



An AI-Supported Hospital Laundry Processing System (AIHLPS)

Ibrahim Zincir, Kaan Kurtel, Ufuk Celikkan
Izmir University of Economics, Izmir, Turkiye

Abstract—To ensure a hygienic and safe healthcare environment, all operational processes, including the collection, cleaning, and storage of patient linens, are strictly regulated in accordance with standards and policies. Personnel must clearly understand and implement these standards and policies to effectively prevent contamination. Healthcare facilities maintain these regulations written in natural language, in many cases containing ambiguous information. They also must contend with local, national, and international variations in these regulations. This further exacerbates ambiguities. Artificial Intelligence (AI) and natural language processing serve as a bridge between human language and ICT-based applications. They can provide faster, more precise, and more adaptable solutions to ever-changing conditions. This study proposes an artificial intelligence supported laundry processing system (AIHLPS) to do risk analysis tailored to the regulatory and operational risk factors associated with hospital laundry management. The framework processes various text documents using a Large Language Model (LLM) and classifies laundry items via its Decision Model to determine washing parameters.

Keywords—medical laundry, hospital laundry management, large language model, artificial intelligence

I. INTRODUCTION

Pinpointing the exact origin of hospital-acquired infections can be challenging due to a wide range of possible transmission routes within hospital settings—one of which is patient laundry. It is reasonable to consider hospital linens as potential carriers of infectious pathogens. These textiles commonly include bedding, towels, and clothing used by both patients and staff, such as scrubs, lab coats, uniforms, patient gowns, and pajamas, as well as surgical drapes and curtains. In response to growing concerns, hospital and healthcare facility administrators are placing increased emphasis on the role of nurses and staff in ensuring proper management and handling of medical laundry. Staff must understand and follow detailed protocols for the transportation, cleaning, and storage of linens to avoid cross-contamination. It is also essential for them to distinguish between hygienically clean and fully sanitized laundry.

Several factors influence the hospital laundry cleaning processes. These include reducing human error, complying with diverse regulations, assessing linen conditions, responding quickly to changing circumstances, and integrating hospital-and healthcare systems. To emphasize the importance of quick reaction to changing conditions, consider a case where the hospital management needs to change washing and drying policies for healthcare textiles due to the challenges created by Monkeypox, which is spreading rapidly today, as it did with

Covid-19 in the past. Also, consider that hospital laundry items have different cleaning needs due to their different contexts, and healthcare facilities follow different policies regarding reusing, washing, or disposing of these items. Additionally, be reminded that there are often conflicting local, national, or international regulations. International health organizations have published numerous technical guidelines defining the requirements for regulating laundry hygiene in hospitals. Despite some minor differences, these international standards generally share a common narrative. However, in cases of rapidly developing epidemics and migration events, they announce additional sub-rule making it difficult for hospitals to adapt. A similar situation applies to country-based domestic legislation and hospital-specific regulations.

These standards identify risk levels based on the condition of hospital linens. However, the overall system is sensitive to factors such as geographic variations, specific outbreak types, and patient volumes. This means that policies and guidelines for linen sterilization and disinfection can be affected by these factors, leaving healthcare facilities vulnerable to uncontrolled (or delayed) risks. This shows that risk levels must be adaptable to changing conditions.

Traditional manual classification is prone to human error, leading to inefficiencies and potential infection breaches. Our goal in this study is to address the aforementioned issues by proposing a framework called the Risk-Based AI Analysis Module which processes human-generated text to accurately classify the risk level of laundry items and set cleaning parameters accordingly using a decision model. We have primarily used four sources of information as input to the framework. 1) Numerous technical guidelines and regulations defining the requirements for hospital laundry hygiene published by international health organizations (i.e. the World Health Organization-WHO and the European Centre for Disease Prevention and Control-ECDC). 2) country-based domestic regulations (i.e. the US Centers for Disease Control and Prevention-CDC). 3) hospital-based policies, and 4) a rational risk classification of patient care instruments and items. The proposed framework uses large language models, with ChatGPT being a popular example.

II. LITERATURE REVIEW

Hospital laundry cleaning policy, rules, and guidelines for the reduction of risks related to laundry against potential or actual contamination with an infectious agent can be found in [1]-[7]. The effective management of hospital laundry is crucial in infection prevention, as underscored by numerous studies.

According to [7], inadequate textile management directly correlates with increased healthcare-associated infections, emphasizing the criticality of proper laundry handling protocols. Moreover, Lee et al. stated that machine development models, which utilize continuous programming advancements, can help people accurately process their waste. They also noted that the speed and quantity of waste depletion will facilitate the effective increase of waste separation policies [8].

GenAI (Generative AI), a subset of artificial intelligence where artificial intelligence learns from existing data and generates new content based on the patterns and structures it learns [9], [10], is also revolutionizing medical informatics. Chopra [11] and Chakraborty [12] examined the transformative potential of ChatGPT, its development in generative AI, and its applications in healthcare. They highlighted the far-reaching impact of using these technologies in medical decision-making. Furthermore, identified that AI-based systems, especially those utilizing Large Language Models (LLMs), significantly enhance infection control measures by automating real-time data processing and improving compliance with hygiene protocols.

Baker et al. [13] discusses the overall suitability for an IoT healthcare system while evaluating the strengths and weaknesses of the system. Similarly, under the title Artificial Intelligence in Healthcare, [14], [15] discusses the opportunities, challenges and ethical issues in the application of AI to healthcare. Kumar et al. propose an Artificial Intelligence (AI)-based automated solution for COVID-related medical waste type classification and provide data-driven decisions for recycling [16]. Zainordi et al. demonstrated that integration of IoT (Internet of Things) and AI (Artificial Intelligence) technologies in hospital laundry systems leads to improved operational efficiencies [17].

As discussed before, hospitals produce vast quantities of contaminated linen daily, including patient gowns, bedding, surgical drapes, and staff uniforms. Contaminated laundry poses a significant risk for HAIs, potentially leading to severe patient health outcomes increased operational costs and the need for stringent handling protocols [1], [6]. Abney et al. define several factors affecting bacteria, viruses, and mold growth in laundry as fabric composition, storage conditions, usage, season, age of clothing, type of detergent, and several others. They also categorized pathogens detected in textiles before washing as bacteria, fungi, viruses, helminths and protozoa [18]. Considering that these categories also have subcategories, it becomes clear how difficult manual sorting is.

III. HOSPITAL LAUNDRY PROCESSES

This section describes the conventional operations of hospital laundry based on [18] and [20], which helps us in understanding the basic requirements of an ICT-based solution. Laundry operations in a hospital are quite different from those in other domains such as hotel and hospitality. Even within a hospital, different units operate in different contexts, requiring varying cleaning parameters (for example, infectious diseases and maternity wards may use different pH and temperature values). In the light of these and other specific requirements, we propose a Hospital Laundry Management Process consisting of five major activities as illustrated in Fig. 1.

Laundry Collection, Pick-up and Sorting (LC): During the collection process, the staff collects laundry from hospital units and sort the items using the associated laundry information. Article [18] proposes a system that uses washable RFID tags to store this information and assist with item sorting.

Data Collection (DC): During the Data Collection activity all necessary information is gathered to enable the Risk Analysis activity to assign a risk level. This activity may involve the use of physical hardware such as RFID, for data acquisition, in addition to manual data provisioning. Medical staff may visually examine the items and manually enter information about each item's condition into a data repository (e.g., a database). Additionally, after visual inspection staff may make an immediate judgement, assign a risk level to the laundry item and dispose of it in appropriate color-coded collection bins.

Risk Analysis (RA): The primary function of Risk Analysis process is to assign a risk level to each item so that a decision can be made on how the item is cleaned or whether the item must be destroyed. Risk Analysis process uses artificial intelligence to assess the risk level of fabrics. This paper focuses on this process and discusses its details in the following sections.

User Interface (UI): This process facilitates interaction between human users and the rest of the system. Medical staff enter data described in the Data Collection activity using a user interface device, such as a mobile phone or a terminal. If a manual risk assignment is needed it is also performed by this process.

Cleaning (CP): The details of the cleaning activity are outside the scope of this paper. This study focuses on the Risk Analysis aspect of the hospital laundry handling processes.

IV. AI-BASED RISK ANALYSIS MODULE

AI-based risk analysis module learns, infers and makes decisions to ensure that the system follows the correct washing procedures. To achieve this the module must classify the linens using a defined classification scheme.

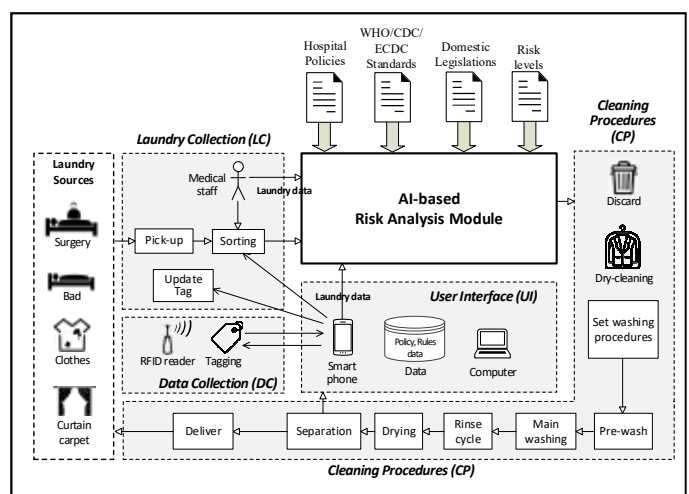


Fig. 1. Hospital Laundry Management Activities

TABLE I. SAMPLE DATASET

Sample	Class
Linens issued but returned unopened	Unused (I)
Blanket from a non-infectious orthopedic patient	Low Risk (II)
Gown from patient suspected of tuberculosis	Medium Risk (III)
Bed cover soaked with blood from emergency trauma unit	High Risk (IV)
Bed sheet returned from a patient in the oncology ward who had nosebleeds and was confirmed COVID-19 positive.	Discard (V)

Spaulding proposed the conventional risk classification in healthcare facilities approximately 65 years ago. Spaulding developed a rational approach to patient care instruments and items, by introducing a clear and logical classification consisting of three main categories: *Critical*, *Semi-critical*, and *Non-critical* [21]. Many organizations [22], [23] used this classification as the de facto standard. After analyzing a number of laundry handling policies we have concluded that the risk specifications given in various standards documents and Spaulding's work needed some update. For example, it is written in some policy documents that laundry was discarded without being cleaned due to its condition [4, p. 4] [23, pp. 10, 16] and in others it was returned to the store without being opened [4, p. 3]. Although rare compared to other types of contamination, any instance of radioactive contamination must be handled using entirely different procedures. For these reasons, a new risk categorization is needed. We leveraged Large Language Models (LLMs) to create five distinct risk classes optimized according to the guidelines from [3]-[7], [22]-[24]. These new risk classes are *Unused (I)*, *Low Risk (II)*, *Medium Risk (III)*, *High Risk (IV)* and *Discard (V)*.

The model uses the new five-level risk classes and the standards to train the dataset. A sample dataset is presented in Table I. As conditions and other environmental factors change over time, the dataset is updated and reused to update the generated model. This leads us to a scalable and adaptable model that enables the automatic classification of laundry in real time

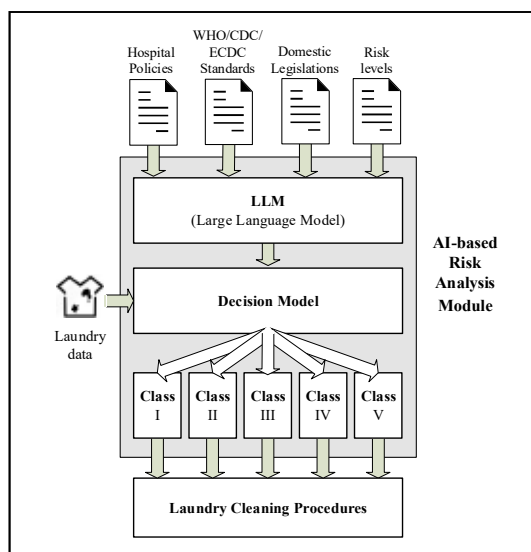


Fig. 2. Technical framework

into five distinct risk-based classes. The generated LLM model ensures compliance with [3]-[7], [22]-[24] and processes real-time data to classify laundry accurately.

AI-Based Risk Analysis Module works as follows: LLM model is first trained using risk levels defined by the specific hospital in question, the hospital's own policies, relevant domestic legislations and regulations, and finally standards from WHO, CDC, and ECDC. This training generates a decision model, and both the input data and the final model are stored inside a database. Then new laundry data (that inherits all the necessary information with respect to i.e. from where this laundry comes from, to whom it belongs to, at what time it is used and for how long as well as for what purpose, and finally when it is last disinfected/cleaned), is presented to the generated decision model via reading the RFID tag implemented on it. After this, the decision model makes a suggestion with respect to which class this laundry belongs to and then presents the necessary laundry cleaning procedures according to that specific class. Fig. 2 demonstrates this AI-Based Risk Analysis Module, presented inside Fig 1, in detail.

TABLE II. SAMPLE WORKFLOW SCENARIOS

• LLM Input Example: “<i>Unopened surgical gown returned from storage.</i>” • Class Assignment: I (Unused) • Workflow: i. Scan RFID tag to confirm unopened status. ii. LLM Verification: AI checks EHR for any contamination alerts. iii. If cleared, return to clean storage. iv. If contamination is suspected (e.g., torn packaging), reroute for rewashing. • Automation: LLM logs the item's status in the inventory system.
• LLM Input Example: “<i>Blanket from non-infectious orthopedic patient.</i>” • Class Assignment: II (Low Risk) • Workflow: i. Place in white linen bags (automated dispensing system). ii. LLM Confirmation: AI verifies patient's infection status via EHR. iii. Wash at $\geq 60^{\circ}\text{C}$ with standard detergent. iv. Store in designated clean linen area (tracked via barcode). • Automation: AI updates linen usage logs in real time.
• LLM Input Example: “<i>Gown from patient with persistent cough awaiting TB results.</i>” • Class Assignment: III (Medium Risk) • Workflow: i. Place in yellow biohazard bags (color-coded). ii. LLM Alert: Flags for separate washing at $\geq 70^{\circ}\text{C}$ with disinfectant. iii. Post-wash inspection using AI-powered visual scanning for stains. iv. If cleared, return to circulation; else, escalate to Class IV. • Automation: AI documents handling compliance for audits.
• LLM Input Example: “<i>Blood-soaked bed cover from trauma unit.</i>” • Class Assignment: IV (High Risk) • Workflow: i. Place in red leak-proof biohazard bags. ii. Staff must wear PPE (gloves, gowns, masks). iii. LLM-controlled Washing: • Main washing: High temperature -- 70°C - 90°C (158°F - 194°F), special bleaches, 10 minutes. • Optional UV treatment for additional sterilization. iv. Final AI Verification: Ensures no residual contamination. • Automation: AI generates disposal logs for regulatory compliance.
• LLM Input Example: “<i>Single-use chemotherapy drape.</i>” • Class Assignment: V (Discard) • Workflow: i. Barcode-tagged for hazardous waste tracking. ii. LLM Confirmation: Ensures no accidental reintroduction into the system. iii. Disposed of via certified medical waste contractors. iv. AI generates compliance reports for audits. • Automation: Real-time alerts if improper handling detected.

The LLM generates a ruleset to classify the laundry items. A sample ruleset is given below:

1. IF unused, unopened, and shows no contamination, THEN Class I.
2. IF used by non-infectious patients or staff and shows no biological contamination, THEN Class II.
3. IF from a ward with patients under observation or suspected infection (e.g., isolation ward) but not confirmed, THEN Class III.
4. IF visibly soiled with blood, body fluids, or from a confirmed infectious patient, THEN Class IV.
5. IF single-use, irreversibly damaged, or contaminated with hazardous chemicals, THEN Class V.

V. EXAMPLE WORKFLOW SCENARIOS

The proposed module generates optimized workflow procedures for each of these five classes described above accordingly. Table II depicts sample scenarios and workflows. We generated a simulated dataset to test the proposed framework and achieved 100% accuracy.

VI. CONCLUSION

We have proposed a software system to address the needs of medical laundry. The handling of medical laundry must follow strict guidelines without exception. The rules, policies, and protocols for handling laundry are typically specified in written documents using natural language. These documents attempt to categorize linens and based on this categorization they specify different handling requirements. LLMs exhibit strong language understanding capabilities; therefore, using LLMs in a laundry setting can enable the automation of laundry processing and reduce staff errors caused by interpreting ambiguous documents. By integrating AI-Based Risk Analysis Module (in other words LLM-driven automation), any hospital can transform its laundry management into a much safer, more efficient, and fully traceable system. Furthermore, this model can be replicated in other healthcare settings to reduce HAIs, improve compliance, and optimize resource allocation.

The proposed system uses various documents such as hospital laundry documents, public health agency guidelines for handling medical laundry and legislative documents as input to the LLM and classifies laundry belonging to institutions that provide health services. Once the laundry is classified the washing parameters are determined, or the laundry is discarded. Future improvements could incorporate robotic sorting, blockchain technologies for secure tracking, and expanded sensor integration to support even greater reliability and security procedures. We are currently in discussions with the university hospital to explore a potential collaboration aimed at validating the ideas presented in this paper using real-world datasets.

REFERENCES

- [1] World Health Organization, "Infection prevention and control in the context of coronavirus disease (COVID-19): a living guideline", Geneva: WHO, Aug. 2023. Reference: WHO/2019-nCoV/IPC/guideline/2023.2.
- [2] World Health Organization, "Global analysis of healthcare waste in the context of COVID-19: status, impacts and recommendations," Geneva: World Health Organization; 2022.
- [3] European Centre for Disease Prevention and Control, "Surveillance of healthcare-associated infections and prevention indicators in European intensive care units," HAI-Net ICU protocol, version 2.2, 2015.
- [4] Centers for Disease Control and Prevention, "G. Laundry and Bedding," in Environmental Infection Control Guidelines, CDC, Jan. 2024.
- [5] NHS East London Foundation Trust, "Linen and Laundry Policy 3.0," Feb. 2024.
- [6] NHS Leicestershire Partnership, "Linen and Laundry Management Policy," March 2025.
- [7] W.A. Rutala, and D.J. Weber, "Infection control: The role of disinfection and sterilization," in Journal of Hospital Infection, 2019, vol. 103, no. 3, pp. 207-214.
- [8] Z. Lee, Y.C. Wu, and W. Xukang, "Automated Machine Learning in Waste Classification: A Revolutionary Approach to Efficiency and Accuracy," in 2023 12th Int. Conf. on Computing and Pattern Recognition (ICCPR 2023), October 27-29, 2023, Qingdao, China. ACM.
- [9] X. Wang et al., "The Internet of Things in the Era of Generative AI: Vision and Challenges," in IEEE Internet Comp., 2024, vol. 28, no. 5, pp. 57-64.
- [10] C. Stryker, and M. Scapicchio, "What is generative AI?," IBM, 22 March 2024, <https://www.ibm.com/think/topics/generative-ai>.
- [11] A. Chopra, et al., "Enhancing medical decision-making with ChatGPT and explainable AI," Int. Jour. of Surgery," 2024, vol. 110, no. 8, pp. 5167-5168.
- [12] C. Chakraborty, et al., "ChatGPT or LLMs can provide treatment suggestions for critical patients with antibiotic-resistant infections: a next-generation revolution for medical science?," Int. Journal of Surgery, March 2024, vol. 110, no. 3, pp. 1829-1831.
- [13] S.B. Baker, W. Xiang and I. Atkinson, "Internet of Things for Smart Healthcare: Technologies, Challenges, and Opportunities," in IEEE Access, 2017, vol. 5, pp. 26521-26544.
- [14] European Commission, "Artificial Intelligence in healthcare, Transforming the future of medicine," EC, Accessed: 8 Aug. 2025. [Online]. Available: https://health.ec.europa.eu/health-digital-health-and-care/artificial-intelligence-healthcare_en.
- [15] T. Davenport, and R. Kalakota, "The potential for artificial intelligence in healthcare," in Future Healthc J., Jun. 2019, vol. 6, no. 2, pp. 94-98.
- [16] N.M. Kumar, et al., "Artificial intelligence-based solution for sorting COVID related medical waste streams and supporting data-driven decisions for smart circular economy practice," in Process Safety and Environmental Protection, 2021, vol. 152, pp. 482-494.
- [17] Zainordi M., et al., "Smart Linen Hamper and Laundry Monitoring for Hospital Industry," Evolution In Electrical And Electronic Engineering, 2024, vol. 5, no. 1, pp. 596-602.
- [18] S.E. Abney, M.K. Ijaz, J. McKinney, and C.P. Gerba, "Laundry Hygiene and Odor Control: State of the Science," Applied and Environmental Microbiology, 2021, vol. 87, no. 14.
- [19] K. Kurtel, and U. Celikkan, "Application of Context Aware Laundry Management in Medical Settings," 2024 Medical Technologies Congress (TIPTekno), Mugla, Türkiye, 2024, pp. 1-4.
- [20] U. Celikkan, and K. Kurtel, "A Context-Aware Architecture for the Management of Laundry Business Processes," 14th European Conf. on Knowledge Management - ECKM 2013, Lithuania, 2013, pp. 159-166.
- [21] E.H. Spaulding, "Chemical disinfection of medical and surgical materials," in: Lawrence CA, Block SS, eds. Disinfection, sterilization and preservation. Philadelphia, Lea & Febiger, 1968; pp: 517-531.
- [22] W.A. Rutala, D.J. Weber, and the Healthcare Infection Control Practices Advisory Committee (HICPAC), "Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008", CDC, Update: June 2024,
- [23] World Health Organization and Pan American Health Organization, "Decontamination and Reprocessing of Medical Devices for Health-care Facilities," WHO and PAHO, 2016.
- [24] European Centre for Disease Prevention and Control, "Infection prevention and control in the household management of people with suspected or confirmed coronavirus disease (COVID-19)," March 2020.