



# Designing Future-Ready Restrooms:

A Comprehensive Guide for Robotic Cleaning Integration

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# Introduction

The evolution of restroom design is increasingly influenced by the integration of robotic cleaning systems, including both contact-based and non-contact technologies such as brushes, steam, or spray disinfection. These innovations not only enhance efficiency and hygiene but also support long-term sustainability goals.

This guide provides architects, engineers, and facility managers with professional recommendations for designing robot-ready restrooms, focusing on optimizing layouts, selecting robot-compatible sanitary fittings, strengthening safety protocols, and enabling seamless human-robot collaboration.

All guidance aligns with international benchmarks, including ISO 21542:2021 (Accessibility and usability of the built environment) and ISO 12100:2010 (Safety of machinery — Risk assessment and risk reduction).

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# Accessibility and Space Planning

## 2.1. Toilet Door and Entryway Design

- **Preferred Door Type:** Push-in toilet doors are strongly recommended, as they align with robotic navigation mechanics. Cleaning robots navigate push-in systems with less complexity, ensuring smooth ingress and egress.
  - **Risk Mitigation:** Outward-swinging doors create significant safety hazards. Users pushing doors outward may inadvertently collide with a cleaning robot in motion, posing injury risks to users and operational risks to equipment. This is applicable only for ambulant compliant cubicle which is usually the last cubicle in the toilet.
  - **Doorless and Offset Entrances:** The ideal solution is to eliminate doors entirely. An offset entrance design, which prevents direct line-of-sight into the restroom, preserves user privacy while removing access barriers for robots and people alike.
  - **Sensor-Activated Automated Doors:** Where doors are unavoidable, automated sensor doors — similar to those found in universal access or handicap toilets — should be installed. These enable touch-free access, reduce collision risks, and uphold inclusivity standards.
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## 2.2. Corridor and Aisle Dimensions

- **Main Corridor Width:** For practical implementation, corridors should be at least 900 mm wide, which is sufficient for a single cleaning robot to navigate comfortably. While ISO 21542 recommends 1,500 mm for full two-way traffic, such widths are rarely feasible in existing restrooms and should be considered only for new builds or major renovations.
- **Cubicle Entrance Width:** Toilet cubicle doorways should ideally provide 600 mm minimum clearance to ensure compact-to-medium sized robots can pass through. Most toilet doors measure around 580 mm, and designs should aim to meet or slightly exceed this threshold to future-proof access.
- **Turning Radii:** Large turning radii (1,200 mm) are not strictly necessary for compact robots if corridor width meets the above requirement. Modern robots have demonstrated reliable maneuverability in tighter spaces. For non-contact robots utilizing steam or spray systems, turning radii can be optimized as physical reach constraints are minimized.

# Accessibility and Space Planning

## 2.3. Pathway and Flooring

- **Barrier-Free Access:** Restroom pathways should remain step-free. Where elevation changes are unavoidable, ramps with a maximum gradient of 20° must be provided.
- **Flooring Standards:** Non-slip, waterproof, and smooth-surfaced tiles should be used, compliant with ISO 13007-1:2010. These surfaces reduce slip hazards for users while providing robots with stable traction.
- **Navigation Support:** Embedding color-contrasted markers into flooring can improve sensor accuracy, enabling robots to map and clean more effectively.
- **No kerbs or steps** on flooring leading to the toilet, so that the robot can navigate in and out without problem.

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## 2.4. Dedicated Space for Robotic Systems

- **Docking Stations:** Allocate defined docking zones within or adjacent to restroom facilities. Each docking area should provide 1.5 m<sup>2</sup> of clearance.
- **Alternative Scenario – Swappable Batteries:** In facilities adopting robots with hot-swappable battery systems, docking zones for charging may be minimized or eliminated. Instead, provide a secure battery exchange station with proper storage, charging racks for spare batteries, and safe handling protocols. This approach reduces robot downtime and may free up valuable floor space.
- **Utility Provisioning:** Docking stations should be co-located with reliable power points, water inlets, and drainage lines to support autonomous operation. In selected facilities, owners may require charging stations to be located within a fire-rated enclosure to meet fire safety and building code requirements.
- **Dual Accessibility:** Layouts must ensure sufficient circulation space for simultaneous human and robotic usage, minimizing interference during peak demand.

# Sanitary Fittings Selection

## 3.1. Robot-Compatible Fixtures



### Wall-Mounted Sanitary Ware

Toilets, urinals, and sinks should be wall-mounted to maintain unobstructed floor areas for robotic cleaning. This design should also facilitate steam vacuuming and/or spray-based cleaning systems that rely on line-of-sight access.

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### Inclusion of Squatting WCs

Where cultural or user requirements necessitate squatting WCs, ensure that designs accommodate robotic cleaning access. This includes clear floor space around the WC and materials that can withstand frequent robotic scrubbing and able to withstand exposure to high-temperature steam (up to 130 degree Celsius) and/or common cleaning agents.

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### Touchless Fixtures

Automated dispensers, faucets, and dryers minimize manual contact, improving hygiene while reducing cleaning obstacles. These fixtures must remain resistant to chemical cleaning agents commonly deployed by robots

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### Sanitary Bins

In most commercial female toilet settings, the cleaning staffs are required to wipe clean the external surfaces of the Sanitary Bins in the cubicles, and check on the fill levels of the Bins.

The Sanitary Bins also vary in sizes, depending on the user's and/or the landlord's requirements. Sanitary Bins that are too large in size might bring about cleaning access issues for the cleaning robot hence it is necessary to specify the maximum dimensions for the Sanitary Bins as well. It is also advisable for sanitary bins to be wall-hung.

# Sanitary Fittings Selection

## 3.2. Material Durability

### **Anti-Corrosive Materials**

Frequent exposure to water and cleaning solutions requires fittings to comply with ISO 9227:2017 standards for corrosion resistance.

### **Stain-Resistant Surfaces**

Smooth finishes and anti-stain treatments reduce maintenance frequency and preserve long-term aesthetics.

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## 3.3. Hygiene Support Stations

Integrate well-designed hygiene stations for human cleaners. These should include secure storage for supplies, enhancing coordination between human and robotic cleaning processes.

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# Power, Connectivity, and Charging Infrastructure

## 4.1. Charging Docking Station

- Charging docks should be strategically located in low-traffic zones to avoid obstruction.
  - Allocate **1.5 m<sup>2</sup> per charging dock**, equipped with standard protective covers and compliant with IEC 61851-1:2017.
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## 4.2. Connectivity and Network Systems

- Deploy robust Wi-Fi and IoT-enabled networks to enable real-time robot monitoring.
  - Ensure compliance with ISO/IEC 30141:2018 (IoT Reference Architecture) for interoperability.
  - Enforce strict cybersecurity protocols in line with ISO/IEC 27001:2013 to safeguard user privacy.
  - Compliance EN 62368 European standards for the safety of electrical appliances used in household and commercial environments. This standard covers protection against electric shock, fire hazards, and mechanical risks, thereby enhancing user and facility safety.
  - Fast Charging Capability: Support advanced charging systems capable of delivering a full charge in less than one hour, reducing downtime and maximizing robot operational availability. Charging solutions should incorporate overcurrent protection, thermal management, and be compatible with smart energy management systems to optimize power usage during peak and off-peak periods.
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## 4.3. Safety Infrastructure

- Install **emergency stop switches** on the robot, in accordance with ISO 13850:2015.
- Robots should be equipped with **audible and visual alerts** when in operation to ensure user awareness and prevent accidents.

# Safety and Privacy Considerations

## 5.1. Data Privacy in Monitoring

- Robots fitted with cameras or advanced sensors must enforce data minimization principles. Techniques such as real-time blurring, restricted storage, and privacy zoning should be implemented, aligned with ISO/IEC 27001:2013.
- It is recommended to adopt a two-gate rule before entry: (i) toilet-level occupancy counter shows zero; (ii) stall-line LiDAR/RGB-D geofence confirms no body-shapes in FOV. No video is stored; use on-device blurring and event logs only.

## 5.2. Public Awareness and Communication

- Clear signage must be installed at restroom entrances, aligned with ISO 7001:2007, to inform users of ongoing robotic operations, including transparent communication about data handling practices.

## 5.3. Enhanced Safety Through Non-Contact Systems

- Non-contact cleaning systems reduce risk of chemical exposure, cross-contamination, and accidental surface abrasion.

# Safety and Privacy Considerations

## 5.4. Safety Navigation

Setting up virtual fencing or physical safety barriers in a dynamic restroom environment is not ideal, as this would require constant human intervention and monitoring. Instead, autonomous robots should be equipped with advanced situational awareness technologies and multiple sensors to ensure real-time detection of stall occupancy and safe navigation. For example, robots can determine whether a stall is occupied by detecting if the door is locked and adjust their cleaning path accordingly.

This sensor-driven approach enhances user privacy, minimizes operational disruption during high-traffic periods, and reduces the need for manual supervision or setup of barriers.

**Recommended Sensor Suite for Autonomous Navigation:** Autonomous cleaning robots should be equipped with multiple complementary sensors to enhance navigation precision and real-time obstacle avoidance. Suggested sensor types include:

- **2D LiDAR:** For mapping floor plans and detecting nearby obstacles with high accuracy.
- **3D LiDAR:** For volumetric sensing, enabling detection of overhanging objects and improved spatial awareness.
- **Ultrasonic Sensors:** For short-range obstacle detection, especially in tight spaces.
- **Cameras:** For visual recognition, AI-based anomaly detection, and improving contextual decision-making.
- **Anti-Collision Bumpers:** As a final physical safeguard to detect impact and stop movement immediately, preventing damage or injury.
- Provide ceiling power points and mounts for footfall/ammonia/wet-floor/consumable sensors; integrate with the robot scheduler.

# Human-Robot Collaboration: The Intelligent Assistant Concept

## 6.1. Smart Robots with AI and Machine Learning

The integration of Artificial Intelligence (AI) and Machine Learning (ML) into cleaning robots represents a forward-looking vision for future-ready restrooms. This guidebook does not prescribe fixed standards for these technologies but provides guiding points to anticipate their potential and inform design considerations.

### **Continuous Learning and Adaptation**

Unlike conventional robots limited to static programming, AI-driven robots learn from their environments. With every deployment, they refine internal models of spatial layouts, obstacles, and cleaning

### **Pattern Recognition and Prediction**

Deep learning algorithms empower robots to detect patterns, anticipate outcomes, and make proactive decisions. For instance, they can identify high-traffic restroom periods and adjust cleaning schedules dynamically.

### **Collaborative Intelligence**

As data pools grow across multiple units, robots can share insights at the fleet level. This accelerates learning and enables coordinated collaboration among robots and human workers.

### **Advanced Perception Systems**

Through computer vision, LiDAR, and multimodal sensor fusion, robots collect large volumes of data to map, analyze, and interpret environments in real time. This enables more precise navigation, object handling, and interaction capabilities.

### **Deployment-Based Self-Improvement**

Each deployment strengthens a robot's ability to adapt. Lessons learned in one facility can be generalized and applied to new environments, reducing the need for human intervention and retraining.

### **Contextual Applications**

In restroom environments, AI-driven robots could evolve beyond routine cleaning—optimizing cleaning paths, prioritizing resource use (e.g., water or disinfectants), and adapting to diverse layouts. In broader applications, such as healthcare or domestic settings, robots may personalize assistance by learning user preferences and adapting responses.

This vision highlights the transformative potential of AI and ML: moving robots from static tools into adaptive, learning-driven partners that thrive in dynamic, real-world environments while enhancing safety, efficiency, and reliability.

# Human-Robot Collaboration: The Intelligent Assistant Concept

## 6.2. Division of Roles

### Robots

Perform repetitive tasks such as cleaning and disinfection via automated contact or non-contact systems. Non-contact systems can sanitize delicate or complex surfaces where brushes or pads may potentially cause wear.

Tedious and labour intensive tasks of toilet bowl brushing, urinal and wash basin cleaning, mirror wiping will be done by robot. Human can elevate to do supervision, inspection and some other peripheral tasks to cover gaps.

### Human Cleaners

Focus on high-value tasks, including sanitizing high-touch points, inspection of floor traps (for potential litter which might lead to chokages), litter-picking and removal, cleaning of vanity tops, refilling consumables, and addressing hard-to-reach areas.

## 6.3. Intelligent Scheduling

Robots should not be limited to operating only during off-peak hours. In addition to deep cleaning during scheduled cycles, robots can perform quick spot or 'touch-up' cleaning to support rapid turnaround between peak usage periods. This allows for continuous service and higher cleanliness standards without requiring full or partial restroom closures, while human cleaners focus on more complex tasks during both peak and off-peak times.

## 6.4. Notification Systems

Smart IoT sensors should monitor key parameters such as bin fill levels, soap and tissue stock, and unusual environmental conditions. These sensors can send real-time alerts to facility management systems, allowing human cleaners to respond quickly and efficiently. This approach ensures targeted interventions, optimizes human resources, and maintains consistent service levels.

## 6.5. Data-Driven Efficiency

Robots equipped with AI and analytics can generate cleaning log, outcomes and when paired with installed sensors (footfall counters and/or ammonia sensors) it will enable more effective allocation of human cleaning resources.

# Human-Robot Collaboration: The Intelligent Assistant Concept

## 6.6. Detailed Task Segmentation and Role Clarity

With the growing application of robotics in restroom maintenance, it is critical to define task boundaries that maximize operational efficiency and service quality. Robots excel at repetitive, precision-based, and high-frequency cleaning tasks, which not only improves consistency but also reduces human exposure to labor-intensive or ergonomically challenging activities. By contrast, human cleaners provide the adaptability and oversight necessary to address complex issues, ensuring a resilient and reliable cleaning system.

Accordingly, tasks such as toilet bowl scrubbing, urinal cleaning, mirror wiping, and basin cleaning should be robot-led, as automation in these areas enhances turnaround speed and ensures uniform standards across facilities. Human cleaners, meanwhile, can focus on supervisory roles, quality assurance, replenishment of consumables, and customer-facing interactions that require judgment and flexibility. To ensure continuity of service, clear protocols must be established for human intervention when robots detect anomalies such as excessive waste, blockages, or mechanical faults. Finally, workflows should be redesigned to integrate both human and robotic functions seamlessly, creating an optimized cleaning ecosystem that balances productivity, reliability, and user satisfaction.

## 6.7. Command Centre Concept

With the emergence of advanced Computerized Maintenance Management Systems (CMMS) or Computer-Aided Facilities Management Systems (CAFM), integration of data generated from different sources can be augmented and displayed in unified dashboards. AI-driven autonomous robots can transmit real-time data (i.e. online/offline/standby status, battery/usage reports, error logs, percentage of coverage/completion, etc.) via IoT gateways or APIs. This enables the FM users to operate and scale through the deployment of multiple cleaning robots together with the resident cleaning team via a command centre setting. These command centres could optimise the performance and outcome based deliverable matrixes with such real-time capabilities, month-end audit reports, as well as any probable incident response in both centralised and decentralised environments.

# Human-Robot Collaboration: The Intelligent Assistant Concept

## 6.8. Robot Limitations and Contingency Handling

- Acknowledge limitations such as handling unusual spills, litter removal, or stubborn stains.
- Develop contingency workflows for human cleaners when robots cannot complete tasks or encounter obstacles.

## 6.9. Ergonomics and Workflow Optimization

- Design ergonomic access points near robot zones to minimize fatigue and awkward human movements.
- Recommend joint scheduling software that aligns robot cleaning cycles with human shifts and breaks.



# Future-Proofing Restroom Designs

## 7.1. Scalability

- Design flexibility must allow for incremental increases in robot fleets.
- Provide spare capacity in charging and docking infrastructure.
- Ensure that there are sufficient water points and drainage points.

## 7.2. Sustainability Integration

- Deploy energy-efficient robots in compliance with ISO 50001:2018.
- Adopt water-saving fixtures that are robot-compatible, reinforcing environmental performance targets.
- Include guidance on optimized water use settings for robots and integration of greywater recycling at docking stations.
- Include compatibility with spray or steam disinfection systems, which typically use less water and fewer consumables.

## 7.3. Waste Management and Recycling

- Integrate smart bins equipped with sensors for fill levels.
- Allow robots to assist with basic waste handling, such as bin emptying or compacting, while leaving sorting to humans.

## 7.4. Enhanced Sensor and IoT Integration

- Recommend advanced sensors in dispensers and bins to alert facility management systems of replenishment needs.
- Connect IoT-enabled systems to provide real-time updates for both robots and human staff.

# Future-Proofing Restroom Designs

## 7.5. Maintenance and Cleaning of Robots

- Provide facilities for routine cleaning, sanitization, and maintenance of robots to ensure continued efficiency and hygiene compliance.
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## 7.6. Training and Skills Development

- Develop training programs for human operators to manage robots, perform basic troubleshooting, and execute manual overrides when necessary.
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## 7.7. Privacy and Ethical Use of Data

- Extend privacy protocols to include ethical handling of sensitive restroom data.
  - Establish transparent policies on what data is collected, why, and how it will be used.
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## 7.8. Adaptability Across Facility Types

- Provide tailored design considerations for various restroom scales — from small offices to large public venues.
  - Adapt workflows to suit the intensity of robot-human collaboration across facility sizes.
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# Future-Proofing Restroom Designs

## 7.9. Emergency and Manual Override Procedures

- Define standardized procedures for emergency shutdowns and manual overrides.
  - Train staff on operational continuity plans to ensure safety during disruptions.
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## 7.10. Electrical Safety and Fast Charging Standards

- **Compliance with EN 60335:** Ensure all robotic cleaning equipment and associated charging infrastructure meet EN 60335 European standards for the safety of electrical appliances used in household and commercial environments. This standard covers protection against electric shock, fire hazards, and mechanical risks, thereby enhancing user and facility safety.
  - **Fast Charging Capability:** Support advanced charging systems capable of delivering a full charge in less than one hour, reducing downtime and maximizing robot operational availability. Charging solutions should incorporate overcurrent protection, thermal management, and be compatible with smart energy management systems to optimize power usage during peak and off-peak periods
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# Conclusion

By prioritizing accessibility, automation, and infrastructure flexibility, restrooms can accommodate both human and robotic users — including those employing contact-based or non-contact cleaning technologies such as steam or spray disinfection. Non-contact cleaning systems, such as steam or atomized disinfectant robots, represent an emerging class of hygiene automation.

Incorporating expanded frameworks for task segmentation, contingency planning, ergonomic design, training, waste management, and data-responsible design elevates this guide beyond technical recommendations into a holistic operational framework. With resilient materials, advanced connectivity, and strong human-robot collaboration protocols, facilities can achieve enhanced cleanliness, operational efficiency, and sustainability.

## Alignment with International Standards:

- **ISO 21542: Accessibility and Usability of the Built Environment** – Defines spatial requirements such as corridor widths, door clearances, and turning radii. While originally intended for human accessibility, these standards support cleaning robot navigation, reduce barriers, and promote universal design so humans and robots can coexist safely.
- **ISO 12100: Safety of Machinery – Risk Assessment and Risk Reduction** – Provides a framework for identifying and mitigating hazards such as collisions, electrical risks, and chemical exposures. Incorporating these principles ensures robots have emergency stop features, safe speeds, and compliance with global safety certifications like CE marking.

By aligning with these standards, future-ready restrooms deliver safer, more inclusive, and scalable solutions that anticipate evolving technologies and global best practices.

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