Case Study

Human-Centricity and Resilience in Healthcare: a Case Study in a Blood Collection Centre

	ACTORS	LOCATION
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TIME PERIOD OF THE PROJECT: July 2024 – July 2025

SHORT DESCRIPTION OF THE CASE: The healthcare sector has shown in recent years a growing need for efficient and secure management of clinical and organizational processes. In addition, many healthcare systems, particularly public ones, are often understaffed, forcing workers to operate under high levels of stress. In this context, the competencies of biomedical engineers allow for the analysis of these processes through advanced modelling tools, improving operational efficiency and supporting more informed and human-centred decisions. The case study focuses on the a blood collection centre in Lombardia region, where three main critical issues have been identified. For each critical issue, two scenarios were developed: the current situation (AS-IS) and an improvement proposal (TO-BE). The scenarios were developed with Scene2Model, a software that converts storyboards and visual representations into digital process models. This tool proved essential for clearly visualizing operational dynamics, simulating alternatives, and comparing the current state with possible solutions. The case study aims to contribute to the evolution towards healthcare 5.0, promoting more resilient, human-centric and technologically advanced healthcare processes, combining 4.0 digitalization with human-centred design and the resilience of hospital structures.

1. 5.0 ORGANISATIONAL CHANGES OF HEALTHCARE PROCESSES

1.1. Context

The blood collection centre is an essential department in hospitals, responsible for collecting, preparing, validating, and distributing blood and its components. Its activities include verifying donor-recipient compatibility, performing immunohematology tests, labelling products according to safety protocols, and storing them until administration. The centre's staff includes biologists, laboratory technicians, nurses, and administrative personnel, all specialised and coordinated to ensure safety and efficiency. In our case study, the centre manages three levels of urgency: normal requests (scheduled and non-immediate), which follow standard laboratory timeframes; urgent requests, with faster response times; and extremely urgent requests for life-threatening situations, which require immediate interventions, sometimes using universal blood (i.e., group 0 negative). Activities are organized in shifts to ensure continuous coverage, with greater intensity between 06:00 and 12:00 and a peak from 10:00 to 12:00, when hospital activity is most intense. Day shifts handle scheduled procedures and routine tests, while night shifts ensure availability for emergencies, guaranteeing timely management of all transfusion needs.

The blood collection centre laboratory presents several operational criticalities that affect patient safety and staff wellbeing. Work rhythms are characterized by high pressure, especially during night hours or in periods of greater workload. In these situations, psychophysical stress increases and the risk of human errors grows.

Blood sample labelling represents a particularly sensitive area, entrusted to laboratory technicians. This operation requires the correct association of fundamental information, such as blood group and expiration date. Any error can cause serious consequences, including acute haemolytic reactions or deaths. To save time, labels are often printed in bulk and then applied to the respective bags: an incorrect practice that increases the risk of exchanges and clinical errors, with significant medical-legal and economic implications.

Delivery and shipping management procedures also significantly slow down operations. Recording data from dataloggers for each box containing blood bags can take several minutes. During particularly intense days, this activity can occupy several hours of work. Shipments involve additional manual steps: preparing boxes, loading dataloggers, completing forms, and scanning each individual bag, with cross-checks to ensure data correspondence. These repetitive and poorly automated activities are not only time-consuming but also tedious, increasing the likelihood of errors and compromising service quality.

In summary, the laboratory operates in a context where manual procedures, poor automation, and high work pressure contribute to significant operational risk. If not addressed, these criticalities can compromise patient safety and generate additional stress for operators, with possible negative consequences on the overall quality of the department's performance.

1.2. Human-Centricity Challenges:

From a human-centred perspective, the blood collection centre laboratory faces several significant challenges. Manual, repetitive, and poorly automated procedures increase the cognitive and physical burden on technicians, causing stress and fatigue, especially during peak workloads or night shifts. The constant pressure to ensure sample safety and traceability compromises the psychophysical well-being of operators, while human errors, such as label mix-ups, can have serious clinical consequences. The main challenge is therefore to design processes and tools that reduce the risk of error, optimize workflows, and consider the needs and competencies of operators, while simultaneously promoting safety, efficiency, and professional satisfaction.

1.3. Resilience Challenges:

In terms of resilience, the blood collection centre laboratory faces challenges related to complex processes that heavily depend on manual operations, making it vulnerable to errors and delays. The management of numerous blood bags, high work pressure, and difficulties in check-in and check-out procedures limit the system's ability to quickly adapt to unforeseen events and demand peaks. The main challenge is to make the operational flow more robust and flexible through targeted interventions. These improvements would ensure service continuity, patient safety, and reduced operational risk even under stressful conditions.

2. Method

For the modelling of processes in the blood collection centre department, Scene2Model software was used [1], developed by OMiLAB (Open Models Initiative Laboratory). This tool transforms visual representations and storyboards into digital process models, simplifying the analysis and optimization of operational workflows. Visual modelling also facilitates clear communication among stakeholders with diverse backgrounds [2].

In the case study, the department's critical issues were represented through storyboards that illustrated the processes in a visual and sequential form. These storyboards, processed in Scene2Model, generated digital models useful for comparing the current situation (AS-IS) with improvement scenarios (TO-BE).

The use of the software allowed for:

- Clear visualization of operational dynamics, making the model accessible and understandable.
- Intuitive simulation of alternative scenarios and evaluation of possible solutions.
- Creation of a replicable basis for the analysis and optimization of similar processes in other hospital contexts.

The current blood component management process follows an established operational sequence that presents significant critical issues: inefficiencies, vulnerabilities, and workloads distributed unevenly across phases and different shifts.

The analysis has identified problems in three fundamental stages of the process, all closely interconnected:

- Acceptance and registration of blood components (*initial phase*).
- Sample labelling *(intermediate phase*).
- Management of the night shift (*final phase*).

In the following subsections (2.2.1, 2.2.2, and 2.2.3), the three different scenarios are presented, with the mapping of the AS-IS situation and the representation in Scene2Model. In Section 2.3, the proposed solutions will be presented, with an evaluation of their impact on the 5.0 dimensions of human-centricity and system resilience, discussed in Section 2.4.

2.2.1. SCENARIO 1: Acceptance and registration of blood components (AS-IS)

Figure 1. Scene2Model Scene of Scenario 1 (AS-IS).

The main critical issue that emerged concerns the initial phase of the check-in process, which includes acceptance, registration, checking, and preparation of blood components. In this phase, the operational flow is slowed down by excessive manual handling, compromising both the efficiency and safety of the process.

Technicians currently have to manually manage all verifications: downloading data from dataloggers to check storage conditions, scanning bags to verify identification data, and preparing paper documentation for shipments. This high load of manual activities not only requires a lot of time but also increases the risk of errors due to inattention or inaccuracies in data transcription.

The visual representation of the scenario highlights this critical issue: the accumulation of boxes and open blood bags indicates operational congestion, while the numerous paper sheets on the work surface show the dependence on manual procedures. The lack of digital tools underscores the absence of technological solutions to reduce repetitive activities. The hourglass next to the documents symbolizes the time wasted on low value-added operations that improve neither service quality nor patient safety.

In a blood collection centre setting, where traceability, speed, and reliability are essential, the excessive reliance on manual practices represents a concrete obstacle to operational efficiency and system resilience.

2.2.2. SCENARIO 2: Sample labelling (AS-IS)

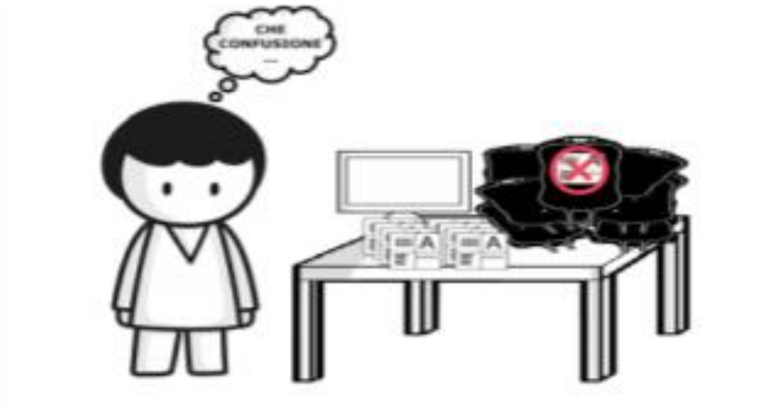

Figure 2. Scene2Model Scene of Scenario 2 (AS-IS).

The second critical issue identified concerns the intermediate phase of the process, namely the labelling activity, currently entrusted exclusively to the manual intervention of laboratory technicians. This delicate operation is often performed under significant pressure, especially during peak hours, increasing the risk of errors.

In the AS-IS scenario, the visual representation shows a technician at the centre of the scene, surrounded by a table full of apparently indistinguishable blood bags and numerous labels printed simultaneously. This symbolic choice highlights a crucial vulnerability in the process: the massive printing of labels for different patients and their subsequent manual association with the bags. This step is particularly critical, as even a single labelling error can cause serious clinical consequences for the patient, including potentially fatal adverse events, with significant medico-legal implications. The red symbol on one of the bags visually represents an "imminent error" or latent risk, emphasising the fragility of a completely manual process vulnerable to human error. This critical issue is directly connected to the one described in Scenario 1, as the inefficiencies and slowdowns in the check-in phase negatively affect subsequent phases, increasing pressure on operators and increasing the overall risk in the entire transfusion flow.

2.2.3. SCENARIO 3: Management of the night shift (AS-IS)

Figure 3. Scene2Model Scene of Scenario 3 (AS-IS).

The third critical issue identified concerns the final phase of the operational cycle: the management of the night shift. During this shift, service continuity must be guaranteed even without full staffing. In this time slot, the department is entrusted to a single resource, who must manage alone a flow of requests often classified as urgent or extremely urgent, in addition to completing the residual activities left by the day shifts.

The current scenario presents two distinct departments: the blood collection centre and, as an example, the Toxicology department, chosen to represent a reduced workload condition typical of summer periods. This situation highlights an imbalance in resource allocation: in the blood collection centre, a technician works alone with a computer, surrounded by numerous requests and samples to process, while in the parallel department, two operators perform a limited number of analyses, using working time inefficiently.

This configuration shows how inefficiencies in the initial and intermediate phases (check-in and labelling) create a delay that impacts night work, transforming it into the accumulation point for unresolved issues during the day. The asymmetry between workloads in different departments highlights the need for more flexible and collaborative strategies in resource management, especially during critical shifts, where the system's resilience is most tested.

2.3. Concrete organisational solution designed

As previously mentioned, this section describes and analyses the TO-BE scenarios for all the critical issues identified and examined in the previous section.

2.3.1. SCENARIO 1: Acceptance and registration of blood components (TO-BE)

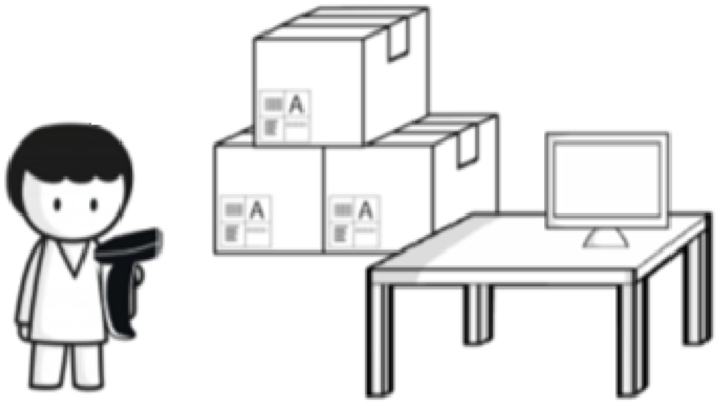

Figure 4. Scene2Model Scene of Scenario 1 (TO-BE).

With the aim of optimizing processes in the blood collection centre department, the first intervention focuses on automating blood component delivery check-in activities, extending it also to the check-out phase, which involves similar operations. The AS-IS scenario has highlighted a current process that is predominantly manual, causing slowdowns, overload of technical staff, and a significant risk of error.

The new TO-BE scenario implements digital tools to improve efficiency and traceability. The workstation is reorganized with technological supports: a barcode scanner to automatically track the blood bags and a computer interface that offers the technician immediate access to control data. The staff, previously isolated and burdened with paper documents, is now supported by technologies that eliminate redundancies, enhance control security, and optimize the operational flow.

At the organisational level, this revision lightens the workload of technicians, shortening verification times and shipment preparation. Traceability improves thanks to data centralisation, which can be consulted at every stage of the cycle. Furthermore, it significantly reduces the risk of human error, particularly frequent in repetitive activities with low added value.

The initial automation also produces benefits in subsequent phases, such as labelling and distribution, allowing better resource allocation and a more balanced operational flow. This TO-BE scenario is therefore not an isolated improvement but represents the first element of a comprehensive revision based on 5.0 principles: a more efficient and human-centric work environment, where technology enhances the operator's role rather than replacing it, making the system more resilient and efficient.

2.3.2. SCENARIO 2: Sample labelling (TO-BE)

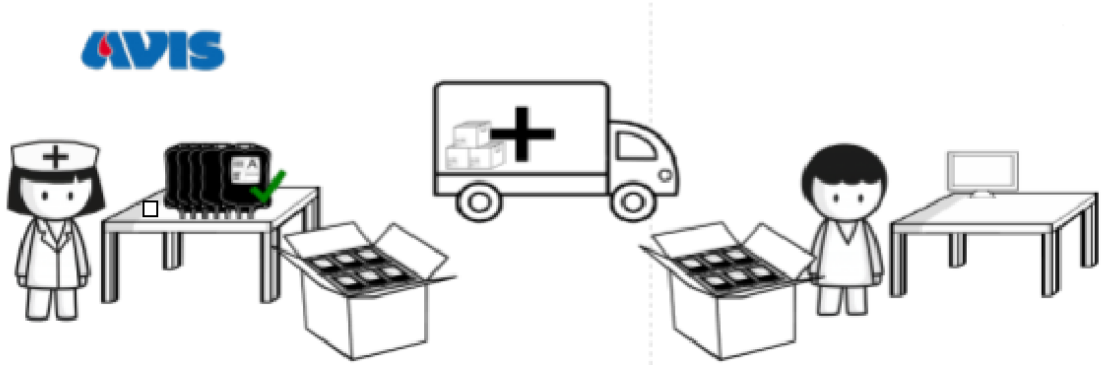

Figure 5. Scene2Model Scene of Scenario 2 (TO-BE).

In the optimization process of blood component management, a key intervention concerns the labelling of blood bags, which in the current scenario (AS-IS) represents a critical point for patient safety and operational efficiency.
The proposed solution (TO-BE) involves moving the labelling from the blood collection centre facility directly to the blood donation centres, such as AVIS (Italian Blood Volunteer Association), one of the main Italian organisations in blood donation working in close collaboration with hospital transfusion services, or other donation facilities.
With this modification, the bags arrive at the blood collection centre already labelled and uniquely identified, dramatically reducing the risk of matching errors. From a management perspective, this redesign eliminates a vulnerable phase and lightens the operational load of the blood collection centre. Additionally, labelling at the donation site improves data accuracy, thanks to the proximity between donor and operator.
Integration with the management software allows automatic acquisition of information in the blood collection centre systems, accelerating the check-in, storage, and distribution phases. This brings two advantages: it reduces the cognitive load for technical staff and increases security and traceability.
From an engineering perspective, the intervention represents a process delocalisation: an activity that is not optimal when centralised is moved closer to the origin of the flow, where it can be performed in a more timely and controlled manner. Furthermore, during peak demand, decentralisation ensures greater flexibility and resilience, improving the responsiveness of the entire transfusion chain.
The visual representation highlights these improvements: the AVIS logo clearly identifies the location of the activity; the donation centre nurse replaces the laboratory technician; the table shows bags already labelled with a green checkmark, a symbol of a correctly completed process. Containers ready for transport, next to a dedicated vehicle, communicate order and timeliness. Finally, the arrival of already labelled bags at the blood collection centre confirms the result: the almost total elimination of human error risk in this critical phase.

2.3.3. SCENARIO 3: Management of the night shift (TO-BE)

Figure 6. Scene2Model Scene of Scenario 3 (TO-BE).

Considering the critical issues of the AS-IS scenario related to night shift management and the concentration of operational workload on a single resource, a reorganisation of staff distribution is proposed without resorting to new hires that would financially burden the hospital administration. The solution is based on optimising available resources: during night shifts or periods with reduced coverage, a laboratory technician from a less busy department is temporarily assigned to the blood collection centre department. This provides support to the biologist on duty, increasing response capacity, reducing individual workload, and improving overall efficiency.

From a management perspective, this proposal represents an intervention with low economic impact but high organisational value. Rather than increasing staff, internal flexibility is used to dynamically distribute operators where most needed, based on historical activity data. The analysis of operational flows enables the identification of departments that, during night shifts, have a reduced workload and can temporarily "lend" a resource without compromising their own efficiency.

The graphical representation through Scene2model highlights the key elements of the new configuration: a worktable with reduced transfusion requests, the biologist supported by a technician from another department, and a list of tasks distributed between the two operators. This symbolic representation illustrates a more equitable distribution of activities, leading to faster response times and more sustainable workload management.

The system structured this way does not eliminate the critical issue, but significantly mitigates it, offering a sustainable and adaptable management solution. This approach reduces the risk of errors due to overload during critical shifts, improves operational performance, and strengthens organisational resilience.

In conclusion, the redistribution of staff during night shifts and at times of greater criticality represents a concrete and realistic intervention, capable of addressing a structural weakness without impacting the hospital budget, aligning with the principles of efficiency and resilience.

2.3.4. The Ideal Process

The ideal process integrates the improvements discussed in the previous subsections (2.3.1, 2.3.2 and 2.3.3) in a holistic manner. Using Scene2Model, the enhanced process addressing the analysed criticalities can be visualised as follows:

Figure 7. Ideal process integrating all proposed improvements.

2.4. Considerations on Human-Centricity and Resilience

The analysis of the three scenarios shows that process optimisation is not merely a technical upgrade but an opportunity to enhance both human-centricity and system resilience, two pillars of the Healthcare 5.0 paradigm.

The proposed interventions place the operator at the centre of organisational redesign. In Scenario 1, automation technologies reduce cognitive and physical burden on laboratory staff, allowing them to focus on higher-value tasks while decreasing errors in repetitive operations. Scenario 2 reinforces this approach by decentralising labelling to AVIS donation sites, creating less stressful conditions for the operators. Scenario 3 creates a more sustainable workload distribution during critical shifts by reallocating staff, reducing isolation and excessive responsibility for night-shift operators. Together, these changes improve professional well-being and healthcare staff empowerment. This aligns with the principle that designing processes with a human-centric approach is crucial to enhance user experience, safety, and efficiency [3].

From a system resilience perspective, these solutions work across complementary dimensions. Automation (Scenario 1) strengthens process robustness through standardisation and traceability, reducing vulnerability to human error. Decentralised labelling (Scenario 2) eliminates a single point of failure and distributes operational risk across the transfusion network, enhancing adaptability and reliability. Scenario 3 introduces flexible human resource allocation that responds dynamically to demand fluctuations, ensuring service continuity during night shifts and workload peaks.

These scenarios demonstrate how human-centricity and resilience interconnect: placing people at the centre of process design improves staff well-being while strengthening the system's capacity to react and adapt to critical situations. By reducing errors, increasing flexibility, and improving traceability, the transfusion chain becomes more efficient and reliable, ready to face future challenges. This approach aligns with recent research that shows how Industry 5.0 technologies can make healthcare systems more human-centred and resilient [4].

2.5. Key Skills and Competences Necessary

The optimisation of blood collection centre processes, as outlined in the TO-BE scenarios, requires not only the introduction of new technologies and organisational solutions, but also the development of a specific set of skills. These competencies are essential for ensuring the effective implementation and long-term sustainability of the proposed changes. The skillset required is therefore hybrid, combining technological literacy with analytical reasoning and human-centric soft skills. In particular, Table 1 presents all the skills required for each analysed scenario.

Table 1. Key skills and competencies for operating and improving the scenarios.

Scenario	Short description	Key skills
Scenario 1 - Automation and traceability through barcode	Introduction of a digital labelling system to reduce manual errors and inefficiencies.	Abilities of effectively using, monitoring and controlling technological devices
		Competencies in ICT deployment and integration
		Digital literacy
		Ability to optimise processes and tasks through automated solutions
Scenario 2 - Collaboration with AVIS and flow management	Digitalisation and coordination between the hospital and external centres to balance supply and demand of blood bags.	Ability to make effective and timely decisions
		Ability to communicate and collaborate across teams (social skills)
		Ability to collaborate and disseminate information effectively
		Ability to perform effectively in high-pressure environments (resilience)
Scenario 3 - Night shift reorganization	Staff redistribution without new hires to reduce overload during critical shifts.	Ability to navigate and implement organizational changes (change management)
		Teamworking and knowledge sharing
		Empathy and emotional intelligence
		Decision-making under stress
		Critical thinking
Across all scenarios	Skills necessary to support implementation and continuous improvement.	Commitment to lifelong learning
		Adaptability and flexibility
		Process analysis
		Self-management
		Problem solving

3. CONCLUSION AND RECOMMENDATIONS

This case study demonstrated how targeted interventions across the blood management process can enhance efficiency, resilience, and staff well-being. The proposed solutions, ranging from decentralised labelling to dynamic personnel allocation, highlight practical improvements achievable without significantly increasing costs.

The use of Scene2model proved fundamental in visualising and modelling the proposed scenarios, creating a shared visual language that facilitated discussion among stakeholders from diverse backgrounds. Beyond illustrating the potential of 5.0 improvements, the case study showcased how visual modelling can bridge communication gaps, making complex processes and solutions more transparent and comprehensible.

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