptive framework, but a dynamic and actionable instrument for operational excellence in surgical waste management.

Its structured format allows the translation of abstract needs—such as cleanliness, sustainability, regulatory compliance, and workflow efficiency—into measurable and controllable process characteristics.

This alignment forms the backbone of a data-driven approach to quality assurance, enabling hospital management and surgical teams to monitor compliance, anticipate risks, and proactively address inefficiencies.

As a central tool for process control, the T-Matrix facilitates the early detection of deviations by linking real-time operational indicators (e.g., waste sorting accuracy, labeling completeness, container replacement timing) with higher-level outcome metrics (e.g., infection rates, environmental impact, disposal cost).

This linkage enables a closed-loop feedback system, where deviations in the process can be traced directly to customer-impacting outcomes, fostering a culture of evidence-based corrective action.



CUSTOMER WORDS					RESULTS MEASURES	PROCESS MEASURES				
incorrect waste segregation	time to fill a bin into the OR	Set and Sort in order	training staff WM protocols	regular audits and monitoring		total n. bins	n. yellow bins (contaminated waste)	n. of steps before final disposal		
●	○			●	total kg of waste	●	○			
●	○	△		●	contaminated kg of waste	○	●			
		○	●		n. of tracked bins		●			
					lead time for waste segregation		●	●		

Figure 15 - T - Matrix

Moreover, the T-Matrix is pivotal in standardization efforts, serving as a foundation for the development of operating procedures, training materials, and compliance audits. By clearly articulating the relationships between needs, quality drivers, and performance indicators, it ensures that all stakeholders—from surgical nurses to environmental health officers—are aligned around a shared framework of priorities and expectations.

4.3.4.4 Control and individual chart

To monitor and optimize the waste management process during cholecystectomy procedures, a control chart-based approach was adopted to evaluate two critical indicators: the quantity of waste generated (in kilograms) and the frequency of contaminated bins recorded within the operating rooms.

This analytical method, grounded in statistical process control, provides a visual and data-driven representation of process behaviour over time, distinguishing between natural process variation and deviations that may signal underlying issues requiring intervention.

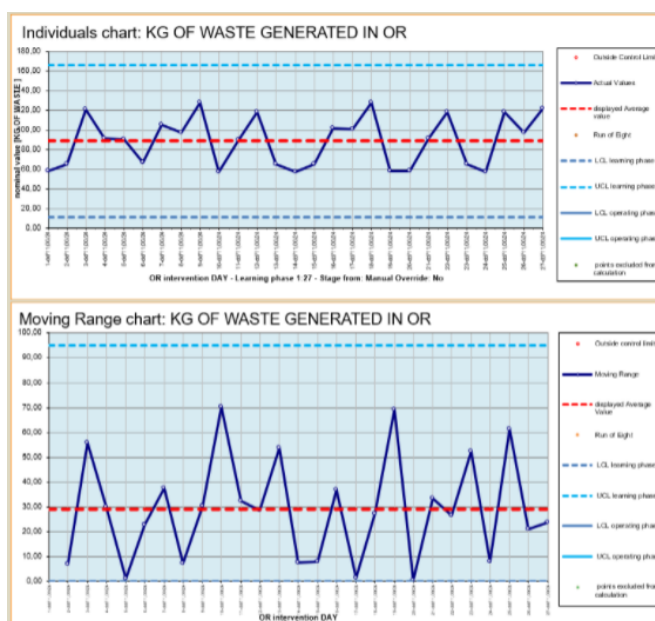


Figure 16 - Individual and moving range control chart and individual chart for kg of waste



For the continuous variable of waste weight, an \bar{X} (X-bar) control chart was employed. This chart tracks the average kilograms of waste produced per surgical procedure (or per day), plotted across successive time intervals.

The center line (CL) represents the process mean, while the upper and lower control limits (UCL and LCL) are calculated based on the standard deviation of the dataset, typically set at three sigma from the mean. This enables the detection of statistically significant shifts or trends in waste volume, such as a gradual increase in disposable material usage or an abrupt spike linked to procedural anomalies or improper bin use. In parallel, a range (R) chart was included to monitor the dispersion within the subgroups, providing insight into variability and consistency of waste output across cases.

For the evaluation of contaminated bins—defined as containers in which waste was not properly segregated according to hospital and regulatory protocols—an attribute control chart was utilized. Specifically, a c-chart was constructed to track the count of contaminated bins per day.

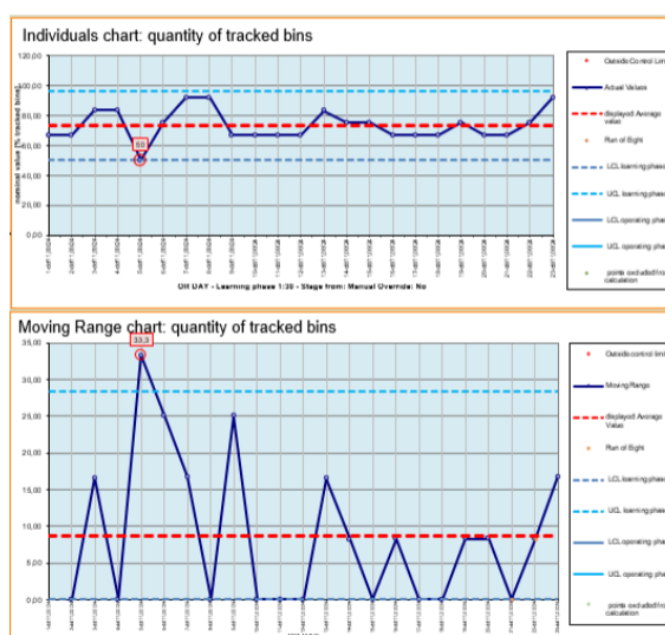


Figure 17 - Individual and moving range control chart for tracked bins

In cases where the volume of procedures varied significantly, a u-chart was alternatively considered to normalize the data by the number of procedures or bins used. These charts allow for the assessment of the frequency and distribution of classification errors, which may result from staff noncompliance, inadequate training, unclear signage, or suboptimal bin placement.

The control charts collectively serve as an essential tool for real-time process surveillance, early warning of deviations, and longitudinal assessment of the effectiveness of waste segregation interventions. When plotted over a defined monitoring period—such as a 30-day surgical cycle—they provide visual evidence of process stability or instability, enabling targeted root cause investigations and the implementation of corrective actions.

This statistical approach is integral to Lean Six Sigma and hospital quality assurance systems, as it links frontline operational metrics with higher-level goals of sustainability, safety, and regulatory compliance.



4.3.5 ANALYZE Phase

4.3.5.1 Ishikawa diagram (cause-effect)

In the domain of non-conformity management, the T-Matrix integrates seamlessly with tools such as root cause analysis, Ishikawa diagrams (Figure 18), helping to isolate the sources of process failure or inefficiency. For instance, if a pattern of improper waste segregation emerges, the matrix can guide investigations toward specific CTQs or procedural gaps, ultimately supporting root cause identification and the deployment of corrective actions within the DMAIC cycle.

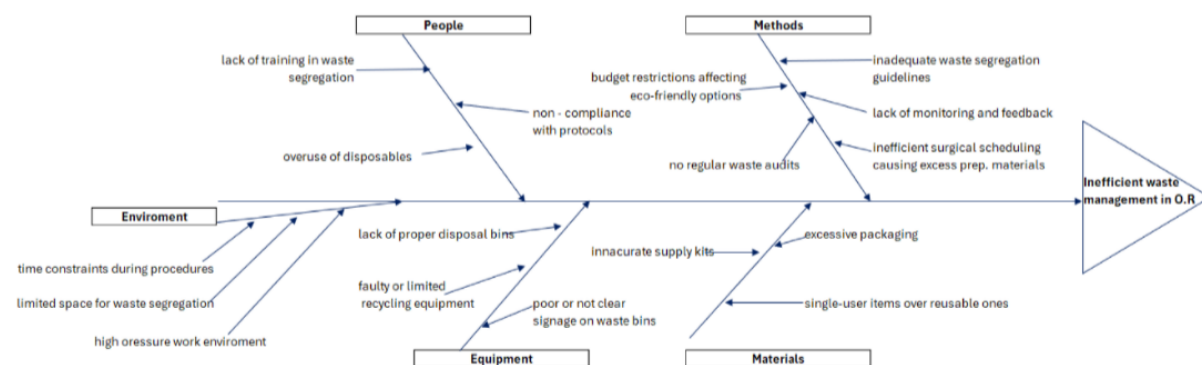


Figure 18 - Ishikawa diagram

Finally, the T-Matrix enables informed decision-making in sustainability strategies, aligning waste management practices with broader institutional goals for environmental stewardship and resource optimization. It empowers teams to not only reduce waste and costs but also to evaluate and communicate the long-term impact of interventions, integrating Lean Six Sigma principles with hospital-wide sustainability and health compliance frameworks.

4.3.6 IMPROVE Phase

4.3.6.1 Progress Decision Program Chart (PDPC)

The Process Decision Program Charts (PDPC) have two main uses: document steps to completing a process and impact analysis. PDPC does this through a systematic exploration of a process and what could go wrong. This is a helpful project management tool in the Improve phase of DMAIC before implementing your plan, but I find it helpful in the Analyze phase after process mapping to check my understanding of the current state.

Within the framework of waste management in operating rooms, the Process Decision Program Chart (PDPC) serves as a proactive planning tool to anticipate operational failures and ensure compliance with clinical, environmental, and safety standards. By mapping out each step of the waste handling process—from segregation at the point of generation to final disposal—the PDPC enables surgical teams and quality managers to identify potential breakdowns or non-conformities.

This method ensures that no critical aspect of the process is overlooked and that contingency plans are developed proactively.

In the context of operating room (OR) waste management, the PDPC plays a pivotal role in ensuring efficient, safe, and sustainable handling of medical waste. The waste management process involves multiple stakeholders—surgeons, nurses, cleaning staff, logistics personnel—and includes highly sensitive material, such as biohazardous waste, sharps, and



pharmaceutical discards. Any failure in this chain can result in regulatory violations, environmental contamination, or increased infection risk for patients and staff.

Common risks may include improper waste segregation, delays in bin replacement, contamination of recyclable materials, or overflow of biohazard containers. For each of these, the PDPC guides the development of targeted countermeasures, such as improved labeling systems, staff training protocols, or real-time monitoring alerts.

The PDPC's application in surgical settings directly supports objectives such as reducing the volume of contaminated waste, optimizing bin turnover times, and maintaining sterile conditions. By embedding risk controls into the workflow, it minimizes disruptions and aligns waste practices with Lean Six Sigma and sustainability principles.

Ultimately, the PDPC enhances the reliability and resilience of operating room waste management. It empowers teams to prevent errors before they occur, reinforces accountability, and contributes to a safer, more efficient surgical environment.

At its core, the PDPC is built as a hierarchical diagram that begins with a clearly defined objective (the goal), followed by the main activities or tasks necessary to achieve that goal. Each task is then expanded with possible problems or failure modes that could obstruct or compromise it. Finally, for each of these potential problems, the PDPC includes countermeasures or preventive actions that can either eliminate the risk or minimize its impact.

To develop a Process Decision Program Charts tailored for use in a waste management process in operating rooms, the following steps are needed:

- 1) Define the Objective or Goal: Clearly state the main goal of the process.
- 2) Identify the Main Activities: Break the process down into major steps or phases. These should reflect key stages of the workflow (Preparation of waste bins before surgery; Waste segregation during the procedure; Post-surgery bin handling; Final transport and disposal)
- 3) Identify Potential Problems for Each Activity: For each main activity, brainstorm what could go wrong. Think of errors, delays, failures, or compliance issues (Incorrect color-coded bin placement; Noncompliant waste segregation by staff; Delayed bin replacement; Spillage during transport)
- 4) Develop Countermeasures: For each problem, define practical and preventive countermeasures. These may be procedural, training-based, or technical (Implement pre-surgery checklist for bin setup; Staff refresher training on waste classification; Assign OR assistant to monitor bin levels; Use sealed transport containers with absorbent pads)

The implementation of a Process Decision Program Chart (PDPC) in operating room waste management represents a strategic step toward ensuring safety, compliance, and operational efficiency. By systematically identifying potential risks and defining targeted countermeasures, the PDPC empowers healthcare teams to proactively address critical issues before they escalate.

This structured approach not only minimizes the likelihood of contamination, misclassification, or procedural delays, but also supports continuous improvement and standardization across surgical workflows. Ultimately, the PDPC fosters a resilient and sustainable waste management system—aligned with Lean Six Sigma principles and responsive to both clinical and environmental responsibilities.

The following image represents the PCPD developed for the specific use case:

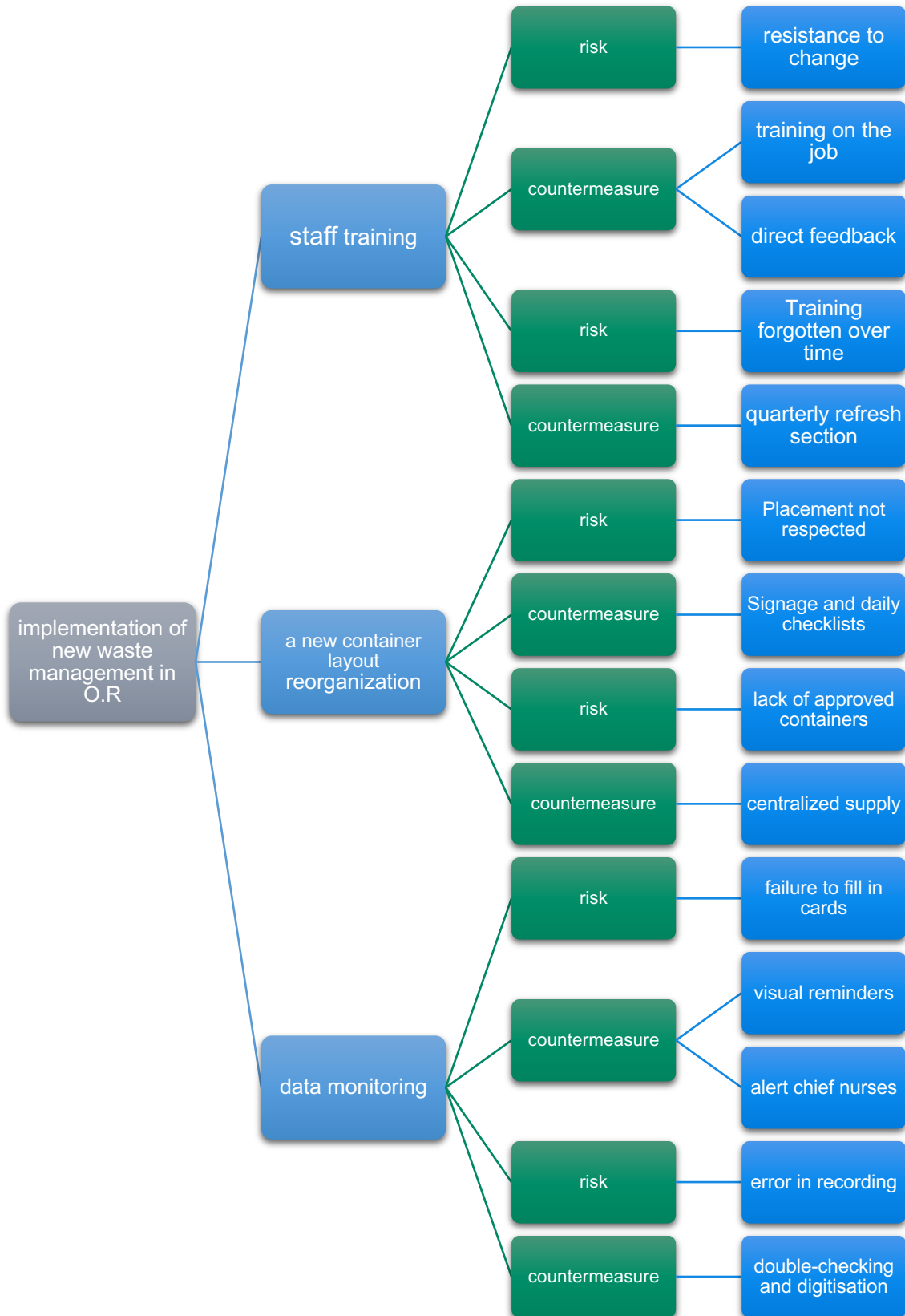


Figure 19 - PDPC



4.3.7 CONTROL Phase

4.3.7.1 5S

5S methodology is a Lean tool focused on workplace organization and standardization to improve efficiency, safety, and quality. It originated in Japan and is widely used across industries, including healthcare.

Each “S” stands for a Japanese term with an English equivalent:

- 1) **Seiri (Sort)**
Eliminate unnecessary items from the workspace. Keep only what is essential.
- 2) **Seiton (Set in order)**
Arrange necessary items for easy access and use. "A place for everything, and everything in its place."
- 3) **Seiso (Shine)**
Clean the workspace regularly to maintain standards and detect problems early.
- 4) **Seiketsu (Standardize)**
Develop consistent procedures and visual standards to maintain the organization.
- 5) **Shitsuke (Sustain)**
Instill discipline and responsibility to maintain and continuously improve the 5S system.

In operating room waste management, applying 5S helps ensure proper placement of waste bins, reduces time spent searching for disposal materials, and maintains hygiene and compliance with infection control standards.

Table 17 - 5s Table

5S Step	Application in OR Waste Management	Impact
1. Sort	Remove unused waste bins, outdated labels, and non-compliant waste materials from the OR.	Reduces clutter, eliminates confusion, ensures only essential bins are available.
2. Set in Order	Position color-coded waste bins (e.g., infectious, non-infectious, sharps) consistently across all ORs.	Improves access, prevents misclassification, shortens time for waste disposal during surgery.
3. Shine	Implement cleaning protocols for bins and surrounding areas before and after each procedure.	Prevents biohazard risks, promotes hygiene, facilitates compliance with infection control.
4. Standardize	Create visual guides and SOPs showing bin placement, waste segregation rules, and proper disposal practices.	Ensures process consistency among all staff and shifts, enabling reliable waste practices.
5. Sustain	Integrate 5S checks into daily routines, assign responsibilities, and conduct regular audits with feedback loops.	Builds habit and accountability, supports long-term process stability and continuous improvement.

4.3.7.2 Visual Management

In the Improve phase of Lean Six Sigma, Visual Management plays a crucial role in reinforcing new process standards, reducing variability, and supporting behavioral change. It uses visual cues, signals, and displays to communicate critical process information at a glance, enabling faster decision-making, improved compliance, and real-time control.

In the context of waste management in operating rooms, Visual Management enhances efficiency and safety by making correct actions obvious and deviations immediately visible. Examples include color-coded waste bins, floor markings indicating proper bin placement, posters illustrating waste segregation rules, and wallboards displaying KPIs like contaminated waste volume or bin turnover times.



These visual tools ensure that all staff—regardless of shift or role—can follow standard procedures without ambiguity. This alignment fosters a culture of accountability and continuous improvement, making Visual Management a key enabler of sustainable gains achieved during the Improve phase.

For the specific use case in cholecystectomy, procedures are conducted in ORs equipped with multiple waste bins for different types of medical waste (infectious, non-infectious, sharp objects).

Listed below are Operating Room Visual Management applications:

- Color-coded bins with large icons and bilingual labels (e.g., *Red = Infectious, Yellow = Sharps, Black = General Waste*).
- Wall-mounted posters above each station, displaying waste segregation rules with pictograms (e.g., what goes where).
- Floor markings and bin placement standardization to ensure every OR has the same spatial layout.
- Real-time fill-level indicators (colored tags or digital sensors) showing when bins are near capacity to avoid overflow.

Results:

- Faster and more accurate waste disposal by nurses and surgical staff.
- Fewer incidents of misclassified waste (tracked by audits).
- Improved audit scores for sustainability and safety compliance.

Table 18 - Visual management

Function	Description	Actions	Impact
Standardization Reinforcement	Visual cues help staff follow standardized waste handling procedures.	Posters above bins showing what waste goes where (e.g., infectious vs. recyclable).	Reduced errors in waste segregation. Reinforces SOPs
Error Prevention	Visual signals reduce the chance of mistakes.	Coloured bin lids and signs prevent misclassification (e.g., no sharps in general waste).	Faster and more accurate sorting
Workflow Optimization	Floor markings and layout guides optimize movement and access.	Marked zones for bin placement improve waste disposal speed during surgery.	Increase compliance Reduces confusion under pressure
Real-Time Feedback	Dashboards and visual KPIs alert staff to anomalies or delays.	Best OR Waste Management	Prevents overflow Support timely emptying
Team Alignment & Engagement	Visual tools keep everyone informed, reducing variation among staff.	Posters above bins showing what waste goes where (e.g., infectious vs. recyclable).	Drives continuous improvement

4.3.7.3 Standardize

In the Control phase, "*Standardize*" refers to the process of documenting and institutionalizing the improved procedures identified, to ensure they are consistently applied, sustained over time, and reproducible across all shifts or teams.



Though not formally part of the DMAIC acronym, standardization is central to the Control phase, which aims to maintain the gains achieved during process improvement. Standardization plays a crucial role in enhancing organizational efficiency and effectiveness. By preventing regression to previous inefficient practices, it ensures that the organization consistently moves forward with improved methods.

Consistency across staff, shifts, and departments is maintained, which is essential for delivering reliable and high-quality services. Additionally, standardization facilitates the training and onboarding of new personnel, making it easier for them to adapt and perform their roles effectively. Moreover, it creates a solid foundation for continuous improvement, allowing the organization to build upon established practices and innovate further.

Standardization tools in Lean Six Sigma are essential for maintaining consistency and efficiency within an organization.

- **Standard Operating Procedures (SOPs):** provide step-by-step instructions to ensure tasks are performed correctly and uniformly.
- **Standard Work Sheets:** define tasks, sequences, and timing, ensuring that work is carried out in a structured manner.
- **Control Charts:** are used to monitor stability over time, allowing for the identification of any deviations from the norm.
- **Checklists and Audit Forms:** are crucial for compliance verification, ensuring that all processes meet the required standards.

Together, these tools contribute to a more organized, efficient, and effective operational environment

A Standard Operating Procedure (SOP) is a documented set of step-by-step instructions that outline how to carry out a specific task or process consistently and safely.

It ensures that procedures are performed correctly, uniformly, and in compliance with regulatory standards. In the context of Operating Room Waste Management, an SOP may describe how to correctly segregate waste into color-coded bins, who is responsible for replacing full containers, how often audits are performed, and how to report anomalies such as incorrect disposal or contamination.

The purpose of an SOP is to ensure consistency across staff shifts, reduce human error, improve safety and compliance, and support training and onboarding.

An SOP may describe:

- How to correctly segregate waste into color-coded bins
- Who is responsible for replacing full containers
- How often audits are performed
- How to report anomalies (e.g., incorrect disposal or contamination)
- Purpose
- Ensure consistency across staff shifts
- Reduce human error
- Improve safety and compliance
- Support training and onboarding

The following table shows a template of SOP:



Table 19 - SOP Template for Operating Room

Standard Operating Procedure (SOP)	
Title: Surgical Waste Disposal in Operating Rooms	
Department: Operating Room n. [insert n. of O.R]	
Effective Date: [Insert Date]	
Revision #: 01	
Approved by: [Insert Name/Title]	
<p>i. Purpose</p> <p>To ensure correct, safe, and standardized disposal of surgical waste, minimizing risk of contamination, improving sustainability, and ensuring regulatory compliance.</p>	
<p>ii. Scope</p> <p>This SOP applies to all personnel involved in waste handling and disposal during and after surgical procedures in the operating rooms of [Hospital Name].</p>	
<p>iii. Responsibilities</p> <ul style="list-style-type: none"> - Nursing Staff: Perform immediate disposal and segregation during procedures. - Surgical Assistants: Assist with accurate classification and placement of waste. - Cleaning Staff: Ensure timely removal and replacement of full bins post-procedure. - Environmental Supervisor: Monitor compliance, provide training, and perform audits. 	
<p>iv. Materials and Equipment</p> <ul style="list-style-type: none"> - Red bins: Infectious waste - Yellow bins: Sharps - Black bins: General waste - Biohazard bags - PPE: gloves, mask, gown - Visual posters for reference 	
<p>v. Procedure</p> <ol style="list-style-type: none"> a) Before Surgery <ul style="list-style-type: none"> • Verify bins are empty, clean, and correctly labeled and placed. • Ensure signage is visible and undamaged. b) During Surgery <ul style="list-style-type: none"> • Immediately dispose of materials into correct bin using visual guides. • Do not overfill containers. c) After Surgery <ul style="list-style-type: none"> • Seal and remove full containers using proper PPE. • Replace with new, labeled containers. • Report any misclassification or overflow. d) End of Shift <ul style="list-style-type: none"> • Check for compliance. • Document discrepancies or incidents in waste log. 	
<p>vi. Documentation</p> <ul style="list-style-type: none"> • Waste Disposal Log • Incident Report Forms • Audit Checklists 	
<p>vii. References</p> <ul style="list-style-type: none"> • WHO Guidelines on Healthcare Waste • Local waste management legislation • Internal hospital waste segregation policy 	



4.3.7.4 Review

While "Review" is not officially recognized as a standalone phase in the standard DMAIC cycle, it is a critical activity embedded within the Control phase. This activity involves systematically assessing the improved process to ensure that the gains achieved are sustained over time. The review process focuses on maintaining stable performance and identifying any deviations that may require corrective actions.

By regularly evaluating the process, organizations can verify that the improvements are consistently applied, key performance indicators (KPIs) are met, and there is no regression to previous inefficient practices. The review also helps in identifying early warning signs of deviation, ensuring that the process continues to operate at the desired level of performance. The Table 20 indicates reviewed actions that have helped to identify variations in this final phase.

Table 20 - Reviewed actions for waste management in OR

Area	Reviewed actions
Process Adherence	Are staff using the correct bins? Are SOPs followed during procedures?
Performance Metrics	Has the contaminated waste volume decreased? Are fill times within limits?
Visual Controls	Are visual aids/posters in place and legible? Are color codes respected?
Audit Results	Do weekly audits show sustained compliance? Are errors recurring?
Environmental Indicators	Has the CO ₂ impact from misclassified waste been reduced?
Training and Competency	Are staff trained on new procedures? Do they pass re-certification if required?

This structured evaluation is essential for continuous improvement, allowing organizations to build upon established practices and innovate further and is crucial for maintaining stable performance and identifying any deviations that may require corrective actions.

By regularly assessing the process, organizations can verify that the improvements are consistently implemented, ensuring that the process continues to operate at the desired level of performance.

A good review process in the Control phase of Lean Six Sigma ensures that sustained improvements are confirmed, risks or drifts in process compliance are identified, and plans for continuous improvement or transfer to other departments are established. This structured evaluation is crucial for maintaining stable performance and identifying any deviations that may require corrective actions.

By regularly assessing the process, organizations can verify that the improvements are consistently implemented, ensuring that the process continues to operate at the desired level of performance. This structured evaluation is essential for continuous improvement, allowing organizations to build upon established practices and innovate further.



Table 21 - Review Template for Operating Room

Control Phase Review Checklist – Lean Six Sigma
Process: Operating Room Waste Management
Department: Operating Room n. [insert n. of O.R]
Review Date: [Insert Date]
Reviewed by: [Insert Name/Title]
1. Process Adherence <ul style="list-style-type: none"> • Are correct waste bins used in all ORs? [Yes / No] • Are staff following standard operating procedures (SOPs)? [Yes / No] • Are visual management tools (e.g., posters, bin labels) clearly visible and up-to-date? [Yes / No]
2. Performance Metrics <ul style="list-style-type: none"> • Contaminated waste (kg/procedure): _____ • Average bin fill time (minutes): _____ • CO₂ reduction estimate (kg): _____ • Recyclable waste correctly segregated (%): _____
3. Training & Competency <ul style="list-style-type: none"> • Have all relevant staff been trained on updated procedures? [Yes / No] • Are training records up to date? [Yes / No] • Is refresher training scheduled? [Yes / No]
4. Audit & Monitoring <ul style="list-style-type: none"> • Are regular audits conducted and documented? [Yes / No] • Are audit results showing sustained compliance? [Yes / No] • Are non-compliances addressed with follow-up actions? [Yes / No]
5. Continuous Improvement <ul style="list-style-type: none"> • Are opportunities for further improvement identified? [Yes / No] • Are improvement suggestions documented and tracked? [Yes / No] • Feedback from OR staff collected and reviewed? [Yes / No]

5 Ethical and data privacy aspects

No patients were involved in the execution or validation of this use case.

All activities were conducted within the operational and environmental management scope of the surgical area, without the collection, processing, or storage of personal health data.

As such, no identifiable patient information was accessed or used at any stage of the study.

The methodology fully complies with applicable data protection regulations, including the principles of the General Data Protection Regulation (GDPR), and maintains a strict focus on operational processes, environmental outcomes, and staff behavioral compliance.

Ethical safeguards were upheld to ensure that the project remained within the boundaries of organizational quality improvement and sustainability efforts, without ethical implications for patient care or confidentiality.



6 Conclusion

The application of the Green Lean Six Sigma (GLSS) methodology to surgical waste management within the operating rooms (ORs) of Policlinico Gemelli represents a pivotal step toward integrating process optimization, sustainability, and regulatory compliance in a high-risk, high-intensity healthcare environment. ORs are among the most waste-intensive areas of hospitals, producing a disproportionate amount of hazardous and mixed waste due to the strict sterility requirements, time-sensitive procedures, and lack of waste classification awareness under clinical pressure.

The deployment of a structured, data-driven methodology such as GLSS enabled the systematic identification, analysis, and mitigation of inefficiencies in waste segregation and disposal.

Through a meticulous execution of the DMAIC cycle (Define–Measure–Analyze–Improve–Control), the project produced verifiable improvements across environmental, operational, and human dimensions.

The effort focused not merely on reducing waste quantities but on reshaping behaviors, standardizing workflows, and creating a resilient system of continuous improvement grounded in Lean principles and Six Sigma discipline.

Improved Segregation and Environmental Performance

The primary outcome of the intervention was a significant improvement in the accuracy of waste segregation during and after cholecystectomy procedures. Pre-intervention data revealed that a substantial portion of clean or recyclable materials—such as packaging, non-infectious disposables, and paper—were improperly disposed of in red-labeled contaminated waste bins. As a result, the volume of infectious waste was artificially inflated, increasing both incineration costs and associated environmental impact.

By introducing color-coded bins, icon-based bilingual labeling, and standardized placement within the ORs, and reinforcing these elements with visual guides and training modules, the rate of misclassification was dramatically reduced.

This led to a notable reduction in kilograms of contaminated waste per procedure, with direct consequences for lower CO₂ emissions, less incineration load, and an overall improvement in the hospital's environmental performance indicators.

Standardization and Time Optimization

Standardization played a pivotal role in improving daily waste management routines. Prior to the intervention, inconsistencies in bin type, labeling, and layout contributed to confusion and delays in disposal, particularly during high-pressure procedures.

The project implemented a standard bin configuration for all ORs, with designated positions, color alignment, and clear visual instructions.

This spatial and procedural standardization contributed to:

- A shorter average time required for sorting waste, especially during cleanup and turnover phases;
- Lower error rates across different shifts and personnel;
- Increased confidence and autonomy among staff, as the process became more intuitive and less reliant on verbal instruction or memorization.

These efficiencies not only benefited the waste management process but also supported broader surgical performance metrics, including reduced turnaround time and smoother workflow transitions between procedures.



Behavioral Engagement and Cultural Change

One of the key insights gained during implementation was the importance of behavioral consistency and staff engagement.

The success of any Lean Six Sigma intervention in a clinical setting depends heavily on human factors. In this project, nursing teams, surgical technicians, and cleaning staff were involved from the beginning, not only through observation and audit but also as active participants in idea generation, root cause analysis, and solution prioritization.

Targeted training sessions, combined with daily use of SOPs and on-site visual prompts, helped embed the new waste segregation habits. Staff demonstrated increased ownership of the waste management process, and follow-up surveys indicated higher levels of understanding and commitment to the best environmental practices.

Control and Long-Term Sustainability Tools

To sustain the improvements and ensure replicability, two critical control instruments were developed:

1. **Waste Disposal Procedure Checklist**
This checklist is now used before and after each surgical session to verify bin setup, label visibility, compliance with waste classification rules, and readiness of the waste station. It acts as a daily tool for frontline teams and as a compliance verification mechanism for supervisors.
2. **Review Action Template**
This template is used monthly by the Environmental Services Quality Team to track:
 - Volume of contaminated waste per procedure
 - Time to fill bins
 - CO₂ emission estimates
 - Training compliance
 - Audit scores and trends over time
 - Deviation reports and corrective actions

Together, these tools establish a feedback-controlled loop that not only maintains process stability but actively encourages performance review and adaptive learning.

Strategic and Systemic Impact

The outcomes of this project transcend the immediate scope of waste handling. It provides a validated model for how operational excellence, staff empowerment, and environmental sustainability can be pursued simultaneously within complex hospital systems. The methodology and tools developed are now considered scalable to other surgical units and replicable across hospital networks, with minimal adaptation required.

In addition to quantitative gains—such as reduced contaminated waste and emissions—the intervention produced qualitative improvements in organizational culture, with teams now more aware of the environmental implications of their daily routines.

The experience reinforced the notion that environmental stewardship is not external to clinical care but a fundamental aspect of responsible, modern healthcare delivery.

Furthermore, the tools and frameworks developed are scalable and transferable to other surgical units or hospital departments.

The structured methodology allows replication, continuous monitoring, and iterative refinement—key attributes for long-term cultural and organizational change in healthcare waste management.



Table 22 - Conclusion Summary of the OR Use Case

Result Area	Impact
Waste Segregation	Misclassification reduced; increased bin accuracy across all ORs
CO ₂ Emissions	Lower emissions due to a reduction in contaminated waste requiring incineration
Time Optimization	Less time needed for sorting and post-op cleanup due to standardized setup
Staff Behavior	Higher compliance and engagement through visual tools and targeted training
Long-Term Control	SOPs, audit templates, and review checklists are institutionalized

This Green Lean Six Sigma use case serves as evidence that when process improvement is aligned with sustainability and people-centered design, healthcare systems can advance not only in clinical outcomes, but in environmental responsibility and institutional resilience.

It is possible to say that the GLSS-HC methodology described in this document complies with the requirements and the key standards indicated in D2.1- Report on requirement definition. Here below in Table 23 a summary is provided.

Table 23 - Summary of compliance with D2.1 requirements

Requirement/Standards	How GLSS-HC satisfies the requirement
Make sure that GLSS-HC methodology is well integrated with the methodologies developed in WP3 and described in <i>D3.1- Model of the knowledge sharing and decision support system-v1</i>	GLSS-HC uses the environmental factors and cost categories exposed in D3.1; refers to the CSRD report as a possible source; refers to the Open LCA as environmental impact calculator
Include the Patient-Reported Experience Measures (PREMs) and Patient-Reported Outcome Measures (PROMs) in the set of KPIs to assess the process performance.	PROMs-Patient-Reported Outcome Measures and PREMs-Patient-Reported Experience Measures are captured in the Quadruple Aims about “improving population health” (corresponding to the PROMs) and “enhancing patient experience” (corresponding to the PREMs)
Define HC-specific methods to engage operators in the business process reengineering activities	A key issue in the HC is the healthcare operators’ lack of time for attending meetings not strictly contributing to their operational tasks. And are not normally knowledgeable about management/organization science. The use of the artifacts help and of terms near to their profession may facilitate their involvement in brainstorming sessions. Moreover, the ENGAGE facilitation methods (described in <i>D4.4- Participatory staff engagement model-v1</i>) could be integrated with the GLSS-HC methodology to get productive staff involvement in the DMAIC stages
Leverage the already available information not only from administrative systems but also from healthcare-specific and energy/facility management systems	GLSS-HC artifact <i>B.4-Typical reports available in a Hospital</i> satisfies this requirement
Standards: <ul style="list-style-type: none"> ISO 14044: 2006 - Environmental management – Life Cycle 	The GLSS-HC complies with clause 9-Performance Evaluation of the ISO 7101:2023 , expanding the indicators currently used by the HCOs to cover the



<p>Assessment – Requirements and guidelines</p> <ul style="list-style-type: none"> • ISO 7101:2023 Healthcare organization management — Management systems for quality in healthcare organizations — Requirements 	<p>new important aspect of the environmental sustainability, as required by the CSRD.</p> <p>The GLSS-HC complies with the ISO 14044: 2006 because adopts the LCA methodology for the evaluation of the environmental impacts</p>
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The GLSS-HC can contribute to the Knowledge Sharing System, under development in Task 3.1., providing a framework to capture knowledge about methods and for reducing the environmental impact of the HCOs.

After M18, the validation, by M 32, when the final version of the methodology is due, will regard both the framework and the inputs from ChatGPT.

The validation will take into account the results of the three use cases (FPG, FHAG and UKHD) and will leverage the healthcare expertise of all the 5 HCOs partnering CARING NATURE (FPG, FHAG, UKHAD, WPH, 7HRC).

A survey involving the Reference Stakeholder Group will also be launched to get their feedback.

The document has taken inputs from *D2.1-Report on requirement definition* (the requirements and reference standards) and *D3.1-Model of the knowledge sharing and decision support system-v1* (the LCA approach, the environmental impact factors, other indicators)

It provides input to *D4.7- Green Lean Six Sigma methodology for health and care-v2* (due at M32), where the final version of the GLSS-HC methodology will be described and *D6.1-Validation report* (due at M30), where the three GLSS-HC use cases will be reported.

It may also provide input to *D3.3-Model of the knowledge sharing and decision support system-v2* (due at M32), in case the GLSS-HC is adopted among the frameworks to capture the knowledge.



Bibliography

Ali M. (2023). Lean Six Sigma Body of Knowledge for Healthcare Industry Administrators: Implementation of Lessons Learned in Applied Engineering. *Journal of Technology Studies*, 48(1), 18–32.

Alkainaidri A. et al (2018) Improving Healthcare Referral System Using Lean Six Sigma, *American Journal of Industrial and Business Management*, 8, 193-206

Alnemer R. et al. (2022). The Role of Medical Technology in Improving Healthcare Quality: A Critical Review. *EPH-International Journal of Medical and Health Science* 8.3 (2022): 1-9.

Ashmore S., Ruthven T. (2015). Using root cause analysis techniques in clinical audit, A collaborative document produced by the Healthcare Quality Improvement Partnership (HQIP) and Clinical Audit Support Centre (CASC), ISBN NO 978-1-907561-06-1

Bodenhimer T. et al. (2014), From Triple to Quadruple Aim: Care of the Patient Requires Care of the Provider, *ANNALS OF FAMILY MEDICINE*, VOL. 12, NO. 6, , NOVEMBER/DECEMBER 2014

D2.1-Report on requirement definition, CARING NATURE deliverable, 28/06/2024

D3.1- Model of the knowledge sharing and decision support system-v1, CARING NATURE deliverable, 31/03/2025

De Belvis A.G.et al., (2021). How to define a quadruple aim framework to assess value in critical pathway of the patients with *Clostridioides difficile* infection, *European Review for Medical and Pharmacological Sciences*, 2021; 25: 4597-4610

Delleci Y. (2023) Lean Six Sigma: A New Powerful Process Improvement Methodology. *The Journal of research and scientific studies*.

EC (2010). European Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010

EU Commission, Green Forum. Life Cycle Assessment & the EF methods-Comprehensive coverage of impacts, https://green-business.ec.europa.eu/environmental-footprint-methods/life-cycle-assessment-ef-methods_en

Ferreira D. et al. (2022). Ferreira, David, and Pedro Cunha. Ranking Critical Tools in the Implementation of Lean Six Sigma as an Integrated Management System in Portugal., arXiv preprint arXiv:2212.00088 (2022)

George M. L. (2003). *Lean Six Sigma for Service: How to Use Lean Speed and Six Sigma Quality to Improve Services and Transactions*, McGraw-Hill, ISBN 0-07-141821-0

ISO 14044, 2006. ISO 14044: 2006 - Environmental management – Life Cycle Assessment – Requirements and guidelines

McDermott O. (2022). Lean Six Sigma in Healthcare: A Systematic Literature Review on Motivations and Benefits. *Processes*. 10, 1910.



Niemeijer G. C. et al (2012), The usefulness of lean six sigma to the development of a clinical pathway for hip fractures, *Journal of Evaluation in Clinical Practice* 19 (2013) 909–914

Sijm-Eeken M. et al., 2024. Implementation of Green Lean Six Sigma in Dutch Healthcare: A Qualitative Study of Healthcare Professionals' Experiences, *Nurs. Rep.* 2024, 14, 2877–2895. <https://doi.org/10.3390/nursrep14040210>

Sohal A. et al (2022), Success factors for lean six sigma projects in healthcare, *Journal of Management Control*

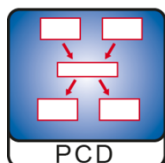
SSGI-Six Sigma Global Institute (accessed 16 March 2025) Which Industries Benefit from Lean Six Sigma? <https://www.6sigmacertificationonline.com/which-industries-benefit-from-lean-six-sigma/>

WHO, (2020). *Diagnosis-related groups (DRG): A Question & Answer guide on case-based classification and payment systems/* Aurelie Klein, Inke Mathauer, Karin Stenberg, Triin Habicht, editors.



Annex A-Tools

A.1 Problem Context Diagram (PCD)



Definition and purpose

A Project Context Diagram (PCD) visually represents the interactions between a system and its external environment. It shows how the system interacts with other actors, data stores, and external systems.

PCDs are used early in a project to help for

- **Scope Definition:** PCDs help define the boundaries of the system by identifying the external entities it interacts with.
- **Requirement Gathering:** They aid in identifying both functional and non-functional requirements by showing how the system interacts with its environment.
- **Communication:** PCDs serve as a communication tool, allowing stakeholders (technical and non-technical) to understand the system's scope and interactions.
- **Stakeholder Identification:** They can help identify and categorize stakeholders involved in the project.
- **Understanding the System:** PCDs offer a simplified, high-level view of the system's operations, making it easier to grasp the overall picture.

Key elements

A PCD helps visualize the system's boundaries, its interactions with the external world, and the data or information flowing between them, providing a clear and concise overview of the system's context. It includes following components:

- **System:** the central focus of the diagram, representing the system or component being analysed.
- **External Entities:** other actors, systems, or databases that interact with the system.
- **Data Flows:** arrows that show the direction of data or information exchange between the system and external entities.
- **Relationships:** visual representation of how the system interacts with its environment, including data flows, control flows, and other interactions.

A.2 Charter



Definition and purpose

A project charter is a document that formally initiates a project, providing project managers with the authority to use organizational resources and outlining the project's purpose, scope, and key objectives.



It serves as a foundational document, clarifying roles, responsibilities, and a shared understanding of the project's goals, supporting

- **Formal Authorization:** It officially authorizes the project to begin.
- **Shared Understanding:** It creates a common understanding of the project's purpose, scope, and goals among stakeholders.
- **Project Planning Foundation:** It serves as a foundation for developing a more detailed project plan.
- **Decision-Making Guide:** It provides a reference point for decision-making throughout the project.
- **Risk Management:** It can help identify and address potential risks early on.
- **Communication:** It facilitates communication among stakeholders and ensures everyone is on the same page.

Key elements

- **Project Title:** A clear and concise name for the project.
- **Project Purpose/Justification:** Explains why the project is being undertaken and its expected benefits.
- **Project Objectives:** Specific, measurable goals the project aims to achieve.
- **Project Scope:** Defines the boundaries of the project, including what is included and excluded.
- **Project Deliverables:** Tangible products or services the project will produce.
- **Project Stakeholders:** Lists individuals or groups with a vested interest in the project.
- **Project Timeline:** High-level overview of the project schedule.
- **Project Budget:** An estimate of the resources needed.
- **Roles and Responsibilities:** Defines who is responsible for what tasks.
- **Project Manager's Authority:** Specifies the project manager's authority level.
- **Project Sponsor:** Identifies the individual or group supporting the project.

A.3 Contract



Definition and purpose

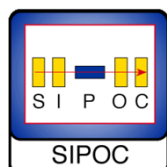
A team contract, also known as a team agreement or charter, is a document collaboratively created by team members to outline the expectations, responsibilities, and guidelines for how the team will work together. It serves as a reference point for the team, helping to clarify roles, communication protocols, and conflict resolution processes, ultimately fostering a more productive and collaborative environment.



Key elements

- Purpose: To establish a shared understanding and agreement among team members about how they will work together, including expectations, roles, responsibilities, and norms.
- Content: Team goals and objectives: What the team aims to achieve.
- Individual responsibilities: What each team member is expected to contribute.
- Benefits: Clear expectations: Everyone knows what's expected of them.
- Improved collaboration: Teams are more likely to work together effectively.
- Reduced conflict: Clear expectations and guidelines can minimize misunderstandings and disputes.
- Increased accountability: Team members are more likely to take ownership of their responsibilities.
- Stronger team cohesion: Shared understanding and agreement can build stronger team bonds.
- Meeting times and communication protocols: How the team will communicate and coordinate their work.
- Decision-making processes: How the team will make decisions.
- Conflict resolution procedures: How the team will address disagreements and conflicts.
- Ground rules and norms: Expectations for behaviour and conduct.

A.4 SIPOC



Definition and purpose

A SIPOC diagram is a tool that visually documents a business process from start to finish, highlighting key elements: Suppliers, Inputs, Process, Outputs, and Customers. It helps teams understand a process, agree on a common language, and identify areas for improvement.

SIPOC diagrams are often used in Lean Six Sigma process improvement projects. They provide a high-level overview, enabling decision-makers to quickly grasp the process and identify potential bottlenecks or areas for streamlining.

Key elements

SIPOC diagrams are particularly useful for mapping and clarifying the relationships between these elements

- Suppliers: The entities providing inputs to the process.
- Inputs: The resources or materials used by the process.
- Process: The steps or activities that transform inputs into outputs.
- Outputs: The results or products of the process.
- Customers: The recipients of the process outputs.



A.5 Linear Flowchart



Definition and purpose

A tool that describes the sequence of steps in a process. Helps to view the work steps and decisions needed to complete a process

A linear flowchart visually represents a process by depicting a straight-line sequence of steps, from beginning to end, with minimal branching or decision points. It's a simple and easy-to-understand way to illustrate a process with a clear, step-by-step path.

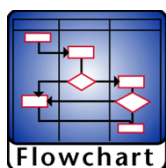
Key elements

- Purpose: Shared and agreed overview of a process
- Visually displays the sequence of activities
- Shows the boundaries of a process
- Identifies the essential steps
- Helps identify quality concerns

Steps to create a linear chart

1. Begin by identifying what triggers the start of the process
2. Establish what signals the process has been completed
3. Establish the first and last steps (scope!)
4. Describe each major activity using a verb followed by a noun if possible

A.6 Integrated flowchart



Definition and purpose

An integrated flowchart is a type of flowchart that visually represents a process or system that involves multiple interconnected parts or components. It's a way to illustrate how different elements work together to achieve a specific outcome. Essentially, it's a flowchart that highlights the integrated nature of a process, showing how inputs, processes, and outputs are linked

Key elements

- Multiple Components: It typically depicts several distinct parts or modules that are interacting within the overall system.



- **Data Flow:** It visually shows how information or materials move between different components or processes.
- **Interdependencies:** It clarifies the relationships and dependencies between the various parts, illustrating how changes in one area can impact others.
- **Decision Points:** It may include decision points or branching scenarios to show how different paths or outcomes can arise within the integrated system.
- **Integration Focus:** The primary focus is to demonstrate the interconnectedness and collaborative nature of the process, rather than simply outlining individual steps.

A.7 8 Waste



Definition and purpose

The tool provides 8 categories of waste. The wastes, in the LSS language are activities or resources that do not add value to the customer but consume resources and time.

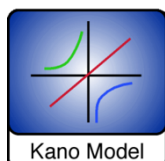
Understanding and addressing these wastes is crucial for improving efficiency, reducing costs, and increasing customer satisfaction in any process, not just in manufacturing.

Key elements

The 8 categories of waste are:

- **Defects:** Production that does not meet quality standards, requiring rework, repair, or disposal.
- **Overproduction:** Producing more than what is needed or ahead of customer demand.
- **Waiting:** Idle time of people, equipment, or materials, due to lack of synchronization or bottlenecks.
- **Non-Utilized Talent:** Failing to engage employees' knowledge and skills, or using them for tasks they are not best suited for.
- **Transportation:** Moving materials or goods unnecessarily, causing delays or damage.
- **Inventory:** Excess stock of raw materials, work-in-progress, or finished goods, tying up capital and space.
- **Motion:** Unnecessary movements of people, equipment, or machinery during the work process.
- **Extra Processing:** Performing additional steps or operations beyond what is required by the customer or necessary to meet quality standards.

A.8 Kano Model





Definition and purpose

The Kano Model is a framework used for understanding and prioritizing product/service features based on their impact on customer satisfaction. The model categorizes the features into different levels, and mechanism, of customer satisfaction, which helps in prioritizing features that are most likely to delight or dissatisfy customers.

Key elements

It classifies features into categories based on their impact on customer satisfaction, including:

- **Must-haves:** These are basic features that customers expect to be present in a product or service. If these features are not present, customers will be dissatisfied.
- **Performance features:** These features directly impact customer satisfaction and dissatisfaction. The more these features are present, the higher the satisfaction.
- **Delighters:** These are features that can create a positive emotional experience for the customer and lead to increased satisfaction beyond expectations.

It helps teams prioritize features by understanding their potential for satisfaction or dissatisfaction. It allows to focus on features that are most likely to delight customers or avoid causing dissatisfaction.

It works going through three steps:

- **Customer Input:** The model typically involves gathering customer feedback on different product features using surveys or interviews.
- **Analysis:** The collected data is analysed to identify which features fall into each category (must-haves, performance features, or delighters).
- **Prioritization:** Based on the analysis, teams can prioritize feature development efforts, focusing on features that are most likely to create a positive customer experience.

Benefits:

- **Improved Product/Service Development:** Helps teams prioritize features based on customer needs and preferences.
- **Increased Customer Satisfaction:** Focuses on creating features that are likely to delight customers and meet their expectations.
- **Resource Optimization:** Allows teams to allocate resources effectively by focusing on features that have the greatest impact on customer satisfaction.
- **Enhanced Business Outcomes:** By focusing on customer satisfaction, the Kano Model can help improve product quality, increase customer loyalty, and drive business growth.

A.9 T- Matrix



Definition and purpose

T-matrix is a type of matrix diagram used to analyse the relationships between three sets of elements. It's a flipped L-matrix, where one primary list (like products) is compared to two other



lists (e.g., organization in scope and customers), but the relationship between the two lists (organization in scope and customers) is not directly analysed.

In Lean Six Sigma: T-matrix diagrams are tools used to identify relationships between process inputs, outputs, and other factors. They help in understanding cause-and-effect relationships and identifying areas for improvement.

Key elements

- Three groups: It compares one main group with two other groups, but not the two groups with each other.
- Primary list in the centre: The main list is placed in the middle, and the other two lists are positioned on either side.
- Visualization of relationships: The matrix visually represents the relationships between the elements of the three groups, with symbols indicating the presence and the strength of the relationship
- Used for identifying connections: It helps to understand how elements in one group relate to elements in the other two, revealing potential areas for improvement.

A.10 Data Collection



Definition and purpose

Data collection helps define the current state of the process (baseline) and provide evidence for improvement efforts.

It allows

- Quantifying the problem: By measuring key process parameters, data helps describe the problem and understand its scope.
- Identifying process variations: Data collection helps identify the sources of variation within the process, which can be used to pinpoint areas for improvement.
- Tracking progress: Data collected throughout the project can be used to track the impact of changes and validate the success of improvement initiatives.
- Supporting decision-making: Data provides the foundation for informed decisions throughout the Lean Six Sigma project.

Key elements

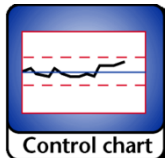
Data Collection methods include

- Checklists: Used to track specific steps or tasks in a process and identify deviations or non-conformances.
- Surveys: Used to gather data on customer satisfaction, employee perceptions, or other relevant areas.
- Measurements: Using tools like gauges, scales, or other measuring instruments to collect quantitative data.
- Observations: Observing process activities or interactions to gather information.



- Document review: Analysing existing documents, records, or reports to extract relevant data. "

A.11 Control Chart



Definition and purpose

A control chart is a graphical tool used to monitor a process's stability and performance over time. It helps identify when a process is operating within expected parameters or when there are indications of special cause variation that require investigation.

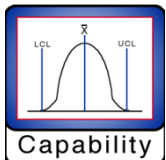
It supports:

- Process Monitoring: Control charts are essential for monitoring process stability, ensuring consistent performance.
- Identifying Out-of-Control Conditions: Points that fall outside the control limits indicate a potential issue requiring investigation.
- Root Cause Analysis: If a process is out of control, the control chart can help identify potential causes and trigger root cause analysis.
- Continuous Improvement: By tracking process performance and identifying areas for improvement, control charts support continuous process improvement efforts.

Key elements

- Data Plotting: It displays data points collected over time, illustrating how a process changes.
- Control Limits: Upper and lower control limits (UCL and LCL) are established, representing the natural boundaries of acceptable variation.
- Center Line: A center line shows the average or target value of the process.
- Visual Aid: The chart helps visually distinguish between common cause variation (normal fluctuations) and special cause variation (unusual deviations).

A.12 Capability Analysis



Definition and purpose

Capability analysis is a statistical method used to assess a process's ability to meet customer requirements and specifications. It quantifies how well a process performs against defined tolerance limits, providing insights into its potential and actual performance levels. This analysis is crucial for identifying areas for improvement and optimizing processes for better quality and efficiency.

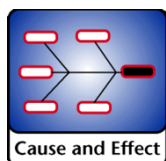
Capability analysis helps determine the true capability of a process and estimate the proportion of product that may not meet specifications. It also allows organizations to compare their quality levels and allocate resources effectively.



Key elements

- Process Capability Index (Cp, Cpk): These indices compare the process spread to the tolerance limits, indicating how well a process is centered and its ability to produce parts within the tolerance range.
- Sigma Level: A measure of the defect rate, with higher sigma levels indicating lower defect rates.
- Defects Per Million Opportunities (DPMO): Another metric for measuring defect rates, often used in the context of Six Sigma.
- Benefits:
 - Quantifiable Performance: Provides a clear understanding of process performance in relation to customer requirements.
 - Opportunity Identification: Helps pinpoint areas where process variation or non-conformance is occurring.
 - Improvement Strategies: Provides data-driven insights to guide process improvement efforts.
 - Lean Six Sigma Integration:
 - Capability analysis helps define the problem, gather data, and identify root causes for process variation.

A.13 Cause-Effect Diagram



Definition and purpose

In Lean Six Sigma, a Cause and Effect Diagram, also known as a Fishbone Diagram or Ishikawa Diagram, is a visual tool used to identify and categorize potential causes of a problem or effect. It helps in systematically exploring the root causes of an issue by organizing potential causes into categories.

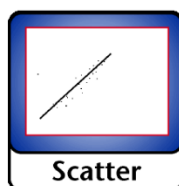
Key elements

- Visual Representation: The diagram resembles a fishbone, with the problem or effect at the "head" and potential causes branching out from the "spine" into categories like the 6Ms (Man, Machine, Material, Method, Measurement, and Environment) or the 5Ps (People, Process, Product, Parts, and Place).
- Structured Brainstorming: It provides a structured framework for brainstorming and capturing potential causes, ensuring that all contributing factors are considered.
- Root Cause Analysis: By systematically exploring each cause, the diagram helps identify the root causes of the problem, which can then be addressed to improve processes.
- Communication Tool: The visual nature of the diagram facilitates communication among team members and stakeholders, ensuring everyone understands the problem and potential solutions.
- Data Collection Aid: The diagram can also serve as a roadmap for planning data collection and analysis to validate the identified causes and effects.



- Benefits:
 - Improved Problem-Solving: Facilitates a systematic approach to problem-solving and root cause analysis.
 - Enhanced Communication: Provides a clear and visual representation of potential causes, promoting communication among team members.
 - Data-Driven Decision Making: Guides data collection and analysis to validate identified causes and improve decision-making.
 - Increased Process Improvement: Helps identify and address the root causes of problems, leading to improved processes and outcomes.

A.14 Scatter Diagram



Definition and purpose

In Lean Six Sigma, a scatter diagram (also known as a scatter plot) is a graphical tool used to visualize the relationship between two quantitative variables. It helps identify patterns, trends, and potential correlations between the variables, aiding in understanding cause-and-effect relationships within a process.

Key elements

- Two-dimensional graph:
- A scatter diagram plots data points on a two-dimensional graph, where each point represents a pair of values for the two variables.
- Visual representation: It provides a visual representation of the relationship between the variables, making it easier to identify patterns and trends that might not be immediately apparent from raw data.
- Identifying correlations: Scatter diagrams can help determine the strength and direction of the correlation between the variables (positive, negative, or none).
- Analyzing cause-and-effect: They can be used to analyze potential cause-and-effect relationships, helping to identify which variables may be influencing the outcome of a process.
- Identifying outliers: Outliers, or data points that deviate significantly from the general trend, can also be easily identified on a scatter diagram.

To understand process variation: By analyzing how one variable might affect another, teams can gain insights into potential sources of process variation.

To prioritize problem-solving efforts: The insights gained from scatter diagrams can help teams prioritize which potential causes of a problem may have the most significant impact and should be addressed first.

A.14 Pareto Diagram

Definition and purpose



A Pareto diagram, also known as a Pareto chart, is a visual tool used to identify and prioritize the most significant causes of a problem or issue. It's a bar chart that displays categories of data in descending order of frequency or impact, with a line graph showing the cumulative percentage. This helps teams focus on the "vital few" causes that account for the majority of problems, aligning with the Pareto principle, or 80/20 rule.

Key elements

- **Visual Representation:**The diagram uses bars to represent different categories of defects or problems, arranged in order of their frequency or cost.
- **Cumulative Line:**A line graph shows the cumulative percentage of the total, making it easy to see how much of the problem is caused by the top few categories.
- **80/20 Rule:**The principle behind the Pareto diagram is that a small number of causes often account for the majority of the problems.
- **Focus on "Vital Few":**By visually highlighting the most frequent or costly causes, the diagram helps teams focus their efforts on the issues that will have the biggest impact on process improvement.

A.15 Idea Generation



Definition and purpose

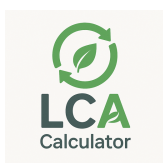
A step to prioritise direct causes - root cause analysis - identify a potential solution

Key elements

to define possible solutions, generating a set of possible solutions to the cause of variation taking in consideration:

What possible solutions were generated for each root cause and how? Has the need to create flow in the process been addressed? Does the proposed solution create pull from the customer demand?

A.16 LCA Calculator



Definition and purpose

LCA calculator is a specialized tool designed to model, analyse, and interpret the environmental impacts of products, processes, or services across their entire life cycle — from raw material extraction to end-of-life disposal. These tools support all major phases of **Life Cycle Assessment** as defined by ISO 14040/44: goal and scope definition, inventory analysis (LCI), impact assessment (LCIA), and interpretation.

LCA software is a tool designed to support the process of conducting environmental impact assessment of a product, process, or service.



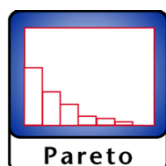
Environmental Life Cycle Assessment is a structured, comprehensive, and internationally recognized technique for assessing the environmental aspects of a product (i.e., good or service) and the potential environmental impacts throughout the product's life cycle. During the life cycle, the product/process requires input in the form of resources and energy but also emits outputs such as emissions. Using these inputs and outputs, a set of indicator scores are calculated and presented as different environmental impact category indicators such as climate change, resource depletion, human toxicity, and freshwater eutrophication, etc.

Key elements

The Life Cycle Assessment (LCA) software like openLCA, Sphera's LCA, SimaPro, One Click LCA, etc. are tools to model the potential environmental impacts at each stage of a product's life cycle. An LCA software integrated with the Life Cycle Inventory (LCI) database is used to allocate inputs and outputs data to various impact categories. These impact categories are set by various Life Cycle Impact Assessment (LCIA) methods like environmental footprint (EF) method, ReCiPé, and CML 200. Some software comes with its own databases, most LCI databases commercially available need to be bought separately.

Each software offers different functionalities, generally LCA tools enable the user to create its product system, specify the input and output data, select the LCIA method and calculate the environmental impact using the environmental indicators attributed to the selected method. The software typically includes sensitivity analysis and reporting tools to generate customizable reports and visualizations, making it easier to communicate findings to stakeholders.

A.17 Pareto Diagram



Definition and purpose

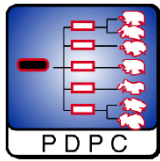
In Lean Six Sigma, a Pareto diagram, also known as a Pareto chart, is a visual tool used to identify and prioritize the most significant causes of a problem or issue. It's a bar chart that displays categories of data in descending order of frequency or impact, with a line graph showing the cumulative percentage. This helps teams focus on the "vital few" causes that account for the majority of problems, aligning with the Pareto principle, or 80/20 rule.

Key elements

- **Visual Representation:** The diagram uses bars to represent different categories of defects or problems, arranged in order of their frequency or cost.
- **Cumulative Line:** A line graph shows the cumulative percentage of the total, making it easy to see how much of the problem is caused by the top few categories.
- **80/20 Rule:** The principle behind the Pareto diagram is that a small number of causes often account for the majority of the problems.
- **Focus on "Vital Few":** By visually highlighting the most frequent or costly causes, the diagram helps teams focus their efforts on the issues that will have the biggest impact on process improvement.
- **Lean Six Sigma Application:** In the Analyze phase of DMAIC, Pareto diagrams help identify root causes and prioritize improvements.
- **Easy to Understand:** The visual format makes it easy for teams to understand the data and communicate findings effectively.



A.18 PDPC



Definition and purpose

a visual tool used for contingency planning and risk analysis.

Key elements

It helps identify potential problems and develop countermeasures to mitigate risks during process implementation

- Map the process: Draw a flowchart of the process being analyzed, detailing each step and decision point.
- Identify potential problems: Brainstorm possible issues or failures that could occur at each step.
- Evaluate potential problems: Analyze the likelihood and impact of each problem, prioritizing those with high likelihood and high impact.
- Develop countermeasures: For each prioritized problem, brainstorm actions that can be taken to prevent or mitigate the issue.
- Evaluate countermeasures: Assess the practicality and effectiveness of each countermeasure, considering factors like cost, time, and ease of implementation.
- Document the PDPC: Create a visual chart that clearly shows the process, potential problems, and proposed countermeasures.

A.19 5S



Definition and purpose

a tool for creating an organized workspace and are one of the foundations of good process management

Key elements

5S (Sort, Straighten, Shine, Standardise, Sustain) Support process management and create and environment where you are able to quickly recognize when an abnormal condition is present; provide a basis for eliminating waste and establishing continual improvement; provide a structure for improving customer satisfaction, quality and health and safety, and generate ownership and pride in the workplace



A.20 Visual Management



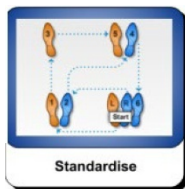
Definition and purpose

a view of process steps, measures, team activities, and any abnormal conditions that may impact the capability of a process

Key elements

Provides a basis for the effective management of the process using clear visual displays; provides clear performance monitoring and identifies any process deviations quickly; promotes ownership of the process; identifies actions and ownership; improves teamwork; provides a basis for continual improvement

A.21 Standardize



Definition and purpose

a detailed description of how a well-defined process should be operated.

Key elements

It may be implemented in several different forms depending of the context but must be clear, concise and easily communicated, for consistency, less training time, creates a visible standard to work to

A.22 Review



Definition and purpose

A tool to review the process regularly to continually learn and develop theories on how work can be improved by identifying opportunities to remove waste and opportunities to reduce variation.

Key elements

Provides a regular opportunity to reflect on the whole process, provides a place for strategy deployment, ensures generic learning can be shared amongst process managers and helps process owner evaluate opportunities for step change improvement.



Annex B-Artifacts of the GLSS-HC methodology

B.1 Reference List of Clinical Episodes

In clinical pathways the Clinical Episodes help standardize and streamline the patient journey through five phases.

Initial Assessment

- This phase involves collecting detailed patient information, such as symptoms, medical history, physical examination findings, and preliminary tests.
- The goal is to form an initial working diagnosis and determine the urgency and direction of care.

Example: For a patient with chest pain, this would involve an ECG, blood tests, vital signs, and medical history.

Evaluation/Staging

- This phase involves confirming the diagnosis and determining the severity or stage of the condition.
- It may include advanced diagnostic tools such as imaging (e.g., MRI, CT scan), biopsies, or lab tests.

Example: In breast cancer, staging would determine if it's localized or has spread to lymph nodes or other organs.

Treatment

- This phase is based on the diagnosis and staging, involves defining and implementing a treatment plan.
- May include surgery, medication, chemotherapy, radiation, lifestyle changes, etc.
- Multidisciplinary care is often involved to address various aspects of the condition.

Example: For diabetes, this might include insulin therapy, dietary modifications, and education.

Rehabilitation

- Focuses on helping the patient recover and regain function after treatment.
- Can include physical therapy, occupational therapy, psychological support, and patient education.
- Aimed at improving quality of life and reducing complications or disability.

Example: After a stroke, rehabilitation may involve speech therapy, mobility training, and cognitive exercises.

Follow-up/Monitoring



- Involves ongoing assessments after initial treatment or recovery to:
 - Check for recurrence or progression
 - Monitor for side effects or complications
 - Adjust treatment if needed
- Can be long-term and is often critical for chronic diseases or after cancer treatment.

Example: Regular blood tests and imaging for a patient in remission from lymphoma.

B.2 Reference List of CWAs

Clinical Work Area	Description
1. Operating Room (OR)	A sterile environment where surgical operations are performed by specialized medical teams under anaesthesia.
2. Interventional Radiology	A department that uses imaging techniques (e.g., fluoroscopy, CT, ultrasound) to guide minimally invasive procedures such as biopsies, stent placements, or embolization.
3. Intensive Care Unit (ICU):	A specialized unit for critically ill patients requiring constant monitoring and support for vital functions, often including mechanical ventilation or life support.
4. Emergency Department (ED):	A high-acuity area where patients receive immediate assessment and treatment for urgent and life-threatening conditions.
5. General Ward:	A hospital area for patients who need ongoing medical care and observation but not intensive or emergency services.
6. Day Surgery Unit	Also known as ambulatory or same-day surgery, this unit provides surgical procedures that don't require overnight hospitalization.
7. Outpatient Clinics	Departments where patients receive consultations, diagnostics, and treatment without being admitted to the hospital.
8. Radiology/Imaging Department	Provides diagnostic imaging services such as X-rays, CT scans, MRIs, and ultrasounds to support diagnosis and treatment planning.
9. Radiotherapy	A specialized unit where cancer patients receive treatment using high-energy radiation to destroy or shrink tumours.
10. Clinical Laboratory	Performs diagnostic testing on samples (blood, urine, tissues) to support diagnosis, monitoring, and treatment of diseases.
11. Pathology Laboratory	Analyzes tissues, organs, and bodily fluids to diagnose disease, often through histopathology or cytology.
12. Pharmacy (Hospital):	Dispenses medications to inpatients and outpatients, ensures proper medication management, and supports clinical decision-making.
13. Dialysis Unit	Provides renal replacement therapy for patients with kidney failure, typically through haemodialysis or peritoneal dialysis.
14. NICU (Neonatal Intensive Care Unit)	A specialized ICU for critically ill or premature newborns requiring intensive medical care and monitoring.
15. Chemotherapy Unit	Administers cancer treatments using chemical agents (chemotherapy) in a controlled and monitored environment.



16. Burn Unit	A specialized unit for treating patients with severe burns, providing wound care, fluid resuscitation, and rehabilitation.
17. Sterile Processing Department (SPD)	Responsible for the decontamination, sterilization, and preparation of surgical instruments and equipment for reuse.
18. Morgue/Autopsy Suite	A secure area where deceased patients are held and post-mortem examinations (autopsies) are performed to determine cause of death.

B.3 Medical technologies by CWA

Medical technologies include diagnostic tools, therapeutic devices, health information systems, and wearable technologies (*Alnemer R. et al., 2022*) and monitoring devices.

Clinical Area	Diagnostic Tools	Monitoring Tools	Therapeutic Devices	Health Information Systems	Wearable Technologies
1. Operating Room (OR)	Intraoperative imaging, laparoscopes	Anaesthesia monitors, ECG, capnography	Electrocautery, surgical robots, infusion pumps	OR management software, anaesthesia records	Smart glasses, biometric sensors
2. Interventional Radiology	Angiography systems, ultrasound, CT-guided imaging	Hemodynamic monitors, ECG, SpO ₂	Catheters, ablation tools, embolization coils	PACS, RIS, procedure logs	Lead aprons with sensors, HUDs
3. Intensive Care Unit (ICU)	Portable X-ray, ABG analysers, ultrasound	Multi-parameter monitors, central telemetry	Ventilators, CRRT, ECMO	ICU EMR, acuity scoring	Glucose monitors, biosensor patches
4. Emergency Department (ED)	POCUS, ECG machines, rapid tests	Portable vitals monitors, trauma monitors	Defibrillators, auto-ventilators, IV pumps	EDIS	Triage wristbands, alert bracelets
5. General Ward	Mobile X-ray, bladder scanners	Vitals monitors, telemetry	Infusion pumps, mobility aids	EMR, nurse call	Activity trackers, fall detection
6. Day Surgery Unit	Ultrasound, endoscopes	Perioperative monitors, pulse oximeters	Laparoscopic instruments, electro-surgical units	Surgical scheduling, EMR	Pre/post-op monitors
7. Outpatient Clinics	Ultrasound, digital otoscopes, spirometers	BP monitors, handheld ECGs	Nebulizers, laser therapy	EHR, scheduling systems	Fitness trackers synced to EHR
8. Radiology/Imaging Department	MRI, CT, X-ray, mammography	Contrast injection monitors, vitals (sedated pts)	Interventional tools (shared)	PACS, RIS	Sensor-embedded lead garments
9. Radiotherapy	Simulation CT/MRI, PET	Motion tracking systems	LINAC, brachytherapy	Treatment planning,	Immobilization wearables



				oncology EMR	
10. Clinical Laboratory	Auto-analysers, haematology analysers	Sample tracking, environment monitors	N/A	LIS	RFID lab coats
11. Pathology Laboratory	Digital pathology scanners, microscopes	Tissue processor monitors, QC tools	N/A	LIS, pathology image systems	AR glasses
12. Pharmacy (Hospital)	Barcode scanners	Inventory systems, temperature logs	Dispensing cabinets, compounding robots	Pharmacy IS, BCMA	Smart glasses for verification
13. Dialysis Unit	Blood chemistry analysers	Dialysis machine monitors, fluid balance	Haemodialysis, peritoneal dialysis	Dialysis software, EMR	Home dialysis monitors, BP trackers
14. NICU	Portable ultrasound, ABG analysers	Neonatal monitors, SpO ₂ systems	Incubators, CPAP, phototherapy	Neonatal EMR, tracking	Smart diapers, neonatal biosensors
15. Chemotherapy Unit	Blood count analysers	Infusion monitors, vitals monitors	Chemotherapy pumps, port access systems	Oncology EMR, protocols	Infusion monitors, symptom apps
16. Burn Unit	Thermographic imaging, wound scanners	Vitals, fluid loss monitors	NPWT, laser debridement	Burn documentation systems	Smart bandages
17. Sterile Processing Department (SPD)	Biological indicators, sterilization integrators	Sterilizer performance monitors	N/A	Instrument tracking, inventory	RFID badges
18. Morgue/Autopsy Suite	Post-mortem CT, autopsy tools	Environment monitors	N/A	Autopsy reports, case tracking	Air quality safety wearables

B.4 Typical reports available in a Hospital

Below is a list of **typical hospital reports** and the **types of data** that can be extracted from them, related to **Cost, Patient and caregivers satisfaction, Worker satisfaction, Clinical performance, Environmental impact (with an additional focus on waste management and energy consumption)**.

In addition to the routine reports, listed below, a source of data may be the sustainability report, filled in compliance with the **CSRD** European Directive (if the HCO is in the scope of the Directive and complies with it) and Cost data referred to the **DRGs**.

Financial and Cost Reports

Purpose: Monitor hospital expenses, revenues, and cost-effectiveness.

Data Available:

- Total cost per patient or per procedure
- Department-wise or service-line financials
- Cost of waste management



- Cost of energy

Common Report Names:

- Cost Accounting Reports
- Revenue Cycle Reports
- Budget Variance Reports
- Profit & Loss Statements

Patient and Caregiver Satisfaction Reports

Purpose: Measure satisfaction and experience.

Data Available:

- Patient satisfaction scores
- Family/caregiver satisfaction surveys
- Feedback from discharge interviews

Common Report Names:

- Patient Experience Reports
- Discharge Survey Analysis
- Complaint & Compliment Logs

Worker Satisfaction and Human Resources Reports

Purpose: Track workforce morale, performance, and engagement.

Data Available:

- Staff satisfaction surveys
- Burnout and engagement levels
- Absenteeism and turnover rates
- Training and professional development metrics

Common Report Names:

- HR Dashboard Reports
- Staff Engagement Reports
- Workforce Analytics
- Exit Interview Summaries

Clinical Performance Reports

Purpose: Assess quality of care and patient outcomes.

Data Available:

- Infection rates, readmission rates, mortality rates
- Compliance with clinical guidelines
- Length of stay, complications, adverse events
- Benchmarking vs national standards

Common Report Names:

- Quality Metrics Reports
- Clinical Outcomes Dashboards
- Clinical Audit Reports
- Hospital Performance Indicators

Environmental Reports

Purpose: Monitor ecological impact and sustainable practices.

Data Available:

- Carbon footprint
- Energy and water usage
- Greenhouse gas emissions
- Initiatives for sustainable practices

Common Report Names:

- Sustainability Reports
- Environmental Impact Assessments
- Green Hospital Reports

Waste Management Reports

Purpose: Track how waste is generated, handled, and disposed of.

Data Available:

- Medical vs non-medical waste volumes



- Hazardous waste disposal compliance
- Waste segregation practices
- Recycling rates

Common Report Names:

- Biomedical Waste Reports
- Waste Audit Reports
- Environmental Health & Safety Reports

Energy Consumption Reports

Purpose: Monitor hospital energy use and efficiency.

Data Available:

- Monthly/annual electricity, gas, and water usage
- Peak usage times and high-demand areas
- Use of renewable energy sources

Common Report Names:

- Energy Management Reports
- Utility Consumption Logs
- Facility Management Dashboards

B.5 4-ple aim + environmental KPIs

Perspective ¹²	Factors/KPIs
Cost	<ul style="list-style-type: none"> • Initial Investment, Acquisition and Capital Costs • Installation-Transport Costs • Operational Costs • Maintenance and Repair Costs • End-of-Life Costs • Risk management costs (e.g. insurance)
Patient and caregivers satisfaction	<ul style="list-style-type: none"> • Safe, comfortable and clean environment • Respect for privacy • Indication received at the moment of dismissions • Treated with dignity • Involved in the care plan • The staff listen carefully to the patient • Method and content of communication with doctors and health Personnel • Coordination between members of the medical staff • Emotional distress or burnout due to caregiving responsibilities. • Time relatives spend on administrative procedures, care coordination, and travel related to patient support.
Worker satisfaction	<ul style="list-style-type: none"> • Level of workload • Professional development • Burnout level (Maslach Burnout Inventory Test)
Clinical performance (production and outcome)	<ul style="list-style-type: none"> • Waiting list • Length of stay • Readmission rate • Mortality rate • Adverse event rate • Complications related to the illness and the treatment
Environmental impact	<ul style="list-style-type: none"> • Water use

¹² Source of Cost and Environmental impact: [D3.1- Model of the knowledge sharing and decision support system-v1]. Source of the other KPIs: adapted from (De Belvis A.G.et al., 2021)



	<ul style="list-style-type: none"> • Cumulative energy demand • Abiotic Depletion (ADP elements) • Abiotic Depletion (ADP fossil): • Acidification Potential (AP) • Eutrophication Potential (EP) • Freshwater Aquatic • Ecotoxicity Potential (FAETP inf.) • Global Warming Potential (GWP 100 years) • Global Warming Potential (GWP 100 years), excl. biogenic carbon • Human Toxicity Potential (HTP inf.) • Marine Aquatic Ecotoxicity Pot. (MAETP inf.) • Ozone Layer Depletion Potential (ODP, steady state) • Photochemical Ozone Creation Potential (POCP) • Terrestrial Ecotoxicity Potential (TETP inf.)
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B.6 Types of Waste by CWA

In the following three tables, reference is done to the 14 types of waste used at FPG.

Clinical Area	Infectious	Liquid (No Water)	Liquid (Water)	Chemical	Radioactive
1. Operating Room (OR)	Bloody dressings, used gloves	Blood, body fluids	Surgical rinse water	Anaesthetics, disinfectants	Rare (only if using radioactive tracers)
2. Interventional Radiology	Catheters, blood-stained materials	Contrast medium with blood	Flushing fluids	Contrast agents	Yes (radioisotope tracers like Tc-99m)
3. Intensive Care Unit (ICU)	Suction canisters, soiled linens	Body fluids	Bed bath water	IV drugs, disinfectants	Rare
4. Emergency Department (ED):	Wound dressings, trauma waste	Blood, vomit	Floor cleaning water	Disinfectants, antiseptics	Occasionally (nuclear med emergencies)
5. General Ward:	Dressing changes, bed linens	Blood, urine	Washing water	Cleaning agents	Rare
6. Day Surgery Unit	Dressings, gloves	Wound exudate	Cleaning fluids	Anaesthetic agents	Rare
7. Outpatient Clinics	Swabs, used examination gloves	Minor wound fluids	Hand wash water	Cleaning sprays, alcohol	Rare
8. Radiology/Imaging Department	Contrast-stained disposables	Contrast agents	Flush water	Film developer (if analog), cleaners	Yes (nuclear imaging tracers)
9. Radiotherapy	Dressings from irradiated areas	None specific	Hand wash water	Surface disinfectants	Yes – isotopes (e.g., I-131, Cs-137)
10. Clinical Laboratory	Contaminated pipettes, gloves	Blood, cultures	Sink rinse water	Stains, reagents	Yes (if radiolabelled)



					reagents used)
11. Pathology Laboratory	Autopsy samples, tissue prep waste	Formalin waste	Cleaning water	Xylene, formalin	Rare
12. Pharmacy (Hospital):	Contaminated drug prep gloves	Liquid medications	Washing area water	Expired chemicals, cytotoxics	Rare
13. Dialysis Unit	Blood-soaked filters, gloves	Heparinized blood	Dialysate discharge	Disinfectants, anticoagulants	No
14. NICU (Neonatal Intensive Care Unit)	Diapers, infected feeding tubes	Neonatal secretions	Bath water	Sterilizing fluids	Rare
15. Chemotherapy Unit	IV lines, gloves with cytotoxic drugs	Drug spills	Hand rinse water	Cytotoxic drug waste	Sometimes (radiolabelled drugs)
16. Burn Unit	Wound dressings, infected linen	Oozing exudate	Bath water	Creams, topical anaesthetics	Rare
17. Sterile Processing Department (SPD)	None (usually pre/post cleaning)	None usually	Instrument washing water	Detergents, decontaminants	No
18. Morgue/Autopsy Suite	Soiled gloves, autopsy cloths	Blood, embalming fluids	Cleaning/disinfecting water	Formalin, fixatives	Rare

Clinical Area	Biomedical (No Food)	Biomedical (Food)	Food	Plastic
1. Operating Room (OR)	Tissue, organs, amputated limbs	Meal waste from isolation ORs	Staff meals	IV tubing, syringes
2. Interventional Radiology	Removed biopsy tissue	N/A	N/A	Catheter packaging, syringes
3. Intensive Care Unit (ICU):	Dressings, suctioned tissues	Isolation patient food waste	Patient leftovers	IV bags, tubing, suction sets
4. Emergency Department (ED):	Trauma tissue, swabs	Emergency meals in infectious cases	General ED food waste	Syringes, gloves, blood bags
5. General Ward:	Biopsy remnants, minor surgery tissue	Isolation patient food	Patient food waste	Medication packaging, PPE
6. Day Surgery Unit	Removed skin/tissue samples	Isolation case food	Light snack waste from patients	Single-use surgical plastics
7. Outpatient Clinics	Wart removals, minor tissue	N/A	Waiting area food waste	Syringes, wrappers



8. Radiology/Imaging Department	None usually	N/A	N/A	X-ray plate covers, contrast tubing
9. Radiotherapy	Biopsy from radiation sites	N/A	N/A	Shields, treatment plastics
10. Clinical Laboratory	Tissue slides, microbial cultures	N/A	N/A	Test tubes, pipette tips
11. Pathology Laboratory	Organs, tissue blocks	N/A	N/A	Cassette containers, gloves
12. Pharmacy (Hospital):	Vaccine waste	N/A	Staff food waste	Pill bottles, blister packs
13. Dialysis Unit	Dialyzer parts with residual blood	N/A	Patient snacks	Tubing, dialysis sets
14. NICU (Neonatal Intensive Care Unit)	Umbilical cords, tissues	Isolation baby food	Infant feeding leftovers	Incubation tubing, pacifiers
15. Chemotherapy Unit	Drug-contaminated disposables	N/A	N/A	IV bags, chemo ports
16. Burn Unit	Burned tissue debris	N/A	Restricted diet waste	Wound dressings in plastic
17. Sterile Processing Department (SPD)	N/A	N/A	Staff lunch waste	Sterile wrap, plastic trays
18. Morgue/Autopsy Suite	Organs, body parts, fluids	N/A	N/A	Body bag plastics, gloves

Clinical Area	Glass	Paper & Cardboard	Wood	Metal	Mixed Waste
1. Operating Room (OR)	Glass medicine vials	Procedure checklists, sterile wrap, packaging, bins	Wood splints	Surgical instruments	Surgical waste bin with mixed disposables
2. Interventional Radiology	Glass contrast containers	Imaging request forms	N/A	Metal guide wires	Mixed packaging and clinical waste
3. Intensive Care Unit (ICU):	Glass ampoules, vials	Medication charts, paper towels	N/A	Bed rails, equipment parts	Isolation bin contents with mixed waste
4. Emergency Department (ED):	Broken vials, ampoules	Admission forms, packaging	N/A	Metal scissors, tools	Mixed urgent waste in disposal bins
5. General Ward:	Medicine bottles	Nursing notes, patient files	N/A	Bed frame parts, IV poles	Ward bins with varied waste



6. Day Surgery Unit	Ampoules, glass tubes	Patient info sheets	N/A	Instrument parts	Sharps bin with varied contents
7. Outpatient Clinics	Glass slides (e.g. dermoscopy)	Prescription sheets	N/A	Tools, tongue depressors	General bin with office + clinical waste
8. Radiology/Imaging Department	Imaging vials	Referral forms, reports	N/A	Machine parts	Imaging room disposables
9. Radiotherapy	Radioisotope vials	Treatment documentation	N/A	Treatment head parts	Shielding waste + packaging
10. Clinical Laboratory	Slide covers, reagent vials	Lab reports, printouts, packaging, bins	N/A	Metal racks	Mixed specimen disposables
11. Pathology Laboratory	Specimen jars	Request forms, report paper	N/A	Dissection tools	Disposal with organ/tissue containers
12. Pharmacy (Hospital):	Ampoules, drug vials	Labels, medicine info sheets	Pallet wood from bulk stock	Aluminium seals, tools	Expired meds and packaging
13. Dialysis Unit	Machine component glass	Patient forms	N/A	Machine casings	Tubing with blood + packaging
14. NICU (Neonatal Intensive Care Unit)	Medicine bottles	Growth charts, paper logs	Crib parts	Equipment clips	Diaper waste mixed with wrappings
15. Chemotherapy Unit	Drug vials, glass ampoules	Administration sheets	N/A	Drug-safe bins	Cytotoxic waste bin with multiple items
16. Burn Unit	Ointment jars	Medical charts	Bed frame materials	Burn bath tools	Mixed infected waste and disposables
17. Sterile Processing Department (SPD)	Instrument trays	Packing slips	Crate wood from shipping	Surgical tool bins	Contaminated packs with mixed material
18. Morgue/Autopsy Suite	Tissue jars, glassware	Death records, tags	Autopsy table frame	Saw blades, tools	Packaging

B.7 Types environmental impacts by CWA

Categories of environmental impacts vs Clinical Work Areas



Clinical Work Area	Environmental Impact Category													
	Water Use	Cumulative Energy Demand	Abiotic Depletion (ADP elements)	Abiotic Depletion (ADP fossil)	Acidification Potential (AP)	Eutrophication Potential (EP)	Freshwater Aquatic Ecotoxicity Potential (FAETP inf.)	Global Warming Potential (GWP 100 years)	Global Warming Potential (GWP 100 years), excl. biogenic carbon	Human Toxicity Potential (HTP inf.)	Marine Aquatic Ecotoxicity Pot. (MAETP inf.)	Ozone Layer Depletion Potential (ODP, steady state)	Photochemical Ozone Creation Potential (POCP)	Terrestrial Ecotoxicity Potential (TETP inf.)
Operating Room (OR)	✓	✓		✓	✓			✓	✓				✓	
Interventional Radiology		✓		✓				✓						
Intensive Care Unit (ICU)	✓	✓		✓	✓	✓	✓	✓						
Emergency Department (ED)				✓							✓			✓
General Ward														
Day Surgery Unit														
Outpatient Clinics														
Radiology/Imaging Department		✓	✓	✓				✓	✓			✓	✓	
Radiotherapy		✓		✓				✓						
Clinical Laboratory			✓			✓					✓			✓
Pathology Laboratory			✓							✓				✓
Pharmacy (Hospital)						✓	✓			✓	✓			✓
Dialysis Unit	✓													
NICU (Neonatal Intensive Care Unit)	✓	✓												
Chemotherapy Unit		✓					✓			✓				
Burn Unit	✓													
Sterile Processing Department (SPD)	✓	✓			✓				✓				✓	
Morgue/Autopsy Suite												✓		
Origin of the impact														
Upstream origin			x	x				x	x			x		
In the Hospital	x	x			x			x	x	x			x	
Downstream				x	x	x	x			x	x			x

Reasons of environmental impacts of the Clinical Work Areas

Environmental Impact Category	Clinical Work Areas	Reason for Environmental Impact
Water Use	OR, ICU, Dialysis Unit, SPD, Burn Unit, NICU	High water use for sterilization (OR, SPD), patient hygiene (ICU, Burn Unit), and dialysis treatment.
Cumulative Energy Demand	OR, ICU, Radiotherapy, Imaging, Chemotherapy, NICU	Energy-intensive equipment (surgical lights, ventilators, MRIs, linear accelerators), 24/7 operation in ICU/NICU.
Abiotic Depletion (ADP elements)	Clinical Laboratory, Pathology Lab, Imaging	Use of rare elements in diagnostic reagents, radiology contrast agents, and lab instrumentation.
Abiotic Depletion (ADP fossil)	All Areas (esp. OR, Radiology, Transport)	Fossil fuel consumption for equipment use, heating, and transport (e.g., anaesthesia gases, single-use plastics).
Acidification Potential (AP)	OR, ICU, SPD	Emissions from volatile aesthetic gases, sterilizers, and cleaning chemicals contribute to acid rain formation.
Eutrophication Potential (EP)	Clinical Lab, Pharmacy, ICU	Discharge of nitrogen- or phosphate-rich chemicals and pharmaceuticals into wastewater systems.
Freshwater Aquatic Ecotoxicity (FAETP)	Pharmacy, Chemotherapy Unit, ICU	Improper disposal of pharmaceuticals and cytotoxic drugs impacting freshwater ecosystems.
Global Warming Potential (GWP 100 years)	OR, ICU, Imaging, Radiotherapy	Use of potent anaesthetic gases (e.g., desflurane), energy use, and refrigerants with high GWP.
GWP excl. biogenic carbon	OR, Imaging, SPD	Focuses on GHGs excluding biologically derived CO ₂ – especially relevant for synthetic gases and equipment use.
Human Toxicity Potential (HTP)	Pharmacy, Chemotherapy, Pathology Lab	Exposure to hazardous drugs (e.g., antineoplastics), chemicals, and formaldehyde-based preservatives.
Marine Aquatic Ecotoxicity (MAETP)	Laboratory, Pharmacy, ED	Lab and pharmaceutical waste (e.g., antibiotics, heavy metals) entering sewage impacting marine life.



Ozone Layer Depletion Potential (ODP)	Imaging, Refrigeration Systems, Morgue	Use of older refrigerants (CFCs/HCFCs) in cooling systems, morgue refrigeration units.
Photochemical Ozone Creation Potential (POCP)	OR, SPD, Imaging	Volatile Organic Compounds VOCs from solvents, sterilizers, and disinfectants contribute to ground-level ozone (smog).
Terrestrial Ecotoxicity Potential (TETP)	Pharmacy, Lab, Pathology, ED	Solid hazardous waste and chemical residues affecting soil ecosystems and landfills.

B.8 Examples of the 8 LSS wastes by CWA

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Clinical Area	Transport	Inventory	Motion	Waiting	Overproduction	Overprocessing	Defects	Skills Underutilized
Operating Room (OR)	Unneeded patient/equipment moves	Excess surgical packs	Searching for tools	Delays starting surgery	Extra instruments opened	Duplicate surgical checklists	Instrument miscounts	Surgeons doing setup or non-surgical prep
Interventional Radiology	Patient transport delays from wards	Overstock of specialized catheters or contrast agents	Staff walking to retrieve imaging tools or drugs.	Equipment downtime; physician availability	Prepping unnecessary procedures.	Redundant imaging or documentation.	Incorrect image labelling; contrast dosing errors.	Techs doing clerical work
Intensive Care Unit (ICU)	Moving patients to other areas	Overstocked IV meds/equipment	Retrieving supplies across unit	Waiting for labs or radiology	Redundant labs ordered	Repeated documentation	Ventilator-associated errors	Nurses doing cleaning or clerical tasks
Emergency Dept. (ED)	Moving patients between zones	Overstocked med trays	Staff walking across zones	Wait times for rooms/labs	Unneeded tests/labs ordered	Re-charting in multiple systems	Misdiagnosis, duplicate meds	Nurse doing non-clinical tasks
General Ward	Transport for imaging	Excess linens and supplies	Walking for charts, meds	Discharge planning delays	Extra meds or meals delivered	Redundant nursing notes	Missed doses, patient falls	Nurses doing porter or admin work
Day Surgery Unit	Moving patients between prep/recovery	Prepped kits not used	Staff movement between OR and Post-Anaesthesia Care Unit.	Delays in surgery turnover	Extra cases scheduled	Repeated consent verification	Documentation or surgical delays	Surgeons/nurses doing scheduling/admin
Outpatient Clinics	Patients moving to	Expired vaccines	Fetching charts or printouts	Long appointment	Repetitive forms	Repeating data in EMR	Patient ID errors	Medical Assistants doing



	labs/imaging	brochures		ment delays	filled by patients			purely clerical tasks
Radiology/Imaging Department	Patient moved to fixed scanners	Overstock of contrast media	Walking between machines	Report turnaround delays	Repeat scans ordered unnecessarily	Manual entry of same protocols	Image quality issues	Radiologists doing clerical reviews
Radiotherapy								
Clinical Laboratory	Manual sample transport	Overstocked reagents	Moving between lab stations	Backlog in processing	Duplicate test orders	Redundant validation of normal results	Mislabelling or haemolyzed samples	Technicians underused in process improvement
Pathology Lab	Specimen moved between sites	Excess fixatives/stains	Searching for archived slides	Waiting for specimen delivery	Preparing extra slides	Over-documenting gross descriptions	Slide contamination	Pathologists doing transcription work
Pharmacy (Hospital)	Delivering meds without prioritization	Expired or duplicated stock	Searching for rarely used meds	Delays in verification or delivery	Prepping PRN meds not used	Rechecking non-critical prescriptions	Dosage, labelling errors	Pharmacists doing technician or delivery roles
Dialysis Unit	Patient bed/machine movement	Unused dialysis supplies	Walking to retrieve heparin, tubing	Patients waiting for slots	Overmixed dialysate	Manual documentation of vitals	Site infections, incorrect runs	Nurses doing logistics tasks
NICU	Moving infants to other units	Excess bottles/feeding supplies	Walking for feeding tubes, warmers	Delayed specialist consults	Extra monitoring or labs	Repeated vitals and charting	Feeding or medication errors	NNPs doing basic care
Chemotherapy Unit	Moving between pharmacy/lab/infusion	Chemo bags prepared but not used	Nurses retrieving PPE, IVs	Delays waiting for drug prep	Making unused pre-mix chemo	Double/triple drug verifications	Infusion errors	Oncologists doing admin duties
Burn Unit	Transport to debridement or OR	Extra wound care packs	Nurses gathering dressing supplies	OR access or wound care delays	Preparing unused sterile kits	Re-charting dressing procedures	Infection due to improper dressings	Specialists doing routine dressing changes
Sterile Processing Dept.	Moving trays between buildings/floors	Overstocked or unused surgical tools	Walking across reprocessing stations	Waiting on dirty instruments	Sterilizing rarely used tools	Double-cleaning due to tracking issues	Sterilization failures	Techs not engaged in process mapping
Morgue/Autopsy Suite	Transport of bodies	Overstock of rarely	Walking for	Waiting for release	Preparing unnecessary	Over-document	Mislabelling or	Pathologists doing



	between units	used autopsy tools	forms/tools	or approval	sary samples	nting findings	sample mix-ups	non-expert admin work
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B.9 Examples of causes by CWA and by aim

Examples of causes of High Cost

Clinical Work Area	People	Equipment	Methods	Materials	Environment
1. Operating Room (OR)	Overtime pay due to inefficiencies	High maintenance costs for surgical robots	Inefficient scheduling increasing idle time	Overuse of disposable instruments	Energy-intensive ventilation systems
2. Interventional Radiology	Underutilization of staff resources	Costly imaging equipment downtime	Overuse of expensive procedures	Wastage of contrast materials	Special infrastructure maintenance
3. Intensive Care Unit (ICU)	High staffing requirements per patient	Expensive equipment upkeep	Redundant monitoring procedures	Excessive use of single-use devices	High energy consumption
4. Emergency Department (ED)	Excess staff turnover costs	Frequent repair of diagnostic tools	Unnecessary testing protocols	High-cost supplies used in low acuity cases	Space expansion for crowding
5. General Ward	Low productivity from overburdened staff	Maintenance of outdated equipment	Inefficient patient discharge planning	Wastage from overstocked supplies	Poor insulation raising utility bills
6. Day Surgery Unit	Staff idle time between cases	Short lifecycle of sterilization units	Inefficient turnover protocols	Disposable packs not fully utilized	Space underutilization
7. Outpatient Clinics	Extended admin workload on clinicians	Frequent tech support for EMR	Overbooking leading to cancellations	Excess patient education material printing	Underused consultation rooms
8. Radiology/Imaging Department	Inefficient use of radiologists' time	High cost of imaging equipment downtime	Redundant imaging requests	Wastage of films and contrast agents	High shielding costs
9. Radiotherapy	Underutilization of therapy staff	Breakdowns of LINACs	Delays increasing session time	Wastage of costly isotopes	Specialized facility costs
10. Clinical Laboratory	Duplicate work due to staff error	Unplanned analyzer maintenance	Manual data entry increasing FTE costs	Reagent spoilage	Cooling systems for machines
11. Pathology Lab	Delayed results requiring retesting	Breakdowns of microscopes or scanners	Batching inefficiencies	Slide and reagent waste	Humidity control costs
12. Pharmacy (Hospital)	Staffing for manual	Frequent restocking	Non-optimized purchasing	Expired medication disposal	Storage space inefficiencies



	inventory control	automation failures			
13. Dialysis Unit	Intensive staff-to-patient ratios	Costly dialysis machine maintenance	Inefficient shift allocation	Excess consumables use	High water and electricity demand
14. NICU	Highly specialized staffing costs	Maintenance of incubators and monitors	Lengthy patient stays	Specialized supply needs	Climate control for sensitive care
15. Chemotherapy Unit	Specialized oncology staffing	Pump replacement and repair	Non-bundled treatments	High-cost chemotherapy drug waste	Isolated rooms with high utility use
16. Burn Unit	Highly skilled team salaries	Burn-specific therapy device maintenance	Lengthy care protocols	Expensive dressings	Special HVAC systems
17. Sterile Processing Dept.	Overstaffing during non-peak hours	Frequent autoclave repair costs	Redundant processing steps	Sterile wrap overuse	High steam and power usage
18. Morgue/Autopsy Suite	Specialty forensic staff cost	Refrigeration equipment cost	Delays in body processing	Overstock of infrequently used tools	Temperature control requirements

Examples of causes of Low Clinical production

Clinical Work Area	People	Equipment	Methods	Materials	Environment
1. Operating Room (OR)	Insufficient staff coverage	Frequent equipment breakdowns	Inefficient case scheduling	Delayed instrument availability	Inadequate OR layout
2. Interventional Radiology	Limited interventional radiologists	Downtime of imaging systems	Poor coordination with wards	Shortage of sterile tools	Restricted space for equipment
3. Intensive Care Unit (ICU)	Nurse-to-patient ratio too high	Ventilator shortages	Slow admission/discharge processes	Insufficient life-support materials	Cramped space limiting mobility
4. Emergency Dept. (ED)	Understaffed during peak hours	Limited imaging access	Inefficient triage	Basic medical supplies delays	Overcrowding
5. General Ward	Low staff-to-patient ratio	Limited mobile diagnostic devices	Inefficient documentation practices	Shortages of common medical tools	Noise and lack of privacy
6. Day Surgery Unit	Insufficient OR techs or nurses	Delays in sterilization cycles	Poor patient turnover strategy	Missing surgical kits	Lack of prep/recovery beds
7. Outpatient Clinics	Overbooked clinicians	Outdated EMR systems	Long patient wait due to process gaps	Delayed diagnostics access	Congested waiting areas
8. Radiology/Imaging Department	Limited radiologists/techs	Frequent machine downtimes	Delays in exam protocols	Contrast or film shortages	Inadequate shielding areas
9. Radiotherapy	Understaffing for planning and treatment	Breakdowns in LINAC	Complex planning workflows	Limited radioactive isotopes	Confined treatment rooms
10. Clinical Laboratory	Tech shortages during off-hours	Analyzer malfunctions	Manual lab test entry delays	Unstable reagent supply	Restricted bench space



11. Pathology Lab	Lack of trained pathologists	Microscope or scanner issues	Backlog in sample processing	Delays in receiving specimens	Insufficient storage and prep areas
12. Pharmacy (Hospital)	Pharmacist shortage	Slow dispensing systems	Manual drug inventory management	Out-of-stock medications	Poor layout for flow
13. Dialysis Unit	Limited number of dialysis nurses	Machine downtime	Unoptimized session scheduling	Limited dialyzer supplies	Space constraints
14. NICU	Insufficient neonatologists	Faulty incubators or monitors	Complex care protocols	Specialized supplies not available	Overcrowding with sensitive patients
15. Chemotherapy Unit	Low staff for infusion prep	Pump calibration delays	Slow drug ordering systems	Delayed chemotherapy delivery	Cramped infusion bays
16. Burn Unit	Staff shortages due to stress	Delayed wound care equipment	Labor-intensive care plans	High consumption of wound dressings	Overheated or uncomfortable layout
17. Sterile Processing Dept.	Lack of trained sterilization techs	Autoclave failures	Slow instrument turnover procedures	Packaging shortages	Limited workstations
18. Morgue/Autopsy Suite	Low availability of forensic staff	Refrigeration issues	Inefficient body processing steps	Lack of autopsy tools	Restricted, outdated infrastructure

Examples of causes of Low Clinical outcome

Clinical Work Area	People	Equipment	Methods	Materials	Environment
1. Operating Room (OR)	Surgical errors due to fatigue	Malfunctioning surgical tools	Lack of standardized procedures	Substandard surgical supplies	Inadequate lighting affecting visibility
2. Interventional Radiology	Insufficient training in advanced procedures	Poor image quality from outdated machines	Non-adherence to clinical protocols	Incorrect or missing consumables	Ergonomic constraints during procedures
3. Intensive Care Unit (ICU)	Delayed response due to understaffing	Failure of life-support systems	Uncoordinated multidisciplinary care	Lack of critical medications	Limited visibility for monitoring patients
4. Emergency Dept. (ED)	Misdiagnosis under pressure	Slow diagnostics turnaround	Gaps in triage accuracy	Delayed access to life-saving meds	Overcrowding impeding emergency access
5. General Ward	Infrequent patient monitoring	Unavailable monitoring equipment	Inconsistent care routines	Basic care items missing	Noisy, stressful environment
6. Day Surgery Unit	Errors in pre-op assessment	Anaesthesia delivery issues	Poor handoff communication	Inadequate recovery aids	Inadequate post-op space
7. Outpatient Clinics	Incomplete diagnostic assessments	Limited access to point-of-care tools	Disorganized follow-up systems	Unavailable patient education materials	Distracting consultation environment



8. Radiology /Imaging Department	Incorrect image interpretation	Artifacts from faulty equipment	Improper imaging techniques	Low-quality contrast agents	Poor ambient conditions for radiologists
9. Radiotherapy	Improper dose planning	Malfunctioning LINACs	Errors in treatment alignment	Inconsistent quality of shielding materials	Limited emergency accessibility
10. Clinical Laboratory	Sample handling errors	Incorrect calibration of analysers	Delayed test processing	Expired or low-grade reagents	Poor organization causing mix-ups
11. Pathology Lab	Mislabelling of samples	Microscope faults affecting review	Delays in diagnosis	Damaged specimens due to poor packaging	Inadequate workspace for accurate analysis
12. Pharmacy (Hospital)	Dispensing errors	Barcoding failures	Delayed medication reconciliation	Outdated or incorrect drugs	Disorganized storage areas
13. Dialysis Unit	Incorrect settings during dialysis	Dialyzer failure or leakage	Non-adherence to treatment plans	Unreliable filters or tubing	Uncomfortable and stressful setting
14. NICU	Lack of neonatal specialization	Malfunctioning incubators	Inconsistent care protocols	Unavailability of neonatal supplies	Crowded and overstimulating environment
15. Chemotherapy Unit	Incorrect dosage calculations	Infusion pump failures	Non-standardized treatment regimens	Poor drug handling	Fatiguing environment for long sessions
16. Burn Unit	Delayed or incorrect interventions	Lack of advanced wound care devices	Delayed escalation protocols	Poor availability of skin substitutes	Non-sterile or overheated conditions
17. Sterile Processing Dept.	Improper sterilization due to errors	Autoclave malfunction	Non-standardized sterilization procedures	Low-grade wraps or detergents	Uncontrolled humidity or heat
18. Morgue/Autopsy Suite	Inaccurate cause of death determination	Limited diagnostic imaging support	Lack of autopsy guidelines	Inadequate specimen preservation tools	Poor lighting and ventilation

Examples of causes of Low Patients' satisfaction

Clinical Work Area	People	Equipment	Methods	Materials	Environment
1. Operating Room (OR)	Poor communication from surgical staff	Delays due to equipment setup	Unclear pre/post-op instructions	Unavailability of surgical necessities	Intimidating environment
2. Interventional Radiology	Lack of explanation from staff	Long wait due to equipment scheduling	Complex booking process	Insufficient comfort items (blankets, pillows)	Cold, clinical setting
3. Intensive Care Unit (ICU)	Perceived indifference from staff	Noisy monitors and alarms	Limited visiting hours	Lack of personal hygiene supplies	Overcrowded, noisy space



4. Emergency Dept. (ED)	Long wait times, lack of empathy	Delays in imaging or diagnostics	Unclear triage process	Basic amenities often lacking	Uncomfortable, noisy waiting area
5. General Ward	Unattentive or rushed staff	Noise from shared equipment	Unclear daily routines	Unclean linens or supplies	Lack of privacy
6. Day Surgery Unit	Lack of support before discharge	Delays in anaesthesia equipment	Confusing discharge instructions	Missing personal care items	Cramped recovery area
7. Outpatient Clinics	Rushed consultations	Slow check-in systems	Overbooking of appointments	Insufficient seating or brochures	Overcrowded, stuffy waiting rooms
8. Radiology /Imaging Department	Lack of communication during procedures	Machine noise and discomfort	Delayed appointments	No privacy gowns or comfort aids	Cold rooms, harsh lighting
9. Radiotherapy	Inadequate psychological support	Breakdowns causing rescheduling	Rigid treatment timings	Limited comfort measures during treatment	Clinical, sterile ambiance
10. Clinical Laboratory	Impersonal staff behaviour	Sample delays due to automation	Poor labelling or notification systems	Lack of sanitization materials	Crowded blood draw areas
11. Pathology Lab	Lack of updates on test results	Delays in analysis equipment	Backlogged result reporting	Sample mishandling	Opaque and restricted access
12. Pharmacy (Hospital)	Rude or dismissive pharmacy staff	Slow dispensing systems	Confusing drug collection process	Drug shortages	Cramped counters and long lines
13. Dialysis Unit	Lack of emotional support	Discomfort during procedures	Unclear scheduling changes	Insufficient consumables (blankets, water)	Sterile, repetitive surroundings
14. NICU	Limited communication with parents	Alarm fatigue from monitors	Restricted visitation policies	Inaccessibility to baby care resources	High-stress layout
15. Chemotherapy Unit	Lack of empathy during treatment	Pump malfunctions	Inflexible scheduling	Shortage of anti-nausea meds	Cold and isolating bays
16. Burn Unit	Emotional detachment from staff	Therapy equipment failures	Lengthy admission protocols	Shortages of soothing supplies	Heat, odour, discomfort
17. Sterile Processing Dept.	Rare direct contact but delays cause patient frustration	Autoclave delays impacting surgeries	Inadequate tracking of instruments	Improperly sterilized items	Indirect effect via surgical delays
18. Morgue/Autopsy Suite	Insensitive interactions postmortem	Storage delays	Bureaucratic autopsy reporting	Unprepared documentation	Cold, emotionally distressing setting

Examples of causes of Low Health workers' satisfaction

Clinical Work Area	People	Equipment	Methods	Materials	Environment
1. Operating Room (OR)	High stress, long shifts,	Frequent equipment malfunction	Inefficient surgical scheduling,	Inconsistent availability of surgical tools	Poor ventilation,



	insufficient staffing		unclear protocols		cramped space
2. Interventional Radiology	Limited training opportunities, role ambiguity	Downtime of imaging systems	Last-minute case changes, procedural delays	Shortage of specialized catheters	Noise and inadequate lighting
3. Intensive Care Unit (ICU)	Emotional toll, high patient-to-staff ratio	Alarm fatigue from constant alerts	Rapidly changing protocols	Shortage of PPE or ventilator accessories	Overcrowded, noisy environment
4. Emergency Dept. (ED)	Burnout from patient influx, aggression from patients	Delays in diagnostic equipment	Unpredictable triage system	Inconsistent supply of emergency kits	Chaotic, high-noise levels
5. General Ward	Understaffing, low recognition	Limited access to mobile diagnostic devices	Redundant documentation processes	Basic supplies often missing	Dull lighting, poor acoustics
6. Day Surgery Unit	Time pressure, lack of team cohesion	Delays in sterilization equipment	Unrealistic turnover expectations	Occasional shortage of sterile instruments	Limited prep/recovery space
7. Outpatient Clinics	High patient volume, limited administrative support	Slow or outdated EHR systems	Inefficient appointment scheduling	Insufficient medical supplies	Crowded waiting areas
8. Radiology/Imaging Department	Underappreciation of technical roles	Frequent imaging machine downtimes	Redundant imaging requests	Contrast agents not always available	Low lighting, isolated workstations
9. Radiotherapy	Psychological burden, long exposure hours	Linear accelerator breakdowns	Complex treatment planning delays	Shortage of radioisotopes	Radiation safety restrictions
10. Clinical Laboratory	Repetitive tasks, limited career growth	Analyzer calibration issues	Manual entry errors	Inconsistent reagent supply	Poor ventilation, artificial lighting
11. Pathology Lab	Isolation, lack of recognition	Microscope maintenance delays	Backlog in slide reviews	Delays in sample delivery	Dim lighting, long sitting hours
12. Pharmacy (Hospital)	Overwork during peak hours	Pharmacy automation errors	Frequent last-minute orders	Stockouts of critical drugs	Small, crowded workspace
13. Dialysis Unit	Emotional fatigue from chronic care	Dialysis machine malfunctions	Strict session timing issues	Limited access to dialysis kits	Sterile but cramped environment
14. NICU	High stress due to critical patients	Ventilator and incubator issues	Complex care routines	Specialized consumables often delayed	High noise from alarms
15. Chemotherapy Unit	Emotional impact of oncology care	IV infusion pump issues	Lengthy drug prep protocols	Cytotoxic drug handling challenges	Isolated infusion bays
16. Burn Unit	Emotional trauma, under-resourced teams	Negative pressure therapy machine issues	Complex wound care routines	High consumption of specialized dressings	Heat, smell, discomfort



17. Sterile Processing Dept.	Monotonous work, low appreciation	Sterilizer breakdowns	Backlog in instrument reprocessing	Packaging shortages	Hot, confined workspace
18. Morgue/Autopsy Suite	Emotional burden, isolation	Table and refrigeration unit maintenance	Lack of standardized documentation	Limited autopsy tools	Cold, poorly ventilated

Examples of causes of High environmental impact

Clinical Work Area	People	Equipment	Methods	Materials	Environment
1. Operating Room (OR)	Poor waste segregation practices	High energy-consuming equipment	Excessive use of disposables	Non-recyclable surgical kits	Energy-intensive HVAC systems
2. Interventional Radiology	Improper disposal of contrast agents	Energy-hungry imaging systems	Single-use device reliance	Plastic-intensive supply usage	Limited daylight use, high HVAC demand
3. Intensive Care Unit (ICU)	Overuse of single-use items	24/7 power-intensive machines	Over-packaging of sterile goods	Excessive plastic and biomedical waste	Artificial lighting 24/7
4. Emergency Dept. (ED)	Inconsistent recycling enforcement	Old, inefficient diagnostic machines	Over-reliance on disposables	High biohazardous waste volume	Unoptimized energy systems
5. General Ward	Low awareness of green practices	Non-energy efficient monitors	Unnecessary use of consumables	Non-reusable patient care items	High utility use due to poor insulation
6. Day Surgery Unit	Untrained in environmental protocols	Frequent sterilizer cycles	Redundant sterilization procedures	Single-use surgical packs	Unnecessary lighting and HVAC use
7. Outpatient Clinics	Overprinting of documents	Energy-draining old computers	Paper-based workflows	Plastic-heavy sample kits	Inefficient room insulation
8. Radiology/Imaging Department	Improper disposal of imaging materials	High power usage of imaging devices	Repetitive scanning practices	Non-recyclable contrast media packaging	Overcooled scan rooms
9. Radiotherapy	Neglect of radioactive waste protocols	Constant use of high-energy LINACs	Inefficient treatment batching	Isotope packaging waste	Energy-draining shielding systems
10. Clinical Laboratory	Improper sample waste handling	Non-energy efficient analysers	Overuse of reagents and plastics	Disposable labware	Ventilation systems always on
11. Pathology Lab	Improper disposal of biological samples	Outdated microscope lighting	Manual staining with chemical runoff	Non-biodegradable slides and coverslips	Unventilated workspaces
12. Pharmacy (Hospital)	Improper drug disposal	Old refrigerators	Inefficient inventory methods	Excess expired medications	Unoptimized storage areas
13. Dialysis Unit	Water waste due to protocol lapses	High electricity and water-consuming dialysis machines	Lack of dialysate reuse practices	Single-use tubing and filters	Poor water recirculation



14. NICU	Excessive disposable item use	Constant incubator energy use	Overprotection via single-use gear	Multiple non-biodegradable supplies	Need for constant climate control
15. Chemotherapy Unit	Inappropriate handling of cytotoxic waste	Old infusion systems	Non-standardized waste management	Hazardous drug container disposal	High HVAC loads
16. Burn Unit	High water use in wound care	Hydrotherapy systems running long hours	Excessive dressing changes	Specialized dressings generating more waste	Humidity and temperature control burdens
17. Sterile Processing Dept.	Redundant sterilization cycles	High water and energy autoclaves	Excessive use of chemical disinfectants	Overuse of wrapping materials	Steam-heavy and energy-intensive space
18. Morgue/Autopsy Suite	Inadequate body fluid waste handling	Refrigeration units constantly on	Manual autopsy with excess water use	Use of non-degradable body bags	Cold storage energy demands

B.10 Examples of 5S by CWA

Clinical Area	Sort	Set in Order	Shine	Standardize	Sustain
1. Operating Room (OR)	Remove expired tools/supplies	Arrange instruments per procedure	Deep clean between cases	Standard setup checklists	Weekly audits
2. Interventional Radiology	Remove outdated catheters, guidewires, and disposable items no longer used in current protocols	Organize procedure trays with labelled, color-coded compartments for quick access during interventions.	Schedule daily cleaning of imaging equipment and procedure tables, especially between patients.	Develop a checklist for setup and cleanup of interventional suites to ensure consistency across shifts.	Assign staff roles to conduct weekly audits and refresh training on proper inventory and layout maintenance.
3. Intensive Care Unit (ICU)	Discard outdated meds/equipment	Organize emergency carts/equipment	Disinfect patient areas	Uniform equipment placement	Daily team huddles
4. Emergency Dept. (ED)	Clear trauma bay clutter	Mark and stock crash carts	Hourly cleaning during peak times	Standard trauma room layout	5S shift champions
5. General Ward	Remove hallway clutter/furniture	Label nurse station storage	Clean high-touch surfaces	Standard bed layout	Monthly staff reviews
6. Day Surgery Unit	Eliminate duplicate tools/paperwork	Prep bays with standard layouts	Sanitize after each case	Uniform patient flow/documentation	Multidisciplinary reviews
7. Outpatient Clinics	Discard old brochures/broken items	Organize rooms with essential tools only	Daily cleaning of patient areas	Unified room layout/signage	Monthly checklist audits



8. Radiology/Imaging Dept.	Archive old imaging files	Label and store imaging supplies	Clean beds/control rooms	Standard imaging protocols	Visual boards/training
9. Radiotherapy	Eliminate expired dosimetry tools and outdated immobilization devices.	Clearly label and store masks, blocks, and bolus materials by patient name and session.	Perform daily disinfection of treatment machines and surfaces between sessions	Create uniform setup protocols for each treatment type to ensure reproducibility and safety.	Develop a rotating responsibility calendar for staff to maintain equipment logs and storage cleanliness.
10. Clinical Laboratory	Remove expired reagents/sample tubes	Label zones and tools	Clean benches, centrifuges	Standard sample/test process	Peer-review adherence
11. Pathology Lab	Discard old slides and chemicals	Organize slides and tools	Clean microscopes/workstations	Labeling and specimen protocols	Bi-weekly QC checks
12. Pharmacy (Hospital)	Remove expired medications	Categorize drugs by urgency/class	Clean dispensing areas	Standard labelling/shelving	Inventory audits
13. Dialysis Unit	Dispose of expired tubing/filters	Consistent setup of machines/carts	Sanitize chairs/machines post-use	Common setup protocol	5S logs and retraining
14. NICU	Eliminate redundant neonatal items	Organize incubators/supplies by priority	Disinfect incubators/equipment	Standard cart/storage layout	Staff orientation includes 5S
15. Chemotherapy Unit	Discard expired chemo/PPE	Organize meds and protective equipment	Clean chairs/prep areas	Prep and disposal protocol	Nurse/pharmacist checks
16. Burn Unit	Remove expired dressings/tools	Arrange trolleys by burn severity	Clean treatment rooms and vents	Standard wound care/med layout	Weekly feedback sessions
17. Sterile Processing Dept.	Discard damaged tools/packs	Separate clean/dirty zones	Clean sterilizers/workspaces daily	Color-coded trays/process flow	Visual audits
18. Morgue/Autopsy Suite	Remove old chemicals/tools	Organize instruments/containers	Sanitize tables and storage units	Body handling and report protocols	Scheduled inspections

B.11 Some technological innovation trends by CWAs

Operating Room (OR):

- Mini-invasive surgery will substitute open surgery
- Robotic surgical systems enhance precision during complex surgeries.
- Intraoperative imaging provides real-time guidance for surgeons.



Advanced anaesthesia monitoring ensures patient safety and comfort

Interventional radiology

- Advanced Catheter Designs
- 3D Imaging Technology provides enhanced visualization
- Enhanced Navigation Systems enable precise guidance during interventional procedures,

Intensive Care Unit (ICU):

- Continuous hemodynamic monitoring tracks vital signs in real time.
- Advanced ventilators provide personalized respiratory support.

Emergency Department (ED):

- Portable ultrasound devices expedite bedside diagnoses.
- Telemedicine platforms allow remote triage and consultations.
- Real-time data analytics improve decision-making processes.

General Ward:

- Smart beds monitor patient movements and vital signs.
- Electronic health records streamline patient data management.
- Wearable devices allow for continuous health monitoring.
- Robotic-assisted patient handling
- AI-assisted in-ward physical rehabilitation
- POCT Point of Care Testing
- AI-assisted therapy execution

Day Surgery Unit:

- Minimally invasive instruments reduce recovery times.
- Postoperative monitoring systems track patient recovery.
- Patient education tools enhance understanding of procedures.

Outpatient Clinics:

- Wearable health devices track chronic conditions effectively.
- Mobile health apps provide accessible patient education.
- Remote monitoring enhances patient-physician communication.
- POCT Point of Care Testing

Radiology/Imaging Department:

- AI-powered imaging analysis enhances diagnostic accuracy.
- Cloud-based platforms support remote access and collaboration.
- Rapid (high speed) CT and RMN scan
- No contrast medium radiology

Radiotherapy

- Image-Guided Radiation Therapy (IGRT) for more precise radiation delivery



- Intensity-Modulated Radiation Therapy (IMRT) to tailor radiation doses to the shape of the tumour
- Proton Therapy, rather than X-rays, for precise treatment with less collateral damage

Clinical Laboratory:

- Automated analysers boost efficiency and accuracy.
- Point-of-care testing devices provide rapid results.

Pathology Lab:

- Digital pathology systems enable remote analysis.
- Molecular diagnostic tools identify genetic markers.
- Collaborative platforms enhance diagnostic accuracy.
- AI assisted diagnostic

Pharmacy (Hospital):

- Automated dispensing systems ensure medication accuracy.
- Medication management software optimizes inventory control.
- Electronic prescribing reduces errors in medication orders.

Dialysis Unit:

- Portable dialysis machines enable home treatment.
- Wearable dialysis devices offer continuous renal support.
- Remote monitoring enhances patient management..

NICU (Neonatal ICU):

- Neonatal monitoring systems track vital signs closely.
- Integrated incubators maintain optimal conditions for infants.

Chemotherapy Unit:

- Infusion pumps ensure precise drug delivery.
- Patient monitoring systems track treatment side effects.
- Telehealth services support ongoing patient communication..

Burn Unit:

- Advanced wound care products promote healing.
- Telemedicine enables specialist consultations for burn care.
- Real-time monitoring aids in recovery assessment.

Sterile Processing Department:

- Automated sterilization equipment ensures thorough cleaning.
- Tracking systems monitor sterilization processes effectively.
- Quality control measures enhance patient safety.

Morgue/Autopsy Suite:

- Digital Autopsy Tools: Provide non-invasive postmortem examinations.
- Forensic Imaging Systems: Enhance the accuracy of autopsy findings.



B.12 Actions for green transitions in healthcare

Source: (D2.1)

Domain: ENERGY
<i>Adopting energy-efficient practices and integrating renewable energy sources to reduce the carbon footprint and improve the resilience and reliability of energy supply</i>
Actions
1) Implement controls to turn off lights and appliances
2) Integrate occupant education and awareness programs
3) Defrost freezers and refrigerators regularly
4) Conduct regular energy audits
5) Perform an inventory of medical and other equipment
6) Replace older air conditioners, refrigerators and other appliances
Domain: FOOD
<i>Reducing food waste, promoting sustainable nutrition, educate and raise awareness, increase plant-based options</i>
Actions
1) Minimize and beneficially reuse food waste
2) Educate and communicate within the hospital or health care system, as well as to patients and community
3) Establish patient-adjusted portion sizes
4) Supply food that is produced without synthetic pesticides and hormones
Domain: PHARMACEUTICS AND CHEMICALS
<i>Reducing the environmental impact of pharmaceuticals in hospitals, including the education of patients about the appropriate use of medications</i>
Actions
1) Reduce the use of single-use items and promote sterilization and reuse of medical items
2) Substitute products with safer alternatives
3) Use floor-care products that are free of zinc, heavy metals, phthalates, glycol ethers and ammonia
4) Prevent disease exacerbation
5) Educate patients on appropriate inhaler use and shift from carbon-intensive MDIs to low-carbon alternatives
6) Improve packaging, labelling and identification of chemical waste
Domain: SUPPLY CHAIN
<i>Hospitals and healthcare providers ought to adopt environmentally responsible supply chain management strategies, by leveraging their remarkable purchasing power</i>
Actions
1) Implement procurement policies
2) Emphasize efficient supply usage
3) Review procurement practices and local favour suppliers
4) Implement a sustainable purchasing agenda
5) Advocate for Extended Producer Responsibility
6) Placing importance on low-carbon substitutions
7) Coordinate hospital purchases to increase buying power and prioritize suppliers and products with circular economy approaches
Domain: TRAVEL & TRANSPORT
<i>Healthcare organizations should explore alternative transportation options, such as electric or hybrid vehicles, and implement more efficient travel planning strategies</i>
Actions
1) Develop strategies for telemedicine communication
2) Improve digital health and telemedicine
3) Encourage cycling, walking, and alternative transportation modes
4) Incentivize staff to embrace electric vehicles
5) Purchase from local suppliers
6) Dispose of waste near the point of generation
Domain: WASH (water, sanitation and hygiene)
<i>Effective water saving and good water management in hospitals are crucial for both environmental sustainability and operational efficiency</i>
Actions
1) Regularly analyse water quality
2) Implement on-site wastewater treatment

**Domain: WASTE**

Effective waste management practices, such as waste minimization, segregation at the source, proper treatment, and disposal, are essential for ensuring that healthcare activities do not compromise environmental quality and public health

Actions

- 1) Separate bins for potentially infectious waste
- 2) Develop medical device reprocessing initiatives
- 3) Minimize the production of general non-hazardous waste
- 4) Phase-out of incineration of medical waste

Domain: STAFF AND COMMUNITY ENGAGEMENT

The staff and community engagement in sustainability initiatives can drive significant changes through daily practices and decision-making processes

Actions

- 1) Build regional and national networks for climate resilience and sustainability
- 2) Educate healthcare professionals and build their capability
- 3) Engage the health workforce and its associations and unions
- 4) Ensure healthcare facilities have sufficient numbers of healthcare worker
- 5) Advocate for specific policies, regulations, and legislation
- 6) Communicate and increase awareness